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A Reference Handbook

of

THE MEDICAL SCIENCES

EMBRACING THE ENTIRE RANGE OF

SCIENTIFIC AND PRACTICAL MEDICINE

AND

ALLIED SCIENCE

BY VARIOUS WRITERS

A NEW EDITION, COMPLETELY REVISED AND REWRITTEN

EDITED BY ALBERT H. BUCK, M.D.
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VOLUME VII

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A REFERENCE HANDBOOK

OF

THE MEDICAL SCIENCES.

SACCHARIN or **GLUSIDE**—(*Benzoyl-sulphonimide*). A coal-tar product, a derivative of toluene, with the formula $C_6H_4(CO)(SO_2)NH$. It occurs as a light, white powder, odorless but with an intensely sweet taste. It is very slightly soluble in cold water, more so in boiling water, alcohol, and glycerin. Its solution gives an acid reaction, and it forms sweet salts with alkaloids and metals. Its property of combining with alkaloids is taken advantage of to supply quinine and other bitter substances in a more palatable form. The insolubility of gluside is overcome by combining it with soda to form a soda salt which is very soluble. It may be prepared by dissolving one hundred parts in water and neutralizing the solution with bicarbonate of soda and evaporating to dryness; this forms one hundred and thirteen parts of soluble gluside or saccharin. It has been placed in the British Pharmacopœia under the title of Glucidum.

Excepting in its sweetening power, gluside is not allied to sugar in any way. It does not affect polarized light, it lacks the essential character of sugar to produce alcohol by fermentation, and when administered does not increase the production of sugar in the system. It is this latter quality that renders it of value in the treatment of diabetes, where it is desired to avoid the use of sugar as far as possible.

Gluside is two hundred and eighty times as sweet as sugar, and if it is remembered that an ordinary lump of sugar ranges from 150 to 300 grains, it is very evident that one-half to one grain will be an equivalent. Its disadvantages are the distaste that the patients are liable to have for it after using it for a time, and the dry, acrid sensation which it produces in the pharynx. In medicines, it may also be used to replace sugar and syrup for the purpose of rendering them palatable, one grain with a six-ounce mixture furnishing sweetness equal to one ounce of ordinary syrup. To facilitate dispensing, the following solutions are prepared:

Liquor Glusidi.—From the "National Formulary" of the American Pharmaceutical Association. Gluside, 512 grains; bicarbonate of sodium, 240 grains; alcohol, 4 fluidounces; water, sufficient to produce 16 fluidounces. Each drachm represents four grains of gluside.

Elixir Glusidi.—From the "Unofficial Formulary" of the British Pharmaceutical Conference. Gluside, 480 grains; bicarbonate of sodium, 240 grains; rectified spirit, 2½ fluidounces; distilled water, a sufficiency. Rub the gluside and the bicarbonate of sodium in a mortar, with half a pint of distilled water gradually added. When dissolved, add the spirit, filter and wash the filter with sufficient distilled water to make one pint. Each drachm represents three grains. Saccharin may be given freely, as it is devoid of toxic action. In some cases reported its prolonged use has produced symptoms of gastric disturbance with indigestion, but this rarely occurs. As much as seventy-five grains have been given at one dose without producing any ill effect. It is, however, advisable that not more than twenty-five grains daily be administered.

Gluside possesses antiseptic properties in common with other coal-tar derivatives, and for this reason it has been suggested as a remedy in many diseases. It has been used in pulmonary phthisis, acute articular rheumatism, scarlatina, intestinal catarrh, cystitis, and a number of other disorders in which its antiseptic action might prove of service. Of these, cystitis is the only one in which any satisfactory results have been obtained. In this condition it is administered internally and renders the urine antiseptic during its excretion. When there are pus and an alkaline reaction, this is rapidly overcome, and the urine becomes clear and normal in character; the change in the urine being accompanied by a corresponding improvement in the mucous membrane of the bladder. Three grains, in divided doses, daily, is the quantity recommended, and this is to be continued for a prolonged period. The bladder may also be irrigated at the same time.

Beaumont Small.

SACCHAROMYCOSIS.—Our knowledge of pathogenic yeasts and of the pathological conditions produced by them is at present but slight; and the unsatisfactory state of the classification and terminology of the blastomycetes has led to much confusion. Inasmuch as the blastomycetes are usually divided into various genera, *Saccharomyces*, *Oïdium*, *Monilia*, etc., the term *saccharomycosis* should be limited to the pathological conditions produced by the yeasts which are included under the *Saccharomycetes*, viz., those characterized by their power to ferment sugar and form alcohol, of which *Saccharomyces cerevisiæ* may be taken as the type. But few observations of such pathogenic yeasts have been made. The most important contributions to this subject are those of Busse and Curtis.

In 1895 Busse obtained pathogenic yeasts from a woman suffering with a peculiar cystic tumor of the tibia, which on microscopical examination presented the appearance of a sarcomatous-like granulation tissue containing giant cells. From the viscid fluid obtained from the tumor yeast-like fungi were cultivated. Pure cultures of the yeast were pathogenic for mice and rabbits, giving rise, when injected into the animal, to nodules of chronic granulation tissue, and leading to the formation of metastatic miliary nodules in the brain, kidneys, and lungs. The organism grew well on ordinary media, at ordinary and incubator temperatures, forming white, non-characteristic growths, which did not liquefy gelatin. On special media to which malt extract was added the growth was more abundant, and on potato and other media, grayish or black cultures were obtained. Acid media seemed especially to favor its growth. Glucose media were fermented with the production of alcohol and carbonic dioxide. Reproduction took place by budding exclusively. The patient died thirteen months after the appearance of the tibial tumor, and at autopsy numerous foci of disease, containing the yeast in great abundance, were found in the lungs, kidney, and spleen, some reaching the size of an apple. The yeasts were also found in a small corneal vesicle. Microscopically these lesions resembled those of a chronic inflammatory process with caseous and fatty degeneration; in these lesions the yeasts were found in great numbers, lying singly or in colonies.

In the next year a similar case was reported by Curtis, who obtained a yeast, *Saccharomyces subcutaneus tumefaciens*, from myxomatous tumors appearing in a young man, beneath the skin of the neck and thigh, and also from a large ulcer of the loin. Microscopically these tumors resembled myxosarcoma. Both in and between the tumor cells yeasts were found in large numbers. These were easily cultivated, and caused sugar to ferment with the production of alcohol. Dogs, rabbits, rats, and mice were susceptible to inoculation, a chronic inflammation and proliferation being produced at the site of injection. In old cultures endosporous division was seen.

Corselli and Frisco report a case of saccharomycosis in which "sarcomatous" nodules were found in the omentum and mesentery. The chylous ascitic fluid obtained by exploratory puncture during life contained the yeast fungi, which were cultivated and found to be pathogenic for dogs, rabbits, and guinea pigs.

Pathogenic yeast fungi have also been found in cases of chronic catarrh of the uterine cervix (Colfe and Buschke), and in proliferative catarrh of the nasal mucosa (Busse). Saccharomycetes have also been reported as occurring in the secretion from a case of peculiar inflammation of the conjunctiva and cornea; in pharyngitis; in the purulent discharge of otitis media; in the blood, sputum, and urine of a case of typhus (Calmette); in a pseudomembranous angina in a patient suffering from typhoid (Froisier and Achalme). *Saccharomyces ruber* has been regarded as the cause of a house epidemic of intestinal catarrh, the infection occurring through the contamination of milk. This same yeast was isolated by Casagrandi from diabetic urine. When inoculated into animals it produced small nodules containing pus. A variety closely related to, if not identical with *Saccharomyces cerevisiæ*, has been found in the coating of the tongue, in diarrhœal stools, in vomited material, and in diabetic urine.

Inasmuch as the organism of thrush is classed by some writers as a yeast—*Saccharomyces albicans*—the lesions of thrush would be considered under the head of saccharomycosis. (See *Mouth, Diseases of*, in THE APPENDIX.)

Pathogenic saccharomycetes have been found in a number of diseased conditions of the lower animals. *Saccharomyces niger* (Maffuci and Sirleo) has been regarded as the cause of a pulmonary affection which occurs in guinea pigs and resembles tuberculous pneumonia, and of an intestinal condition in the same animal, characterized by ulceration of the mucosa and enlargement of the mesenteric glands. *Saccharomyces guttulatus* has been described by Casagrandi and Buscalioni as occurring in the intestinal tract of mammals. These authors isolated it from the stomach and intestines of rabbits. It causes glucose to ferment with the formation of alcohol and it inverts saccharose. When inoculated into rabbits, guinea-pigs, and rats it produces nodules containing pus, and finally death. Sanfelice obtained from swine a non-liquefying, gas producing yeast—*Saccharomyces granulomatosus*—pathogenic only for swine, and producing granulomatous nodules, containing giant cells, in which the parasites often become calcified. The experimental "pseudo-tumors" produced by the injection of blastomycetes have also been described under the head of saccharomycosis.

The various pathogenic organisms described as saccharomycetes and the lesions ascribed to them can hold but a tentative position in pathology, until more definite light has been thrown upon the subject by additional observation and experimentation.

Aldred Scott Warthin.

SACRO-ILIAC DISEASE.—Tuberculous disease of the sacro-iliac articulation is uncommon and extremely so in childhood. The symptoms are pain, limping, weakness, and change in attitude. The pain is referred to the side of the pelvis or radiates over the buttock or thigh. It is increased by jars, by turning the body suddenly, sometimes by coughing or laughing. A peculiar feeling of insecurity and weakness about the pelvis and hip-joint is a common symptom. The trunk is inclined toward the sound limb, as a result of which the pelvis is lowered on the affected side. The leg seems longer than its fellow, and the patient walks with a peculiar awkward limp. In the early stage of the disease there is no deformity of the limb, but if a pelvic abscess forms the thigh may become flexed. Locally there may be sensitiveness to direct pressure on the articulation and swelling in the neighborhood of the disease, although this is usually a late symptom. Pain is induced by lateral pressure on the pelvis or by any manipulation that disturbs the articulation.

Abscess finally appears in the majority of cases. It may be extra- or intrapelvic. In the latter case it may present itself above the crest of the ilium. It may pass through the sciatic notch or appear in the ischiorectal fossa, or it may break into the rectum.

Sacro-iliac disease may be mistaken for sciatica or for disease of the hip or spine. The freedom of motion and the absence of muscular spasm when the pelvis is fixed, if examination is carefully conducted, should exclude both the one and the other, although the pain on lateral pressure, which is described as the most characteristic symptom, may be simulated closely by primary acetabular disease. The attitude is similar to that of sciatica, but the symptoms of local sensitiveness to jars and to manipulation are much more marked.

TREATMENT.—The local treatment consists in protecting the sensitive parts from injury, and the removal of the disease if it be possible. In the ambulatory treatment a plaster spica bandage or a double Thomas hip brace combined with the use of crutches may be indicated, but in most instances a broad, strong pelvic girdle, which may be drawn tightly about the pelvis, will be most efficient. If motion of the spine causes discomfort, this girdle may be reinforced by some form of spinal brace. Constitutional treatment is of course indicated as in other forms of tuberculous disease.

The PROGNOSIS is unfavorable, probably because the majority of the cases are in adults, a class in which the prognosis of any tuberculous disease is more serious than in childhood. In addition there is usually the complication of an infected and burrowing abscess.

Injury of the Sacro-Iliac Articulation.—All the symptoms described as characteristic of the tuberculous disease of the sacro-iliac articulation may be induced by strain or other injuries of this region, and doubtless by other affections than tuberculosis, such, for example, as rheumatism or infectious arthritis.

Such causes are perhaps more common in early life than is tuberculous disease. The principles of treatment (that is, rest and protection of the sensitive part by the pelvic girdle or other support) are indicated. If this treatment is efficient the cure is usually rapid and complete.

Royal Whitman.

SAEGERSTOWN MINERAL SPRINGS (formerly Eureka Springs).—Crawford County, Pennsylvania.

POST-OFFICE.—Saegerstown. Hotel and sanatorium.

ACCESS.—Viâ main line of the Erie Railroad to Saegerstown, six miles east of Meadville.

Saegerstown is situated on the historic Venango River, now called French Creek, in a beautiful and healthful valley, 1,200 feet above the ocean level. The scenery here is of a charming rural character, and the surroundings offer excellent opportunities for fishing, rowing, hunting, driving, bicycling, etc. The sanatorium is a large and commodious building, having all the modern conveniences of a hotel combined with facilities for the care and treatment of invalids. The grounds are tastefully laid out, and include spaces for croquet, lawn-tennis, and other games. A billiard room and bowling alley have been fitted up for the guests of the house, and during the busy season an orchestra will furnish music in the evening hours. The hotel is open the entire year. There are two mineral springs at Saegerstown, issuing from a bed of rock about three hundred feet deep. An analysis, made in 1896 by W. H. Dean, analytical chemist of Wilkesbarre, showed the following chemical ingredients of one of the springs:

One United States gallon contains (solids): Sodium chloride, gr. 7.46; sodium sulphate, gr. 0.62; potassium sulphate, gr. 0.22; calcium sulphate, gr. 4.33; calcium carbonate, gr. 3.26; magnesium carbonate, gr. 2.85; iron oxide and alumina, gr. 0.15. Total, 18.89 grains.

The water is free from nitrates and nitrites or other organic impurities, and will keep indefinitely without undergoing impairment of mineral properties. The water is bottled and shipped to all points. It will be found useful in the diseases benefited by this class of waters. Elaborate bathing facilities are supplied to visitors at the springs. *James K. Crook.*

SAFFRON.—*Spanish Saffron. Crocus* U. S. P., B. P., P. G. *Stigmata croci. Safran,* Fr. Cod. The dried stigmas of *Crocus sativus* L. (fam. *Iridaceæ*).

The saffron plant is a perennial herb, resembling colchicum, but with an inferior ovary. It grows from a flattened fleshy corm and bears one or two flowers, each possessing a long thread-shaped style, terminating in three long stigmatic branches. These branches, with a very short portion of the style, are collected and dried and constitute the drug. The nativity of the plant is not certainly known. Cultivated plants yield the whole of the product, which is mostly exported from southern Europe, especially Spain. It grows readily in most warm-temperate regions, but the profitable production of saffron is chiefly a labor problem, since nearly four thousand flowers are required to yield an ounce, and its successful production requires exceedingly low-priced labor.

FIG. 4139.—Spanish Saffron.

DESCRIPTION.—Separate stigmas or three attached to a very short portion of their style, each 2 to 3 cm. (about 1 in.) long, flattish-filiform below, dilated and funnelform tubular above, with the margin irregularly notched; orange-brown, the style portion yellow; texture somewhat cartilaginous, unctuous to the touch, strongly and peculiarly aromatic and bitterish. When chewed it tinges the saliva deep orange-yellow.

So costly a drug is of course subject to numerous and cunningly devised methods of adulteration, some of which are provided against as follows by our Pharmacopœia:

When soaked in water, it should not deposit any pulverulent, mineral matter, nor show the presence of organic substances differing in shape from that described.

On agitating 1 part of saffron with 100,000 parts of water, the liquid will acquire a distinct yellow color. No color is imparted to benzin agitated with saffron (absence of *picric acid* and some *other coal-tar colors*).

On drying saffron at 100° C. (212° F.), it should not lose more than fourteen per cent. of its weight (absence of *added water*).

When thus dried, and ignited with free access of air, 100 parts of the dry saffron should not leave more than 7.5 per cent. of ash (absence of *foreign inorganic substances*).

One of the commonest methods of increasing the yield of saffron is that of collecting a large portion of the style with the stigmas, and the possible presence of these styles is referred to in our own and other pharmacopœias. Onion roots have been chopped up and colored to substitute saffron, as have other fibrous or filamentous bodies. The most important substitute, however, and that very generally sold for saffron in this country, is safflower, which will be found described at the close of this article. The detection of adulterants of nearly all kinds is far less easy when the product is pressed into cakes, so that loose or "hay" saffron is always to be preferred. All things considered, the microscope probably offers the most reliable means for detecting adulterants, and a moderately low power suffices for most of them.

CONSTITUENTS.—Saffron owes its odor to about one per cent. of a volatile oil, which differs considerably according to the method of distillation, being sometimes lighter, sometimes heavier than water. Its color is due to the presence of the yellow glucoside *crocin* ($C_{44}H_{70}O_{28}$), which yields reddish *crocetin*. The name *polychroit* was formerly applied to this coloring matter, but the substance so described was subsequently found to be a mixture, consisting largely of crocin. The bitterish taste of crocus is due to a glucoside which has been called picrocrocin. The other constituents of crocus are unimportant. Crocin is very slightly soluble in water, unless rendered alkaline, but is soluble in alcohol. It becomes blue, then violet-brown with concentrated sulphuric acid, and green, afterward yellow and brown, with nitric acid. The yield of volatile oil is greatly increased by previous treatment with sulphuric acid.

ACTION AND USE.—Crocus has had a wonderful history as a drug. It was credited with remarkable powers by the ancients, and is still so, to some extent, by the more ignorant classes. It, however, probably possesses no other medicinal properties than those of a mild aromatic, stimulant, carminative, and antispasmodic, and may be given in doses of 0.3–2 gm. (gr. v.–xxx.). The Pharmacopœia provides a ten-per-cent. tincture. As used at the present day, especially in the United States, it is almost wholly for the purposes of coloring and slight flavoring.

Safflower, Carthamus, African or dyer's saffron, False, American or *Thistle saffron,* consists of the florets of *Carthamus tinctorius* L. (fam. *Compositæ*). Although called American saffron, this plant is of Oriental nativity. It is widely cultivated for ornament and also, to some extent, for the product here described. It produces handsome large flower heads, of an orange-yellow color, at the ends of the branches. From these the florets are plucked out, dried, and constitute the drug. They were formerly largely used for dyeing purposes and are still so used to a considerable extent in India. They constitute a red or deep orange-red mass, of a rather slight characteristic odor and an aromatic and bitterish taste. The individual florets are about 2 cm. ($\frac{4}{5}$ in.) long, though often broken, tubular, and very deeply divided into five linear and nearly equal lobes. The stamens have long exserted coherent anthers and a slender style which is considerably longer than the stamens. The ovary should not be present. The principal coloring matter of safflower is deep yellow and constitutes one-fourth or more of the weight of the drug. It is known as *safflor yellow* ($C_{24}H_{30}O_{15}$) and is soluble in water. There is also a fraction of one per cent. of the red coloring matter *carthamic acid* or *carthamin* ($C_{14}H_{16}O_7$), which is not soluble in water but gives a beautiful purple color in alcohol. The latter coloring matter exists in commerce as a reddish brown, somewhat metallic powder. It is used in rouge-making. The properties and uses of safflower differ but little from those of saffron, and its principal use is in fact the substitution of the latter. *Henry H. Rusby.*

SAGE.—*Garden Sage, Salvia,* U. S. P. The dried leaves of *Salvia officinalis* L. (fam. *Labiatæ*).

This is a half shrubby, gray-hairy perennial, the stems dying down to within a foot or so of the ground in the fall, but branching very freely into herbaceous flowering branches, which are quadrangular and attain a height of two or three feet. The leaves are opposite, the flowers in a mixed spike, with two-lipped, pubescent, bell-shaped calyx, and a conspicuously labiate, blue corolla, with a ring of hairs at the base, inside; upper lip of the corolla concave, notched at the apex, the lower three-lobed; the central one much the largest and longest. Perfect stamens two, with widely divergent anther cells, but one of which in each stamen is perfect. Ovary four lobed. Fruit of four nutlets. Sage, like so many others of our household mints, is a native of Southern Europe. It has, however, been cultivated for centuries, and transplanted to all temperate countries. Leaves rather long and stoutly petioled, the blades 3–7 cm. (about 1–3 in.) long and nearly half as broad, oblong or slightly broader below the middle, rounded or subcordate at the base, mostly blunt at the summit, crenulate, thickish, gray-green, and densely hairy, especially underneath, very strongly veined, the veins finely reticulate, often pinkish or purplish, as is the petiole; aromatic in odor and taste, the latter also bitter and somewhat astringent.

Sage owes its very characteristic odor and its properties as an aromatic drug to a peculiar volatile oil (less than one per cent. in the fresh, up to 2.5 per cent. of the dried leaves). It also contains an unknown bitter substance and apparently tannin, together with resin and a little gum. Oil of sage is a commercial article, and is of a yellowish or greenish yellow color, with a specific gravity of about 0.92. Its chief constituent has been called salviol, but it is now considered identical with thujone, the active constituent of Arbor vitæ, and this occurs also in some other volatile oils. A small amount of cineol is also contained.

Sage resembles the rest of the Mint family in its general action; it is aromatic, a gastric stimulant, and by reason of its bitterness also tonic. It is also, what all are not, mildly astringent. In large quantities of hot water, like many other mints, it is given as a sudorific in the beginning of feverish colds, etc. Sage is useful in mouth washes and as a gargle. It is, however, almost entirely a domestic remedy, and even as such but little used of late, although formerly in high repute. It is one of the ingredients of the formerly official aromatic wine (*Vinum Aromaticum*), an old-fashioned liniment.

W. P. Bolles.

SAINT AUGUSTINE, FLORIDA.—This picturesque and well-known winter resort is situated on the Atlantic coast of Florida, thirty-eight miles southeast from Jacksonville, and about two hundred and fifty miles north of Palm Beach. The city occupies a narrow peninsula opposite Anastasia Island, which forms a breakwater against the open ocean. The surrounding country is flat and sandy and covered with the scrub palmetto.

The town is the oldest in the United States, and has a permanent population of between four and five thousand inhabitants, which number is doubled or more at the height of the season. The city retains many of its antiquities, and is exceedingly quaint and attractive. The narrow streets; the ancient Spanish "coquina," or shell-limestone residences, with their overhanging balconies; the old "City Hall," and Fort Marion, are all exceedingly interesting relics of the Spanish occupancy.

Many new and attractive buildings have of late years sprung up—several extensive hotels of the Spanish style of architecture, with beautiful grounds and courtyards; villas, with grounds ornamented with orange, lemon, and fig trees, palms, and a variety of tropical flowers and shrubs; churches, convents, and the restored Cathedral and Old Market.

The attractions at this resort are many and varied, as can easily be imagined. Besides those already mentioned, there are a United States military post, with daily guard mount, the sea wall affording a delightful promenade along the water front; many excursions by water; visits to the orange groves; drives, hunting, fishing, sailing, golf, and the never ending delight of wandering through the old town. Connected with one of the hotels is a casino, where are Turkish baths, a swimming pool, various entertainment halls, lawn-tennis courts, etc.

The winter climate is a mild, equable, moist one; and in summer the heat is tempered by the sea breezes. Frosts are rare. Although the climate is of a somewhat less tropical nature than that of the resorts on the lower half of the peninsula, such as Palm Beach, Tampa, and Miami, still a very comfortable, mild atmosphere is found here in the winter, and there is a good proportion of sunny days.

The average mean temperature of twenty years for the four seasons, as given by Dr. Wall (*The Climatologist*, October 15th, 1891), is as follows (degrees Fahr.): Spring, 68.5°; summer, 80.3°; autumn, 71.5°; winter, 58.1°, and for the whole year, 69.6°. For the four winter months, according to the same authority, it is, for December, 57.2°; January, 57°; February, 59.9°; March, 63.3°. The average yearly rainfall is about 49 inches, varying quite considerably in different years; for example, it was 67.4 inches in 1880 and 33.9 inches in 1851. The least rainfall appears to be in January. The prevailing winds are from the northeast. The climatic data of Jacksonville, which is only thirty miles to the north of St. Augustine, can be taken as fairly accurately representing those of the latter resort, and the reader is referred to the article upon *Jacksonville* in Vol. V. of the HANDBOOK for more extended meteorological facts.

The water supply is abundant and obtained from artesian wells; and the streets are clean and well lighted. The sanitary conditions of the hotels are carefully looked after.

There is a well-appointed, indeed a luxurious, hydrotherapeutic establishment where hot and cold saline and hydro-electric baths are given by skilled attendants; and cases of rheumatism, gout, and nervous disorders are treated in this way. The Nauheim baths and the Schott system of treatment for heart disease; various methods of electrical applications, gymnastics, douches, and massage are also included in this establishment.

January, February, and March are the months in which St. Augustine is the most frequented. On account of its easy accessibility, mild climate, excellent accommodations and many attractions, this has become a popular and fashionable winter resort, and has been compared to Newport and Saratoga. Excursions to other portions of Florida can easily be made from this point.

Edward O. Otis.

SAINT CATHARINE'S WELL.—POST-OFFICE.—St. Catharine's, Ontario. Hotel, The Welland House.

ACCESS.—Viâ Grand Trunk Railway from Toronto, or Buffalo.

Analysis (Professor Croft).—Ten thousand grains of water contain: Carbonate of iron, gr. 0.5210; carbonate of lime, gr. 0.0820; sulphate of lime, gr. 19.7934; chloride of calcium, gr. 174.4876; chloride of magnesium, gr. 40.6641; chloride of sodium, gr. 378.4196; chloride of potassium, gr. 2.8119; bromide of sodium, a trace; iodide of sodium, gr. 0.0140. Total, 616.7938 grains.

St. Catharine's is situated twelve miles from Niagara Falls in what is termed "the Garden of Canada." There are a number of springs which have long been famous, and at different times sanatoria have been opened. The Welland is under excellent management and has during the past year been enlarged and furnished with all the appliances of a modern sanatorium. A resident physician is in charge with a staff of skilled nurses. Every provision is made to utilize the water after the most approved methods of hydrotherapeutics. The hotel is open throughout the year.

Beaumont Small.

SAINT CLAIR SPRINGS.—St. Clair County, Michigan. POST-OFFICE.—St. Clair Springs. Hotel, The Oakland.

ACCESS.—From Detroit by steamer from the foot of Griswold Street, twice daily; distance fifty miles. Also from Detroit viâ Grand Trunk Railway (foot of Brush Street), twice daily; distance fifty-one miles. Railroad connection for springs can also be made at St. Thomas, Ontario, viâ Canada Southern Railroad. Steamer connection once daily is made at Port Huron, Mich.

St. Clair Springs is one of the strictly first-class health and pleasure resorts of the United States. The Oakland Hotel, situated in a tract of about one hundred and sixty-five acres fronting on the St. Clair River, at the extreme southern portion of the city of St. Clair, affords all the comforts, conveniences, and luxuries to be found at our older Eastern resorts or at the European spas. The hotel is open for the reception of health- or pleasure-seekers all the year round. Two classes of mineral waters of very pronounced yet very different type are found here. The first of these is a powerful muriated saline water. The analysis is by Professor Duffield:

One United States gallon contains (solids): Sodium chloride, gr. 8,120; calcium chloride, gr. 7,382.20; magnesium chloride, gr. 1,012.20; calcium sulphate, gr. 144.20; silica, gr. 416; alumina, gr. 830; and traces of magnesium carbonate, calcium carbonate, magnesium iodide, and magnesium bromide. Total, 17,904.60 grains. Sulphureted hydrogen gas, 25.59 cubic inches.

It will be observed that the water contains an unusually large quantity of chloride of lime. The salt is believed by some observers to possess valuable alterative properties and to be of great assistance in the treatment of the strumous diathesis. The water also possesses all the well-known virtues of the densely charged chloride-of-sodium groups. It is used only for bathing purposes and as a spray or douche. An elegant and elaborate bathhouse, presenting all varieties of baths, sprays, douches, etc., is maintained in connection with the hotel.

The "Salutaris" is a natural gaseous alkaline mineral water, very wholesome and pure. It is said to be entirely free from organic matter, and constitutes an excellent table water. It is bottled and extensively sold in the United States.

The attractions in and about the Oakland Hotel are of a manifold character: expansive shaded lawns, picturesque drives; boating and sailing on the river, and all the indoor pastimes of the day will be found here.

James K. Crook.

SAINT HELENA WHITE SULPHUR SPRINGS.—Napa County, California.

Post-Office.—St. Helena. Hotel and cottages.

Access.—Take ferry from San Francisco foot of Market Street, at 8 A.M. and 4 P.M. Arrive at St. Helena viâ Calistoga train at 11:03 A.M. and 7:08 P.M. Take stage to springs, two miles distant.

One United States Gallon Contains:

Solids.	Spring No. 2. Grains.	Spring No. 6. Grains.	Spring No. 7. Grains.
Carbonate of iron	.62	.56	4.36
Carbonate of magnesium	8.26	11.33	12.84
Sulphate of sodium	21.72	23.41	14.23
Chloride of sodium	1.32	.86	.78
Chloride of calcium	.87	2.22	.65
Sulphides of sodium and calcium	2.65	1.85	1.62
Total solids	35.44	40.23	34.48
Gases.	**Cubic inches.**	**Cubic inches.**	
Sulphureted hydrogen	6.15	4.25	Trace.

This beautiful summer resort is located in one of California's loveliest valleys. The neighboring mountainsides are covered with forests, shrubbery, ferns, and wild flowers of every description. Brooks and cascades are seen on every hand. The grand old California redwoods, which are found here in great abundance, are alone worth a visit to this region. The mineral springs are numerous and valuable, and chiefly of the saline chalybeate type. Mr. Sanford Johnson, the proprietor, furnishes us with the accompanying analysis of three of the springs.

There are six other springs which have not been completely analyzed. The waters vary in temperature from 64.4° to 97.25° F. The analysis shows them to possess valuable tonic properties. They are said to have considerable value in rheumatism and kidney affections.

James K. Crook.

SAINT LOUIS, MO.—This great city of nearly 600,000 inhabitants is situated in the northeastern corner of Missouri upon the Mississippi River, not far from its junction with the Missouri.

A description of the city is hardly necessary or pertinent in this connection, as the climate is the chief consideration, of which certain marked peculiarities deserve mention.

In the first place, as will be observed from the table, the excessive extremes of temperature are striking, the annual range being 123.4° F. Although the winter mean temperature is only a few degrees higher than that of New York, for example, the mean summer temperature is five and one-third degrees higher. In July a maximum temperature of 104° F. is noted, while in January a minimum temperature of − 16° F. occurred in the cold wave of 1889. St. Louis is called a "Southern city," and yet it is seen that the winters are severe and quite like those of a Northern city. The summers are usually very hot, the nights as well as the days, and a continuous high temperature may exist for many days in succession; moreover, this heat may continue through the month of September. In July, 1901, there was hardly a day for three weeks in which the temperature was not 100° F. or over. The daily range of temperature is also seen to be considerable, and, consequently, one might hastily conclude that the summer nights would be comparatively cool; but if the day temperature is very high, a diminution of fifteen or eighteen degrees would still give a high night temperature.

Another striking feature of this climate is the prevalence of south winds throughout the year, except in March, when the blizzards change the direction from south to northwest.

The mean relative humidity indicates a moderate amount of moisture, a little less than that of New York City. The rainfall is not excessive and is pretty evenly distributed throughout the year, rather more falling in the spring and summer. There are a few more clear and fair days in St. Louis than in New York, especially in the summer and autumn. The flatness of the surrounding country and the atmospheric conditions favor the

Climate of St. Louis, Latitude, 38° 38'; Longitude, 90° 12'. Period of Observation, Thirteen Years.

	January.	March.	May.	July.	September.	November.	Spring.	Summer.	Autumn.	Winter.	Year.
Temperature, Degrees Fahr.—											
Average or normal	31.7°	43.1°	66.1°	78.8°	68.0°	42.4°	54.7°	76.8°	55.9°	34.0°	55.3°
Average daily range	15.8	16.8	18.7	18.2	19.2°	15.5					
Mean of warmest	38.7	53.5	75.4	88.2	79.2	52.1					
Mean of coldest	22.9	36.7	56.7	70.0	60.0	36.6					
Highest or maximum	72.0	82.0	93.0	104.0	101.5	82.0					
Lowest or minimum	−16.0	8.0	32.0	57.0	40.0	5.0					
Humidity—											
Average mean relative	71.2%	66%	64.2%	67.9%	64.7%	67.9%	63.3%	67.4%	65.8%	70.9%	60.8%
Precipitation—											
Average in inches	2.19	3.04	3.86	4.36	2.55	2.79	10.25	11.74	8.12	7.48	37.59
Wind—											
Prevailing direction	S.	N. W.	S.	S.	S.	S.	S.	S.	S.	S.	S.
Average hourly velocity in miles	10.2	11.6	9.7	7.7	8.5	10.6	10.7	8.0	9.5	10.2	9.6
Weather—											
Average number of clear days	8.8	7.7	9.8	11.4	13.9	7.7	26.9	33.5	34.4	24.5	119.3
Average number of fair days	11.3	11.9	11.5	12.9	10.9	12.2	35.2	40.5	34.9	33.0	143.6
Average number of clear and fair days	20.1	19.6	21.3	24.3	24.8	19.9	62.1	74.0	69.3	57.5	262.9

formation of tornadoes; and on May 27th, 1896, there occurred in St. Louis one of the most terrific ones ever known in the United States, ploughing in a moment a huge furrow through the city and destroying a large number of lives and an immense amount of property. Such calamities, however, are rare, but, nevertheless, the latent conditions are always existent, and what has happened may happen again.

During the summer months all who are able seek a cooler climate at the seashore or in the mountains; but during the rest of the year St. Louis is a comfortable and wholesome place of residence. It has been feared that the Chicago drainage canal, which empties into the Illinois River,—which latter in turn flows into the Mississippi above St. Louis,—might pollute the waters of this river as it flows past St. Louis. No sure evidence, however, to the writer's knowledge, has been adduced to show that this is the fact, or that the drinking-water, which is derived from the river, is injuriously affected.

For a description of the manifold attractions in and about the city, the guide books must be consulted; and for the history of the founding of the city, the reader is referred to Parkman's fascinating works.

From St. Louis interesting excursions can be made either up the river to St. Paul, or in the other direction to New Orleans. The steamers are comfortable and commodious. From St. Louis to New Orleans is a distance of 1,250 miles, and the steamer occupies about a week in traversing it. For one who desires a slow, restful journey amidst oddly picturesque scenery, a journey soothing to tired nerves and yet of strange interest, this voyage down the Mississippi can be unqualifiedly recommended from personal experience. *Edward O. Otis.*

SAINT LOUIS SPRING.—Gratiot County, Michigan. Post-Office.—St. Louis. Hotels and sanatoriums. Analysis by S. P. Duffield:

One United States gallon contains (solids): Sodium bicarbonate, gr. 88.66; calcium bicarbonate, gr. 57.83; magnesium bicarbonate, gr. 14.58; iron bicarbonate, gr. 1; calcium sulphate, gr. 55.41; calcium silicate, gr. 5.60; silica, gr. 2.40; organic matter and loss, gr. 1.66. Total, 227.14 grains. Gases, sulphuretted hydrogen, a trace; carbonic acid, 5.17 cubic inches.

The results of treatment with these waters, according to Dr. Stiles Kennedy, show them to be especially beneficial in dyspepsia, neuralgia, and chronic rheumatism. The water, as shown by the analysis, is strongly alkaline, and also contains sufficient iron to impart to it the properties of the chalybeate class. The waters were once supposed to be strongly magnetic, but it has been proved by the experiments of Walton, and corroborated by a committee of the Michigan State Medical Society, that the so-called magnetic properties were derived from the metallic tubing which encased the well. The resort is still kept up well and is very popular. *James K. Crook.*

SAINT MORITZ, SWITZERLAND. See *Engadine.*

SAINT PAUL, MINN.—This city, and several other points in Minnesota, were formerly popular as winter health resorts for consumptives, on the theory that steady cold weather was peculiarly bracing to the constitution, and thus hardened the patient was put in a more favorable condition to overcome his disease. There is undoubted truth in this, provided the air is pure as well as cold, and provided other favorable climatic factors exist, such as sunshine, absence of high winds, and dryness. There have been developed, however, other and better climates of the bracing winter type, such as the various well-known resorts in the Alps and in Colorado; and, in consequence, the former reputation of Minnesota has declined. Further, large cities are obviously never so favorable as health resorts for pulmonary tuberculosis, and hence St. Paul and its sister city, Minneapolis, now grown so large, could not be recommended for a residence to those suffering from this disease, even if the climate were better than it actually is.

The characteristics of this climate are, first of all, the steady cold winter weather, the mean temperature of the four months, December, January, February, and March, being 19.6° F., while the minimum temperature has been as low as − 39° F. in December and − 31° in January. Secondly, may be mentioned the freedom from the sudden and constant great variations in temperature so common along the Atlantic coast; it is very cold in winter, but it is a steady cold, and there are no thaws. Again, when we consider the low winter temperature, a relative humidity of 72.4 per cent. indicates a dry atmosphere, quite different from that of New York City, for instance, with about the same relative humidity in winter, but with an average mean winter temperature 14.8° F. higher, the absolute humidity at St. Paul being only half as great in the winter as at New York City; so that we have a dry as well as a cold atmosphere. The average precipitation is seen to be small, about two-thirds of that of New York City.

There is no great amount of wind at St. Paul, particularly in the winter; and a very considerable amount of sunshine. In both of these respects St. Paul shows a marked superiority over New York City.

From its inland location, St. Paul is free from all those perturbations of temperature caused by the influence of the sea, which prevail in the large sea-bound cities of the United States, or in the cities lying upon the great lakes.

St. Paul is a beautiful city, and affords many attractive excursions in the vicinity;—one is to Lake Minnetonka, forty miles distant, a popular summer resort with hotels and cottages, where the air is pure and invigorating, and where many opportunities are afforded for out-of-door life. Convalescents and those suffering from nervous affections are said to do well in this climate. From St. Paul the journey down the Mississippi River begins,

CLIMATE OF ST. PAUL, MINN. LATITUDE, 44° 58'; LONGITUDE, 93° 3'. PERIOD OF OBSERVATION, THIRTEEN YEARS.

	January.	March.	May.	July.	September.	November.	December.	Winter.	Year.
Temperature, Degrees Fahr.—									
Average or normal	12.9	28.5°	58.8°	71.8°	58.4°	30.1°	18.7°	16.6°	43.7°
Mean of warmest	21.3	41.2	68.7	82.8	70.7	40.2	28.2		
Mean of coldest	5.8	22.2	48.3	62.7	50.7	28.8	12.2		
Average daily range	19.5	19.0	20.4	20.1	20.0	16.4	16.0		
Highest or maximum	49.0	68.0	94.0	100.0	91.0	72.0	56.0		
Lowest or minimum	−31.0	−22.5	24.0	46.0	30.0	−24.5	−39.0		
Humidity									
Average mean relative	72.1%	69%	60.5%	69.9%	70.7%	72%	74.3%	72.4%	69.1%
Precipitation									
Average in inches	1.07	1.64	3.72	3.22	3.26	1.42	1.28	3.42	29.94
Wind									
Prevailing direction	N. W.	N. W.	S. E.	S. E.	S. E.	N. W.	N. W.	N. W.	S. E.
Average hourly velocity in miles	7.8	9.2	9.6	7.2	8.2	8.3	7.5	7.8	8.4
Weather									
Average number of clear days	8	8.3	8.8	10.6	9.1	6.5	8.8	25.6	106.2
Average number of fair days	13	12.0	14.2	15.8	13.8	13.7	12.8	36.2	159.9
Average number of clear and fair days	21	20.3	23.0	26.4	22.9	20.2	21.6	61.8	266.1

and the portion between this city and St. Louis, constituting the first stage, is one of beautiful and grand scenery. The distance is about eight hundred miles.

Edward O. Otis.

SALACETOL — salantol, $C_6H_4.OH.CO.OCH_2.COCH_3$ —is a compound of acetone and salicylic acid containing seventy-one per cent. of the latter. It occurs as fine acicular crystals or scales insoluble in cold water, slightly soluble in cold alcohol, and freely soluble in hot alcohol, ether, and chloroform. In its action it resembles salol, the analogous compound of phenol and salicylic acid, and like it separates into its components in the intestine. The dose is 1-3 gm. (gr. xv.-xlv.).

W. A. Bastedo.

SALACTOL is a solution of the lactate and salicylate of sodium in a one-per-cent. solution of hydrogen dioxide. It is employed in diphtheria as a gargle, or applied to the throat with a brush. *W. A. Bastedo.*

SALICIN.—(*Salicinum*, U. S. P., B. P.), $C_{13}H_{18}O_7 =$ 285.33. This is a neutral principle obtained from several species of *Salix* and *Populus* (Fam. *Salicaceæ*).

Salicin is easily prepared from willow bark by extracting with water, precipitating tannin, etc., with litharge, evaporating and crystallizing out the salicin, and purifying by re-solution and repetition of the process. From populin it is prepared by boiling with lime water or barium hydroxide. It can also be prepared synthetically. The following is the official description:

Colorless, or white, silky, shining crystalline needles, or a crystalline powder, odorless, and having a very bitter taste. Permanent in the air.

Soluble, at 15° C. (59° F.), in 28 parts of water, and in 30 parts of alcohol; in 0.7 part of boiling water, and in 2 parts of boiling alcohol; almost insoluble in ether or chloroform.

When heated to 198° C. (388.4° F.), salicin melts, yielding a colorless liquid which, on cooling, congeals to a crystalline mass. Upon ignition, it is consumed, leaving no residue.

Salicin is neutral to litmus paper.

On heating a small portion of salicin in a test tube until it turns brown, then adding a few cubic centimetres of water, and afterward a drop of ferric chloride T.S., a violet color will be produced.

Cold, concentrated sulphuric acid dissolves salicin with a red color; the solution, after the addition of water, becomes colorless, and deposits a dark-red powder insoluble in water or alcohol.

On heating a small portion of salicin with 1 c.c. of potassium dichromate T.S. and 2 c.c. of sulphuric acid, the odor of salicylic aldehyde (or of oil of meadow-sweet, *Spiræa ulmaria* L., Fam. *Rosaceæ*) will become noticeable.

The aqueous solution of salicin is not precipitated by tannic or picric acid, nor by mercuric potassium iodide T.S. (absence of, and difference from, *alkaloids*).

Salicin is a glucoside, yielding, upon treatment with dilute acids or a powerful galvanic current, glucose and saliretin, or saligenin. It is readily convertible into salicylic and related acids and numerous other compounds. In the system it is partly converted into salicylic acid, so that its effects are very similar to those of that substance; but, since the percentage thus changed appears inconstant, its action is very irregular. Between two and three ounces of it are recorded as having been taken with no marked effect, though far smaller amounts are often very active. Although its chemical reactions outside of the body are thus of great interest, they lend but little assistance in determining its physiological action, and its therapeutics is almost wholly empirical. As indicated above, its action is, weakly and irregularly, that of salicylic acid.

Salicin has undoubted antipyretic power, although less than is possessed by quinine or salicylic acid; its antiperiodic action is much less than that of either of them. As a remedy in rheumatism, salicin has also been obliged to yield to the more useful salicylic acid. As a tonic, in small doses, it is occasionally used, but is far inferior to gentian or quinine. Four or five grams (ʒ i. ad ʒ iss.) may be given as a dose, and repeated every three hours; as a tonic 1 or 2 dcgm. (gr. iss. ad gr. iij.) is sufficient.

Henry H. Rusby.

SALICYLAMIDE.—A compound prepared from salicylic acid by the introduction of the amidogen radical. Its chemical formula is $C_6H_4,OH,CONH_2$. The benefit of the combined action of this stimulating radical had already been demonstrated in chloralamide, and the same advantage was looked for in salicylamide. It may be prepared by the action of concentrated ammonia upon oil of wintergreen. It forms in colorless crystals and in thin transparent plates, melting at 142° C. It is soluble in alcohol, ether, chloroform, readily soluble in hot water, and in two hundred and fifty parts of cold water.

Salicylamide was proposed as a substitute for salicylic acid and its salts, the advantage claimed for it being its greater solubility, its tastelessness, and its freedom from any depressing action on the system. A very careful study of its physiological properties has been made by Dr. W. B. Nesbitt, of Toronto (*Therapeutic Gazette*, October, 1891). He sums up the result as follows: 1. Pharmacologically, it prevents conduction in nerve; paralyzes nerve first, then muscle. 2. On the heart, its chief effect is on the motor apparatus, most probably through its activity on conduction. 3. Diminishes spinal reflex for motor impulses. 4. Diminishes spinal conductivity for painful impressions. 5. Diminishes muscular irritability. 6. In mammals, it exerts no particular effect on respiration. 7. It produces no particular effect on blood pressure. In medicinal doses it reduces temperature and causes ataxic gait and hebetude in fowls.

It is employed for all conditions in which the salicylates are indicated. The dose advised is about fifteen grains daily, in divided doses of three to five grains.

Beaumont Small.

SALICYL-BROMANILID. See *Antinervine*.

SALICYLIC ACID AND SALICYLATES.—Salicylic acid, chemically *ortho-oxybenzoic acid*, $HC_7H_5O_3$, takes its name from the principle *salicin*, found in willow bark, from which substance it is possible to make salicylic acid by fusion with potassium hydrate. Salicylic acid in the condition of the ethereal salt, *methyl salicylate*, constitutes about ninety per cent. of oil of gaultheria (wintergreen), and occurs also in other plants Salicylic acid can be made from oil of gaultheria, but at present almost all the acid used in medicine is made, by the process of Kolbe, from carbolic acid. The principle of this process consists in the forcing of a molecule of carbon dioxide upon the molecule of carbolic acid, an addition which just converts one molecule of the phenol into one of salicylic acid. In this process, carbolic acid and a concentrated solution of soda are first evaporated to dryness, and over the product, heated, a stream of dry carbon dioxide is made to pass As a result, one-half of the phenol used is converted into salicylic acid in the condition of sodium salicylate, which salt, on decomposition by treatment of its aqueous solution with hydrochloric acid, yields salicylic acid under its own form. Kolbe's process, by reason of its cheapness, has practically superseded all others for the procurement of salicylic acid.

It will thus be seen that both the natural and the artificial acids are prone to impurities. Their purification, especially that of the synthetic, is a matter of much importance. Carbolic acid is the commonest and one of the most serious impurities, as are the creosotic acids (see below) frequently occurring in the artificial variety. Salicylic acid is official in the United States Pharmacopœia under the title *Acidum Salicylicum*, Salicylic Acid. It occurs in fine, light, perfectly white needle-shaped crystals, or in a white crystalline powder. A reddish tinge in a sample of the acid signifies impurity, and such a sample should be rejected. Salicylic acid is permanent in the air; is, when pure, free from odor of carbolic acid, but has a sweetish taste, with an acrid after-flavor. It dissolves in 450 parts of cold water and in 14 parts of boiling water; in 2.4 parts of cold alcohol, and very readily in boiling alcohol. Although salicylic acid is but feebly soluble in cold water, it dissolves freely in many saline solutions. Thus the pharmacopœial *solution of ammonium acetate* will dissolve twenty-five per cent. of salicylic acid; a twelve-and-a-half-per-cent. aqueous solution of potassium acetate will dissolve twelve and a half per cent. of the acid; a twelve and-a-half per cent. solution of potassium citrate in equal volumes of glycerin and water will dissolve six per cent. All of these solutions possess the sharp stinging taste of the uncombined acid. A serviceable and permanent solution of the acid, and one that instead of being sharp to the taste has a pure bitter flavor only, can be made as follows: Dissolve two parts of borax in twelve of glycerin by the aid of heat; add one part of salicylic acid, continue the heat, and stir until the acid dissolves. Almost all solutions of salicylic acid, either immediately or after a while, turn of a reddish or of a smoky color, resembling that of solutions of carbolic acid.

Salicylic acid is incompatible with strong oxidizing agents, like potassium permanganate, and with chlorine, bromine, iodine, ferric salts, carbonates, the most of which it decomposes, and spirit of nitrous ether. A soft or semi-liquid mass is formed with exalgin, antipyrin, phenacetin, urethane, and other synthetics, as well as with lead acetate and sodium phosphate. The salicylates give precipitates with strong solutions of most alkaloidal salts, as well as with strong acids. Lime water also yields a precipitate.

Salicylic acid, taken into the mouth, has not much taste, proper, but speedily and quite suddenly after the tasting a sharp stinging seizes the *throat*, often severe enough to bring tears to the eyes. Similarly, a little of the dry acid snuffed up the nostrils will sting quite strongly. The acid brings sharp pain to cuts and abrasions, but, swallowed, is much less irritant to the stomach than its effects on the throat would lead to suppose. Large doses, so taken, may upset digestion and cause a strong sensation of heat, and even actual burning pain, but no serious or lasting results follow. The acid is rapidly absorbed from the stomach into the circulation, presumably in saline combination, and thereupon exerts the peculiar influence characteristic of the salicylates (see *Salicylates*, below).

Salicylic acid was at first used as an internal medicine for the procurement of the therapeutic effects of the salicylates, but now, and very properly, salicylates themselves, because of their freedom from the locally irritant action of the uncombined acid, have superseded the acid for this purpose. The present medicinal application of the acid is for local purposes as a deodorant, detergent, or so-called antiseptic—purposes which salicylic acid fulfils by reason of its having a fairly potent germ-sterilizing faculty. (See Salicylic Acid in article *Germicides*.) For general local use, the solution of the acid in a glycerin solution of borax is convenient, this solution bearing any necessary dilution with either water or alcohol without precipitation. A dilution representing a two per-cent. solution of acid is one very commonly employed. For other salicylic preparations for local use, see Salicylic Acid in article *Antiseptics*.

SALICYLATES.—In saline combination, whether with metallic or ethereal bases, the local pungency of free salicylic acid disappears while yet the faculty for constitutional action remains. As already said, it is probable that the acid, when taken as an internal medicine, enters the circulation only after conversion into a salicylate, so that, as a matter of fact, what is commonly called the constitutional action of salicylic acid is, so far as we know, the action of a salicylate. The constitutional effects in question are as follows: After a full dose a non-pyrexial subject experiences, in about fifteen minutes, a moderate reddening of the face with a sense of fulness of the head, or perhaps even a pronounced headache, and a buzzing or roaring in the ears precisely similar to what occurs in cinchonism. Almost simultaneously free perspiration begins, and, according to dose, there is more or less tendency to a reduction of pulse rate, of respiration rate, and of body temperature. Tests for salicylic acid will reveal the presence of the substance in the urine, the saliva, and the sweat. The urine, furthermore, will be discolored, appearing brown by reflected and green by transmitted light, from the presence of indican or of pyrocatechin. It will also contain a something that will reduce copper salts in copper test solutions (Brunton), and will show an increased amount of urea and uric acid. In overdoses, salicylates readily irritate the kidneys, setting up albuminuria; may derange the cerebral faculties, causing hallucinations and delirium; and may dangerously or even fatally depress the functions of heart and lungs, determining collapse or death by failure of respiration. These several untoward effects occur very irregularly, and, according to Squibb, in "a very large proportion" of instances are determined, not by the salicylic acid, but by a *contaminating acid* very commonly present in market samples of salicylic acid, and hence in salicylates derived therefrom. The constitutional effects of salicylates, which are valuable in medicine, do not appear in experimentation with a subject in health. They consist, in general, in a reduction of fever temperatures, and, in particular, in an abatement of pains in fibrous tissues, notably the pains in acute articular rheumatism. The antipyretic power of salicylates is second to none, in all the three elements of quickness, degree, and duration of reduction of temperature. For a full antipyretic effect, however, considerable dosage is necessary—considerable enough to cause disagreeable sweating, *tinnitus aurium*, depression of pulse and respiration rate, and, every now and then, actual toxic symptoms. Other antipyretics, therefore, which act more kindly, are preferable, except in rheumatism. The antirheumatic faculty of salicylates is unapproached by any other known medicine, so that, as is well known, salicylates constitute a standard set of medicines for the treatment of acute rheumatism. Under salicylate medication the fever lessens, pains abate, and the disease runs a shorter as well as milder course. It is therefore particularly as remedies for rheumatism and, though not so surely, for gout that salicylates are prized in medicine.

The salicylates in *common medical use* for the purpose of salicylate medication are the salicylates, respectively, of *sodium*, *lithium*, and *methyl*. The salicylates, respectively, of *physostigmine*, *quinine*, and other alkaloids, are used for the sake of the medicinal action of the respective bases only.

Sodium Salicylate, $2NaC_7H_5O_3.H_2O$. The salt is official in the United States Pharmacopœia under the title *Sodii Salicylas*, Sodium Salicylate. It occurs as an amorphous powder, white, without odor, and having a sweetish, saline, and slightly alkaline taste. It is permanent in the air, dissolves readily in water, glycerin, and boiling alcohol. In cold alcohol it requires six parts for solution. It should be kept in well-stoppered bottles, protected from heat and light. Sodium salicylate is the most commonly used salicylate, and is a very important medicine. It is easily made *in solution* by mixing salicylic acid and a sodic carbonate in the presence of water, whereupon sodium salicylate results, and remains in solution, and carbon dioxide gas escapes in effervescence. From this solution the salt can be obtained by evaporation to dryness, carefully conducted. Extemporaneous preparation of the medicine *in solution* being easy, Squibb points out an advantage of such extemporaneous making of the salt in all cases in which the prescriber or the dispenser may not be certain of the purity of the market article. The point is that it is not possible to establish the purity of a given sample of *sodium salicylate* except by an elaborate chemical analysis, whereas a good sample of *salicylic acid* is immediately recognizable by the simple fact of its *crystalline condition*. Hence, in making one's own sodium salicylate from a selected well-crystallized sample of salicylic acid, purity is assured. And in the instance of this salt purity is important, since, as above said, there is probably good reason to lay many of the untoward effects of salicylates to the door of the contaminating acid of salicylic acid. Squibb recommends the following formula for the preparation of a solution of sodium salicylate of a strength convenient for use as a medicine: "Take of salicylic acid, well crystallized, 437 grains = 28.32 gm.; bicarbonate of sodium, 270 grains = 17.5 gm.; water, free from iron, a sufficient quantity. Put the acid into a vessel of the capacity of a pint, add 4 fluidounces = 120 c.c. of water, stir well together, and then add the bicarbonate of sodium in portions with stirring, until the whole is added and the effervescence is finished. Filter the solution, and wash the filter through with water until the filtered solution measures 6 fluidounces, or 180 c.c. This solution contains 10 grains (= 0.65 gm.) of the medicinal salicylate of sodium in each fluidrachm (= 3.75 c.c.). If made from good materials, the solution before filtration is of a pale, amber color, but as most ordinary filtering paper contains traces of iron, the filtered solution is often of a deeper tint." The proportions of the ingredients for this solution are estimated so that the solution shall be neutral, but, "owing to the varying proportions of hygrometric moisture in the materials," the neutrality may not always be absolute. According to Squibb, a well-made sample of sodium salicylate, prepared by use of a well-crystallized sample of acid, is always, when evaporated to dryness, *white*, and is free from all *odor of carbolic acid*, unless it has been shut up for a long while in a bottle. Even then, however, the odor should be but very faint—only perceptible on close examination, and should disappear upon exposure of the sample to air. *Solutions* of sodium salicylate of good quality should have none of the carbolic-acid smell.

Sodium salicylate is used almost exclusively as an internal medicine, being commonly held to be lacking in the germ-sterilizing faculty which gives salicylic acid, as such, its applicability as a local antiseptic. For the purposes of internal salicylate medication, as set forth above, the salt is thoroughly effective, and, if made from a well-crystallized and therefore fairly pure sample of salicylic acid, rarely produces untoward effects in reasonable doses. So large a quantity as 5 gm. (about seventy-seven grains) has been given at a single dose in rheumatism without producing serious derangement, but the ordinary dosage for an antipyretic or antirheumatic effect does not exceed 1.3 gm. (20 grains) repeated every two hours, for three or four doses, or until a distinct impression is produced, followed by doses of half the quantity every hour or two thereafter, so long as the influence of the medicine may be required. The medicine is readily enough taken in simple aqueous solution, but if the faint, mawkish taste of the salt be objectionable, the addition of twenty per cent. of glycerin and the flavoring with a drop or two of oil of gaultheria will render the mixture perfectly palatable.

Lithium Salicylate, $2LiC_7H_5O_3.H_2O$. The salt is official in the United States Pharmacopœia under the title *Lithii Salicylas*, Lithium Salicylate. It occurs as a whitish powder which deliquesces on exposure to the air. It dissolves freely in water and alcohol, and resembles the sodium salt in taste. It should be kept in well-stoppered bottles. The effects of this salt are similar to those of sodium salicylate, with the possible superaddition of medicinal virtues, in rheumatic or gouty cases, derived from the basic element. The dose is similar to that of the sodic salt.

Methyl Salicylate, $CH_3C_7H_5O_3$. This salicylate is an ethereal body which constitutes nine-tenths of the substance of oil of wintergreen and practically the whole of the volatile oil of betula, both of which oils are themselves official medicines. Under the title, however, *Methyl Salicylas*, Methyl Salicylate, the United States Pharmacopœia recognizes the salicylate as made in the laboratory by distilling salicylic acid or a salicylate with methylic alcohol and sulphuric acid. Methyl salicylate is a colorless or slightly yellowish liquid, with the characteristic odor and taste of oil of wintergreen. It dissolves freely in alcohol. It should be kept in well-stoppered bottles protected from light. Methyl salicylate acts like the salicylates generally, with the usual pungent qualities of the volatile oils. In large doses—half an ounce or more—it is dangerously and even fatally poisonous, causing intense irritation of the stomach and intestines with constitutional symptoms of the salicylic influence. In doses of from five to fifteen minims it makes a very efficient salicylic medicine for rheumatism, and is, with many, the favorite salicylate. It may be administered in emulsion or in capsules.

Sodium Dithio-salicylate. Dithio-salicylic acid is a product of reaction between salicylic acid and sulphur chloride, under the influence of heat. The sodium salt of this product is a grayish-white, very hygroscopic powder, freely soluble in water. It has been proposed as a substitute for ordinary salicylates, on the score of being equally, if not more, potent as an antirheumatic remedy, while it is less apt to disturb the stomach. About 0.2 gm. (gr. iij.) may be given two or three times a day, or oftener, according to indications. It is not official in the United States Pharmacopœia.

Iodo-salicylic Acid is a modification of salicylic acid that has been used as a substitute for the ordinary acid in acute rheumatism. It occurs as a white powder slightly soluble in water, but freely so in alcohol, ether, and the fixed oils. It may be given in quantities of from 1 to 3 gm. (gr. xv. to gr. xlvi.) a day.

Cresotic Acid, Cresotinic Acid.—This is an homologue of salicylic acid to which it is allied in physical, chemical, and physiological properties. Its formula is C_6H_3-$OHCH_3COOH$. There are three isomeric acids, the ortho-, meta-, and paracresotic acids. They are always present in salicylic acid of commerce. In 1890 (*Phar. Jour. and Trans.*, November 22d) Professors Charteris and Dunstan, of Glasgow, pointed out that the ill effects that often followed the employment of salicylic acid were due to the presence of ortho- and paracresotic acids. These statements were described more in detail in a second paper in the *British Medical Journal*, March 25th, 1901.

The only preparation of this acid that has been employed for therapeutic purposes is the paracresotate of sodium. It possess antipyretic and antirheumatic properties similar to those possessed by salicylate of soda, but in a lesser degree. The dose is from five to twenty grains three or four times a day; it is free from toxic action, and may be administered more freely if necessary. *Edward Curtis.*

SALICYLIC ALDEHYDE, salicylous acid, ortho-oxybenzaldehyde, artificial oil of spiræa, $C_6H_4.OH.COH$, is obtained by heating phenol and sodium hydroxide with chloroform. A colorless fluid with the odor of meadowsweet, it is readily soluble in alcohol and chloroform, but in water is soluble only enough to impart its odor. In dose of 0.1–0.5 gm. (gr. iss.–viiss.), it is employed as a diuretic and intestinal antiseptic. *W. A. Bastedo.*

SALICYLIDEN-PHENETIDIN. See *Malakin*.

SALICYLO-ACETIC ACID. See *Aspirin*.

SALICYL-QUININE. See *Saloquinine*.

SALICYL-QUININE SALICYLATE. See *Rheumatin*.

SALICYL-RESORCIN-KETONE, tri-oxy-benzophenone, is a compound which in the intestine sets free salicylic acid and resorcin. It is used externally in skin diseases, and internally as an intestinal antiseptic. Dose, 3–4 gm. (gr. xlv.–lx.). *W. A. Bastedo.*

SALICYL-SULPHONIC ACID.—$C_6H_3(OH)(SO_3H)$-$COOH$. A white crystalline body, very soluble in water and alcohol. It is formed by the action of sulphuric anhydride on salicylic acid.

This compound was recommended as a test for albumin by G. Roch (*Pharm. Centralblatt*, September, 1889) and by Dr. John A. Macwilliam (*British Medical Journal*, April 18th, 1891), working independently of each other. It acts upon all forms of proteid bodies. When the proteid present is a native albumin, a derived albumin, a globulin, or fibrin, the precipitate is not dissolved upon boiling, but becomes decidedly flocculent. When the proteid is an albumose or peptone, the precipitate dissolves upon heating, to reappear on the cooling of the fluid. The peptone and albumose may be distinguished by saturating the solution with ammonium sulphate; the albumose is at once precipitated, while the peptone remains in solution. The peptone may then be detected by adding the salicyl sulphonic test.

Compared with other tests, the delicacy of the salicyl sulphonic test varies, according as a cloudiness immediately (two or three seconds) appears, or follows after one-half to one minute. In the latter case it is one of the most delicate tests we possess, revealing the presence of 1 part of albumin in 12,500 of water; in the former, it is placed by Dr. Macwilliam between the cold nitric acid test and the acetic acid and heat test.

Dr. Roch recommended that a few crystals of the acid should be shaken with the urine, or that 5 c.c. of a twenty-per-cent. solution should be added to 10 c.c. of the urine to be tested. Dr. Macwilliam is more exact in his manipulations. He recommends that a small amount of urine, about twenty minims, be placed in a small test tube, and that to this a drop or two of a *saturated* aqueous solution of the reagent be added. The urine must not be alkaline, and, if necessary, it should be acidulated. On adding the reagent the tube should be shaken quickly, to mix the contents, and the fluid should be examined at once. The occurrence of an opalescence or cloudiness immediately or within a few seconds indicates the presence of proteids. The development of the reaction after an interval of a minute or two shows the presence of proteids in minute quantities, which are probably insignificant from a clinical point of view. The fluid is then to be heated, when the ordinary albumin is coagulated and formed into a flocculent mass. *Beaumont Small.*

SALIFEBRIN, salicylanilid, is a proprietary combination of acetanilid and salicylic acid. *W. A. Bastedo.*

SALIFORMIN, urotropin salicylate. See *Urotropin.*

SALIGALLOL, the di salicylate of pyrogallic acid, is a resinous substance, soluble in chloroform or acetone. Kromayer finds that it has but a weak pyrogallol action, but is of value for the preparation of an excellent skin varnish which may serve as a vehicle for other medicaments. "Solutio saligalloli" is a sixty-six-per-cent. solution of saligallol in acetone. *W. A. Bastedo.*

SALINE SOLUTION, NORMAL. See *Hypodermoclysis.*

SALINS-MOÛTIERS. See *Brides-les-Bains.*

SALIPYRIN.—A compound containing 57.7 parts of antipyrin and 42.3 parts of salicylic acid. It is prepared by adding to a boiling aqueous solution of antipyrin a proper molecular proportion of the acid. It forms as a white, coarsely crystalline powder, odorless, with a not unpleasant sweetish taste. It is almost insoluble in water, about one part in two hundred, sparingly soluble in ether, but readily soluble in alcohol. It is decomposed by acids and alkalies.

It possesses antipyretic and antirheumatic properties, and was introduced as a substitute for the salicylates in the treatment of rheumatic affections. It is probably as serviceable as salicylic acid or antipyrin, but is equally inefficient in preventing relapses, and does not seem to offer any special advantage over other remedies for rheumatism. The amount to be given is one drachm and a half in divided doses, during the day; the first dose being thirty grains and the subsequent doses about fifteen grains each.

As an antipyretic it is not very satisfactory; it requires to be given in doses of thirty grains, to be repeated every hour if necessary. As an analgesic it has proved of value in sciatica, in the pains of myelitis, in neuralgia, and in nervous disease accompanied by pain.

The results of its employment show it to be a harmless and useful drug, but not very reliable. It has not superseded either of its component parts. Profuse perspiration and gastric disturbances frequently follow its employment. *Beaumont Small.*

SALITANNOL, $C_{14}H_{10}O_7$, is a condensation product of salicylic and gallic acids, forming a white, amorphous powder. It is insoluble in water, ether, chloroform, and benzol, slightly soluble in alcohol, and readily soluble in solutions of the caustic alkalies. It is employed surgically as an antiseptic. *W. A. Bastedo.*

SALITHYMOL, $C_6H_3.CH_3.C_3H_7.O.COC_6H_4OH$, is a combination of thymol and salicylic acid somewhat similar to salol. It is obtained by acting with phosphorus trichloride on equimolecular quantities of the sodium compounds of salicylic acid and thymol, and then crystallizing from alcohol. Salithymol is a white crystalline powder of mild sugary taste, very soluble in alcohol and ether, and nearly insoluble in water. Its uses are those of salol, but it is claimed to be preferable, as it sets free thymol in the intestine, while salol liberates phenol. The dose is 0.3–1 gm. (gr. v.–xv.). *W. A. Bastedo.*

SALIVA.—The saliva is formed by the admixture of the secretions of the three pairs of chief salivary glands, viz., the parotid, submaxillary, and sublingual, and of the small buccal glands.

The mechanical and chemical functions of the saliva in connection with deglutition and digestion have already been considered in the articles upon these subjects, and hence the secretion and chemical composition of the fluid only need be taken up in this article.

Secretion.—The three paired salivary glands form typical examples of racemose, tubulo-saccular secreting glands. Each gland possesses a main duct by which the secretion is carried to the mouth. Within the gland this duct divides and subdivides in a racemose fashion, giving rise finally to a large number of minute ductules lined by a single layer of columnar cells. Each ductule, as it passes toward the secreting cells, divides, and the cells lining the secondary ductules so formed become flattened in shape; then each secondary ductule widens to form a tube of secreting cells, which usually possesses branches also lined with similar secreting cells, which may again branch and be lined with secreting cells in similar fashion. Thus a racemose clump of secreting tubules is formed around the end of each ductule. These secreting tubules are termed *alveoli* or *acini*, and are lined by polyhedral cells which surround in a single layer a minute central cavity or *lumen*, into which the secretion is poured when the gland becomes active. This layer of secreting cells is sheathed externally by a thin basement membrane, and lying upon this is a network of fine capillary blood-vessels for the nutrition of the secreting cells. The lymph exuding from this capillary plexus bathes the secreting cells after it has passed through the fine basement membrane, and the cells taking up the lymph, even during periods of rest, transform its constituents into definite chemical substances which are stored up in the cells in such a manner as to be visible under the microscope as minute granules.

When the gland becomes active as a result of stimulation in the natural fashion, two important changes, which have been shown to be independent of each other in their innervation, occur: in the first place, the vaso-dilator fibres supplying the walls of the blood-vessels of the gland are stimulated, so giving rise to an increased blood supply, and hence to an increased flow of water and salts to the secreting cells to serve as a vehicle for carrying off those cell products which have accumulated in the cell during the period of intermission in secretion; in the second place, the gland cells themselves are directly stimulated by the secreto-motor fibres to a change in activity, as a result of which the granules deposited previously in them undergo a chemical modification which renders them soluble and easily transported through the cell into the lumen of the alveolus. The constituent alveoli are bound loosely into small masses visible to the naked eye, which are termed lobules, and these lobules are divided off from one another, and at the same time united to form the gland mass, by coarser bundles of connective tissue, which unite at the outer surface of the gland to form a capsule, varying in the clearness of its definition in the different glands and in different animals, being usually but ill-defined in the case of the parotid gland.

The secreting cells of the salivary glands when observed under the microscope, either in the fresh state or after the use of hardening and staining reagents, present two distinct types of characteristically different appearance, and each type again shows distinct modifications in appearance according to whether it is observed at a period of fasting (loaded) or during a period immediately following digestive activity (unloaded).

These differences in type correspond to a difference in chemical character of the secretion yielded by the respective cells, for it has been shown that one form of cell secretes the *mucin* of the saliva, while the other secretes the *ptyalin*, which confers upon the saliva of certain mammals, including man, its important chemical action upon the starch of the food. (See *Digestion*.)

The relative extent to which the two cells are developed in the corresponding glands of different animals varies within very wide limits, the same gland being almost completely composed of one type in one animal and of the other type in another. In many cases the same gland contains both types of cells, as is particularly well seen in the human submaxillary gland, and in such a case the different characters of the two types of cell can be studied side by side in the same section. Usually the cells occupying any one alveolus are of the same type, either *mucous* or *serous*; but in the mucous alveoli a third type of cell occurs, lying outside the true mucous cells, between these and the basement membrane. From their position and the pressure applied to them by the concentrically arranged cells of their own alveolus on one hand and the adjacent alveoli on the other, these cells as they develop become crescentic in shape and have hence been termed *demilune* cells.

In a mucous alveolus, the mucin-secreting cells present in hardened sections a perfectly clear, homogeneous, glass-like appearance, except for the nucleus, which is usually shrunken and lies at the broader end of the cell close to the basement membrane. This appearance is, however, an *artifact*, and is due to the action of water, alcohol, or other reagent used in the process of manipulation, upon the cell contents; for these mucous cells when examined in the fresh state, teased out in blood serum, are filled up, provided the gland is in the loaded state, by large granules which are stated to be composed of *mucinogen*, a precursor of the mucin found in the saliva. On the other hand, if the gland has been much stimulated before the mucous cells are taken for examination, it is found, according to the degree of stimulation, that these mucinogen granules may either be few in number and confined to the inner zone of the cell, or may be entirely absent. In the process of secretion, then, the mucinogen granules are dissolved, being converted into soluble mucin, which is carried by the stream of water and salts through the mucous cell toward the lumen of the alveolus, and is thence discharged into the duct. Supporting this view, there is the fact that the viscidity and amount of mucin present in the saliva vary with the amount of these clear cells present in the gland.

Various contentions have been put forward as to the nature and purpose of the demilune cells present alongside the mucous cells in the same alveolus, and present also in glands containing no serous alveoli.

These cells differ strikingly in histological appearance from the mucous cells, especially in hardened and stained sections, being not only different in shape and position, as above described, but also smaller, free from mucin granules, and filled instead in the loaded condition with minute highly refractile granules similar to those present in the serous cells (*vide infra*) and disappearing during secretion.

One view was that they were young mucous cells designed later to be pushed toward the lumen and take the place of mucous cells which had broken down in the process of secretion.

There is, however, no good evidence that the mucous cells are disrupted in the process of discharge; no intermediate stages in the process of conversion of demilunes into mucous cells have ever been demonstrated; and, further, the charged and discharged condition of the demilunes as regards their granules, varying as it does concurrently with the state of the gland, proves that they are functionally active and not immature growing cells.

The view has hence been put forward that these demilunes are really serous cells, occurring in chiefly mucous glands and not differing save in shape from the other serous cells which constitute the chief cells in other alveoli. Their peculiar shape can be explained from their position, while the fact that ptyalin in addition to mucin is also found in the secretion of glands containing otherwise only mucous cells points strongly to the demilunes being serous cells.

The cells of the *serous* or *albuminous* alveoli in the loaded condition are filled with minute highly refractile granules which render the cells opaque, disguise the nuclei, and make it difficult even to discern the cell outlines. When the gland is stimulated to secrete, these granules rapidly decrease in number, the cell outlines become clearly marked, soon the nuclei become visible, and the outer zone of the cell clear of granules, and capable of staining with dyes, while the portion of the cell toward the lumen is still loaded with granules. As secretion is pushed to the extreme limit, this luminal zone, however, becomes smaller and smaller, showing that there is a current of dissolution setting toward the lumen.

The intrinsic ferment of the saliva is yielded by these cells, but it is probable, as in the case of the pancreas (*q. v.*), that the ferment is not deposited in the cells in the form of this ferment in the granular condition, but is instead present in the cells in an inactive form called *ptyalinogen*, from which the free ptyalin is formed as solution of the granules takes place in the act of secretion. In some animals, however, as has been shown in the case of the horse, the active ferment is set free in an unknown manner only in the mouth, and not in the gland itself. For if the parotid saliva of the horse be collected, by means of a fine sterilized glass cannula inserted into Stenson's duct, in sterilized glass vessels, it is quite inactive upon starch solutions, and first becomes active when it is agitated by blowing air through it.

Each salivary gland is innervated along two distinct paths, receiving nerve fibres, on the one hand, from the medulla oblongata by a cranial nerve, and, on the other, fibres from the spinal cord through the cervical sympathetic. These nerve fibres have two distinct functions, some passing to the blood-vessels of the glands and regulating its blood supply, while others are purely secretory in character and pass to the secretory cells of the alveoli. The greater number of the secretory fibres are carried by the cranial nerves and are there accompanied by the vaso-dilators; while a smaller number of secretory fibres, which seem especially to be connected with the secretion of the organic constituents of the saliva, pass to the gland viâ the cervical sympathetic accompanied by the vaso-constrictor fibres to the blood vessels.

The cranial fibres for the submaxillary and sublingual glands are carried by the *chorda tympani*, which leaves the facial nerve in the Fallopian canal, crosses the tympanum, and then joins the lingual branch of the fifth. The lingual nerve gives off a branch at the posterior border of the submaxillary gland, which contains the ma-

[illegible] the fibres which had joined previously by way of [illegible] tympani, and this branch, which consists of a number of strands lying close together, contains most of the secreto- and vaso-motor fibres for the submaxillary and sublingual glands. These strands, often wrongly called the chorda tympani nerve, curve backward along the gland ducts and pass with them into the glands.

The cranial fibres for the parotid gland vary in their course in different animals, but frequently they arise from the ninth cranial nerve and course in the nerve of Jacobson, across the tympanic cavity, over the promontory of the tympanum, and pass viâ the small superficial petrosal and otic ganglion to the auriculo-temporal branch of the fifth, by which they are finally distributed to the parotid gland.

The sympathetic fibres to the salivary glands arise from the spinal cord in the upper dorsal region and run to the superior cervical ganglion, where a relay of nerve cells is interposed, round which the original fibres arising from the spinal cord end in arborizations. From the nerve cells of the superior cervical ganglion other fibres arise, chiefly from the lower and middle portion, and, passing to the external carotid, form plexuses upon it and its branches by which the fibres are ultimately carried to the gland without forming any more nerve-cell connections.

A similar cell station has been demonstrated in the case of the chorda tympani fibres, as lying in the many small ganglia between the point at which the fibres leave the lingual nerve and the various points at which the fibres enter the glands.

These ganglia are as a rule microscopic in size, but two can be seen with the naked eye and have been named, viz., the *sublingual*, lying in the angle between lingual and chorda, which is a cell station for fibres passing to the sublingual; and the *submaxillary*, which lies in the hilus of the submaxillary, and forms a cell station on the path of many of the fibres for that gland.

The position of these various cell stations has been demonstrated by Langley by the injection of small doses of nicotine, which paralyzes the junction between nerve fibre and nerve cell, but does not affect the nerve fibres. Hence the position of a nerve station is shown after injection of this drug into a vein, if no effect is now obtained on stimulating centrally to a ganglion, while an effect is still obtainable peripherally to the ganglion, previous experiment before injection of the drug having given an effect at both places.

Experimenting by this method, Langley has shown that every fibre leaving the spinal cord, whether by cranial nerve or sympathetic, ends somewhere on its course in a peripheral ganglion. Such a fibre is termed a preganglionic fibre. From the peripheral ganglion cell a fibre arises which is termed a postganglionic fibre, and this without further interruption passes to distribution in the gland. There is hence in every case one ganglion cell and no more interposed between spinal cord and gland. The preganglionic fibres are in most cases finely medullated (2 to 4 μ), while the postganglionic fibres are probably all non-medullated.

The effect of stimulation upon the nerves has been most closely studied in the case of the submaxillary nerve, but similar results have been obtained by stimulation of the corresponding nerves in the other glands, so that a description of the occurrences in the case of the submaxillary may be taken to hold for the other two glands. Excitation of the peripheral end of the cranial nerve (chorda tympani) causes, after a very short latent period, a rapid flow of a very dilute saliva, containing a very low percentage of organic constituents. Even weak stimulation produces a copious flow, and secretion can be evoked in this manner for a long period without fatiguing the nerve, so that a quantity amounting to forty or fifty times the weight of the gland can be obtained.

Accompanying this rapid secretion there is a marked vaso-dilatation, so that the gland can be seen to become much pinker to the naked eye, and when placed in a plethysmograph shows a large increase in volume.

That the increased flow of saliva is not, however, solely due to an increased blood supply is demonstrated by the following facts:

1. After administration of atropine, the flow of saliva is no longer obtained, although the vaso-dilatation is as great as before, showing that atropine paralyzes secreto-motor fibres but leaves the vaso-dilators untouched.

2. If the cannula placed in the duct of the salivary gland be connected up to a mercurial manometer, and at the same time the carotid blood pressure be similarly observed by means of a second manometer, it is found that the flow of saliva does not stop until the pressure in the salivary manometer has risen considerably higher than that in the carotid. Now, if the secretion were merely an increased filtration due to increased blood supply, this obviously could not be so, for then the saliva would be filtering from a lower to a higher pressure.

These experiments are sufficient to show that a true secretion is taking place in the alveolar cells, under the stimulating influence of a secreto-motor nervous mechanism distinct from the vaso-dilator mechanism.

The effects of stimulation of the cervical sympathetic upon the gland are very different; there is a vaso-constrictor instead of a vaso-dilator effect, and, after a much longer latent period, there is but a scanty flow of a very viscid saliva much richer in organic constituents.

The amount of flow caused by stimulation of the cervical sympathetic is considerably increased if the cranial nerve has been stimulated a few seconds previously.

Now in the natural stimulation of the gland, as by the sight or thought of food, or by the act of mastication, it is a fairly obvious conclusion that both cranial and sympathetic nerve supplies act upon the gland simultaneously, and hence that there will be conjoined the greater flow of water and inorganic salts caused by the cranial nerve fibres, with the stimulation to increased flow of organic substances effected through the cervical sympathetic fibres.

No saliva flows between periods of stimulation, and it has been observed by inserting a cannula into the duct of Stenson in the horse that a flow of saliva occurs only when it is provoked reflexly, as by mastication.

Cutting the cranial nerve gives rise to the so-called "paralytic secretion," first observed by Claude Bernard; this commences commonly in from two to three days after the section, and lasts for a period of three or four weeks, during which time there is a constant slow secretion accompanied by a great decrease in weight of the gland, which finally becomes functionless. No permanent effect of a like nature follows section of the cervical sympathetic.

It is interesting that a much slighter flow accompanies the paralytic secretion, upon the opposite side where the nerves are quite intact; this peculiar secretion is spoken of as "antilytic secretion."

There is no explanation of either paralytic or antilytic secretion, outside the region of mere hypothesis.

The mouth is probably kept moist in man between the periods of eating by the secretion of the small buccal glands, for it has been shown that the secretion of the large glands completely intermits between the meals in cases of artificial fistulæ of the gland ducts.

In man, the sight or even the thought of appetizing food causes an immediate flow; but secretion cannot be evoked in this fashion in some of the lower animals. Thus presenting meat to a dog in which a parotid fistula has been established does not cause a flow of saliva.

Sapid substances are the most powerful reflex stimulants to secretion when placed either on the tongue or on the mucous membrane of the mouth.

The vapors of chloroform and ether cause a rapid secretion when inhaled by the mouth, as a result of the stimulation of the gustatory nerve endings; when administered by the trachea, they are said not to produce this effect.

Alcohol, or water containing chloroform or ether, applied to the mucous membrane of the mouth, causes a rapid secretion.

The sapid substances produce their effect in the following descending order of strength: (1) acids, (2) neutral and alkaline salts, (3) bitter substances, (4) sweet substances; but the acids (including organic acids) are incomparably more effectual in evoking secretion than the other classes of sapid bodies.

Chemical Composition.—The composition of the mixed saliva is very variable, as can readily be understood when it is considered how many glands contribute to its formation. Sublingual saliva is richest in solids, and may contain as much as three per cent.; submaxillary saliva is stated by most observers to contain a higher percentage of solids than the mixed saliva, while parotid saliva is poorest in solid constituents (0.3 to 0.5 per cent.). The total solids of mixed saliva amount to from 0.5 to 1 per cent., and the specific gravity lies between 1.002 and 1.008.

Mixed human saliva is alkaline to litmus and acid to phenolphthalein, indicating that there is an excess of carbon dioxide present above that necessary to form sodium bicarbonate. This is borne out by the large amount of carbon dioxide obtainable from saliva, which contains more of this gas than either blood serum or venous blood. Thus Külz found in saliva 66.7 volumes of CO_2 per 100, and Pflüger 64.7 to 85.1 volumes per 100. This fact is of interest as showing the large amount of metabolism which occurs in the secreting cells, and lends a further proof, if such were necessary, that the process of secretion is not purely one of filtration and osmosis. The average amount of alkalinity to litmus is equivalent to that of a solution of 0.08 per cent. of Na_2CO_3 (Chittenden and Ely).

The organic matter of the saliva is small in total amount, and is present partially in suspension as formed elements and partially in solution.

The formed elements present include squamous cells from the buccal epithelium, salivary corpuscles, and very pale spherules resembling the granules seen in the mucous salivary cells.

The salivary corpuscles are altered leucocytes derived chiefly from the salivary glands, but possibly the tonsils also contribute to their number. The leucocytes pass from the lymph, between the alveolar cells, into the ductules, and become swollen out by imbibition from the saliva, which has a lower osmotic pressure than the lymph. For the same reason the granules which these corpuscles contain are set in active Brownian movement.

The chief organic substances in solution are mucin, ptyalin, and minute traces of proteid. The mucin can be demonstrated by its precipitation on the addition of acetic acid. The presence and action of ptyalin have been considered in the article on *Digestion*. Coagulable proteid is present only in minute traces. Urea is said to be excreted in the saliva in uræmia, and lactic acid in diabetes.

Saliva normally gives a distinct reaction for sulphocyanides when a very dilute solution of ferric chloride is added to it. The test is best carried out by wetting filter paper with ferric chloride so dilute as scarcely to color it, and then adding the saliva, when a red color is obtained. Sulphocyanates are, however, absent in certain individuals, and in the same individual are present at certain times and absent at others.

The inorganic salts present consist chiefly of chlorides, phosphates, and carbonates of the alkalies and alkaline earths, the chief constituent as usual being sodium chloride. The most interesting of the inorganic constituents is calcium bicarbonate; it is this salt which gives rise to the cloudiness observed when saliva is allowed to stand for some time. The precipitation is due to the escape of the excess of carbon dioxide, which had previously held the calcium carbonate in solution. A certain amount of calcium phosphate is similarly precipitated. Such a precipitation occasionally leads to occlusion of the gland ducts by the formation in these of salivary concretions, which consist of a mixture of calcium carbonate and calcium phosphate. When the precipitation occurs on the teeth it is termed tartar; this also contains silica in addition to the calcium salts mentioned above.

Benjamin Moore.

SALIVARY GLANDS AND THEIR DUCTS, DISEASES OF.—*Increased Secretion of the Salivary Glands* (Ptyalism; Salivation).—The normal amount of salivary secretion is from one to three quarts in twenty-four hours, though under exceptional conditions the quantity may be as much as five quarts. While food is being taken the saliva is normally greatly increased, which may also occur during the menstrual period and during gestation. Salivation, likewise, occurs in connection with quite a number of different diseases, such as acute fevers, diseases of the liver, spleen, genital organs, and pancreas, and in all inflammatory conditions of the oral cavity. It is likewise sometimes seen in bulbar paralysis, in diabetes, and in melancholia. Quite a number of drugs are also capable of giving rise to an increased salivary secretion, among which are muscarin, tobacco, pilocarpine, potassium iodide, the salts of arsenic and copper, and mercury and its various compounds. Of all the causes the last mentioned is the one that most frequently occasions the condition, and it is true that the amount necessary to produce this result varies very greatly in different instances—some individuals tolerating large quantities of the drug, while others are affected by very minute doses.

(For the treatment see article on *Mouth, Diseases of*, in THE APPENDIX.)

Decreased Secretion of the Salivary Glands (Xerostomia; Dry Mouth).—The secretions of the salivary and buccal glands may be greatly diminished, or, in some instances, entirely suppressed. The condition is most commonly observed in nervous women, though it is occasionally seen in men as well; it may follow shock or may occur in connection with diabetes and febrile states. As a natural consequence of the arrest of the secretion the tongue and mucous membranes of the cheeks and palate become dry, and mastication and articulation are exceedingly difficult. Osler speaks of a case observed by him in which, on account of the absence of the normal secretion of the mouth, food collected along the gums and became exceedingly hard, presenting somewhat the appearance of a new growth in the oral cavity of the patient; in this instance the affection was cured in about three weeks by the application of the galvanic current.

Treatment. For dry mouth pilocarpine may be used, and, as in the case above cited, electricity may be employed with advantage. Oils applied to the mucous membrane of the mouth are of service in ameliorating the very disagreeable dry state of the oral mucous membrane. The condition is very obstinate.

INFLAMMATION OF THE SALIVARY GLANDS.—There are several distinct and separate varieties of inflammations of the salivary glands at present recognized, and there can be no question but that, as our knowledge increases, many conditions which are at present regarded as being identical will be found to be the result of causes differing widely from each other. There are specific parotitis (see *Mumps*), symptomatic parotitis, and chronic parotitis.

Symptomatic Parotitis.—Symptomatic parotitis is an affection that occurs in connection with a large number of different diseases, though the relationship between inflammations of the glands and the causes that apparently determine them are exceedingly obscure. The condition occurs most commonly during the course of the infectious fevers, such as typhoid, typhus, scarlet fever, rheumatism, pneumonia, peritonitis, pyæmia, septicæmia, and syphilis, but it is also sometimes seen in connection with consumption and gout. When the affection results from acute fevers, the inflammatory phenomena are quite severe, and, as a rule, suppuration results. If the pus be not evacuated by surgical means, it not uncommonly burrows into the tissues of the face to a considerable distance. Inflammations of these glands likewise very curiously often follow laparotomy, and operations upon the genital organs in both men and women. It has also been found associated with facial paralysis, and may occur during pregnancy or follow menstruation.

Treatment.—Ice-bags should be applied in the beginning to relieve the pain, or leeches may be employed for the same purpose. Belladonna ointments are of some service during the acute inflammatory stages. When it is found that suppuration is likely to supervene, poultices should be applied, and at the first indication of suppuration the glands should be incised and the pus evacuated.

Chronic Parotitis.—Chronic parotitis, for clinical purposes, may be divided into two varieties: (*a*) the chronic inflammation of one or more of the glands, with or without history of previous acute disease, and (*b*) the curious inflammatory condition in all of the salivary and lachrymal glands first described by Mikulicz.

(*a*) *Chronic Parotitis with or without Previous Acute Inflammations of the Glands.*—This affection is occasionally observed as a sequel of mumps, and may follow inflammatory conditions occurring in the throat. It has been observed in secondary and tertiary syphilis, in Bright's disease, and as a complication of chronic tuberculosis of the lungs. Some years ago the writer described a case of this kind that occurred in connection with chronic inflammatory changes in the pancreas, in a man suffering from diabetes. The affection may be the result of lead or mercurial poisoning.

Treatment.—Except the condition be of syphilitic origin—in which case mercury and iodide of potassium should be employed—we know of no drugs that affect the course of this disease.

(*b*) *Chronic Symmetrical Inflammation of the Salivary and Lachrymal Glands.*—Since the publication of the paper of Mikulicz, Kümmel has reported a number of instances of this disease, and in this country Osler has recently recorded a very interesting example of the affection. Nothing is known concerning the causation of this malady, but in Osler's case the patient had probably suffered from tertiary syphilis, and the enlargement of the glands gradually subsided under the use of mercury and iodide of potassium. Kümmel found that the salivary glands are completely replaced by mononuclear leucocytes, and suggests the name of achroöcytosis. Osler's patient died later of tuberculosis, and at the autopsy the lachrymal glands were found to be represented by masses of fibrous tissue. Though all of the glands are usually involved, in some instances this is not the case. The swollen glands are painless and the disease generally persists for a number of years. It is of interest to note that it has in some instances rapidly subsided following acute fevers.

Treatment.—In cases in which the disease is secondary to syphilis the appropriate treatment for the latter affection would, of course, be called for, and even in instances in which there is no history of this disease it would be wise to give the patient the benefit of the doubt and to test thoroughly mercury and iodide of potassium. Should these remedies fail, it is not likely that other means would be efficient.

Tumors of the Salivary Glands.—Carcinoma, sarcoma, adenoma, fibroma, fibro-adenoma, chondroma, myoma, and lymphoma occasionally occur in these glands, though none of them are common. Of these tumors fibro-adenoma is perhaps the most frequent. The malignant neoplasms found in the glands generally belong to the epithelial type. In all instances in which the tumors show evidence of malignancy they should be immediately removed.

Diseases of the Ducts of the Glands.—*Calculi*, consisting of carbonate and phosphate of calcium, are occasionally formed in the ducts of the salivary glands, and either they may be discharged or they may lodge in some part of the ducts; they sometimes occasion a retention of the secretions of the glands. Under these circumstances an operation should of course be resorted to to relieve the condition. Occasionally the ducts become dilated in glass-blowers and in musicians; when this occurs the distended ducts present the appearance of a tumor, and contain air which may be mixed with saliva and pus.

Henry Fauntleroy Harris.

SALIX.—*Willow. Saule blanc*, Fr. Cod.—When it was official, this drug was defined by the United States Pharmacopœia as "the bark of *Salix alba* L. and of other species of *Salix* (fam. *Salicaceæ*)." Salicinum now entirely replaces it in the Pharmacopœia. The species named is the common *European white willow*, now quite extensively naturalized in North America. It is a large tree with, when old, a very thick, irregular trunk, dividing near the ground into several great limbs; branches numerous, ascending, rather densely massed; twigs slender, lightly attached to the branches, possessing a light-yellow or greenish-yellow bark and white soft wood; young shoots,

A. B.

Fig. 4140.—Salix Alba. *A*, Staminate; *B*, pistillate.

buds and the under surface of the leaves silky; leaves numerous, alternate, with small lance-ovate stipules and short petioles; the blades two to four inches long and about half an inch wide, lanceolate, acute, whitish beneath, finely serrate; flowers diœcious, in slender weak spikes, each in the axil of a small bract, appearing in early spring. Only the bark of the younger branches should be collected.

Willow bark is "in fragments or quills, from one-twenty-fifth to one-twelfth of an inch (1 to 2 mm.) thick, smooth; outer surface somewhat glossy, brownish or yellowish, more or less finely warty; under the corky layer green; inner surface brownish-white, smooth, the fibres separating in thin layers; inodorous; bitter, and astringent.

Constituents.—Besides ordinary plant constituents, willow contains the following three glucosides: *tannin*, about ten per cent.; *salicin* (which see), about two per cent.; *helicin* ($C_{13}H_{16}O_7 + \frac{3}{4}H_2O$). The properties and uses of the drug depend almost wholly upon the salicin contained, and our article on the latter substance should be consulted. As an antiperiodic, the bark is employed in doses of an ounce or more, in the form of fluid extract, or, as is more common in domestic practice, a decoction or infusion. It is often used as a tonic in doses of about one fifth or less of this amount, the powdered bark being often used for this purpose; also as an intestinal astringent. Salix has sometimes produced good results as an anthelmintic. The powdered bark was formerly considerably employed as a vulnerary, salicylic acid having now entirely replaced it for this purpose in medical practice.

Allied Drugs.—The genus Salix contains about one hundred and sixty species, many of which have been employed like *S. alba*. The plants fall naturally into two classes, the one characterized by the yellow, the other by the purple color of their young shoots. The latter are said to contain more salicin, sometimes above three per cent., the former more tannin.

Populus L. is the botanical name of the Poplars, Popples, Cottonwoods or Aspens, a number of which, both European and American, are used, in the form of their barks and leaves, as willow bark is used. These drugs contain the same constituent as the willows, besides the closely allied glucoside *populin* or *benzoyl-salicin*.

The buds of *P. balsaminifera* L. and *P. candicans* Ait. are known as balm of Gilead buds. Their scales are thickly coated with a very pleasant balsamic scented oleoresin, which possesses mild aromatic, diuretic, expectorant, and vulnerary properties.

Henry H. Rusby.

SALOL—$C_6H_5C_7H_5O_3$. Salol is the name given to the salicylic ether of phenol (carbolic acid). It is compounded of salicylic acid and phenol and represents sixty per cent. of the former substance and forty per cent. of the latter. It is official in the United States Pharmacopœia under the title *Salol*, Salol. Salol is a white crystalline powder, melting at 43° C. (109.4° F.) into a colorless, oily fluid. It is nearly insoluble in water, but dissolves in alcohol, ether, and fixed oils. From its insolubility in aqueous fluids it is practically tasteless in powder, but it has a faint aromatic smell.

Salol is used as a substitute for the common salicylate salts, on the grounds that it is equally effective as a medicine, while at the same time, in medicinal doses, it is much less deranging to digestion on the one hand, and less productive of constitutional toxic effects on the other. It is insoluble in the fluids present in the stomach—whence the lack of gastric derangement in its employment—but suffers solution by chemical decomposition in the small intestine through the action of the pancreatic juice, resolving into salicylic acid and carbolic acid (phenol). Constitutionally, salol, in ordinary dosage, has produced little disturbance beyond an occasional and trifling ringing in the ears. In experimenting, however, with a dosage exceeding 6 gm. (about a drachm and a half) distributed over the twenty-four hours, toxic symptoms have been observed, as might be expected, considering that the medicine is nearly one-half carbolic acid. Salol, taken internally, imparts to the urine of the subject the peculiar coloration seen after ingestion of carbolic acid, a phenomenon that may persist for several days after discontinuance of the medicine. The average medicinal dose of salol for an antirheumatic or antipyretic effect is from 0.6 to 1 gm. (gr. x. to xv.), given twice, or thrice, daily. A dosage reaching 8 gm. (about two drachms), in the course of a day, was followed, in one instance, by severe vomiting, gastralgia, and tinnitus. Salol may be taken dry upon the tongue, in powder, the dose to be washed down with a little water, or may conveniently be administered in pill form.

Because of the fact that salol only gradually suffers resolution into its constituents, the substance makes a useful intestinal disinfectant in diarrhœa or typhoid fever.

Salol should not be given when there is any disease of the kidneys, because of the carbolic acid of its constitution.

Edward Curtis.

SALOL-CAMPHOR.—These two substances, when mixed in certain proportions, alter their physical state and become an oily, colorless liquid, insoluble in water, freely soluble in ether, chloroform, and oils. It is prepared by adding twenty parts, by weight, of powdered camphor to thirty parts of salol, and warming gently until fusion is complete.

It possesses the properties of its constituents, and is highly recommended as a stimulating antiseptic.

Beaumont Small.

SALOPHEN.—(*Acetyl-para-amido-salol.*) A patented compound which is, chemically, salol in which one atom of hydrogen in the phenyl group is replaced by the monivalent group $N_2H(CH_3O)$. It occurs in minute, white, crystalline plates, insoluble in cold water, very slightly soluble in hot water, soluble in alcohol and ether. Alkalies render it soluble, even in cold water. It is without taste or odor, and is neutral in reaction. Salicylic acid is present to the extent of fifty-one per cent. The acid secretion of the stomach has no effect upon it, but when it comes in contact with the pancreatic ferments it is decomposed into salicylic acid and acetyl-para amido-phenol. The object in view in the production of this compound was to improve upon salol by combining with the salicylic acid a phenol compound which was perfectly harmless.

It is recommended as a remedy for acute articular rheumatism in doses of sixty to seventy-five grains during the day, the usual dose being fifteen grains every three or four hours. It does not disagree with the stomach nor produce any toxic symptoms. Relapses and the ordinary complications are not prevented. Salophen has proved serviceable in neuralgia, sciatica, and other painful affections of the nerves. Reports of its favorable use in severe attacks of pruritus have been published. It has also been used with success in influenza.

Beaumont Small.

SALOQUININE, the quinine ester of salicylic acid, $C_6H_4.OH.CO.O.C_{20}H_{23}N_2O$, is a mild substitute for quinine with added analgesic properties. Its advantages, as stated by Overlach, are that it has no disturbing effect upon the digestive or urinary organs or the nervous system, does not produce cinchonism, and is tasteless. He employed it in sciatica in 2 gm. (gr. xxx.) doses with good effect. Tauszk has used it in supraorbital neuralgia, influenza, the pains of locomotor ataxia, muscular rheumatism, acute articular rheumatism, and typhoid fever. He recommends it as an efficient antineuralgic with mild antipyretic action. In doses of 0.5–3 gm. (gr. viij.–xlv.) daily, no vertigo or tinnitus was complained of, though in some cases mild sweating was observed.

Fitch, Sternberg, and von Kolozsvary speak highly of its use in malaria, large doses 0.3–1.3 gm. (gr. v.–xx.), being administered several times a day. Being free from taste it is easily taken by children.

The salicylate of saloquinine is "rheumatin."

W. A. Bastedo.

SALSOMAGGIORE, ITALY.—This new cure resort is pleasantly situated in Northern Italy, Lat. 44° 48' N., Long. 27° 38' E., two hours' ride by rail south from Milan. It lies in the valley of the Po, surrounded by low hills covered with the vine, maize, and mulberry trees. To the south rises the Apennine range.

The village itself is picturesquely situated at an elevation of about 500 feet, and contains 1,200 inhabitants. It is said to be unusually healthy, and is well supplied with good drinking-water.

The climate is temperate, the heat being never unduly excessive, and the sun is hidden by the hills before five o'clock in the summer.

The country round about is very attractive and affords many interesting excursions either by road or by rail. From here Bologna, Parma, Modena, and other spots of interest are readily reached by rail.

The accommodation is excellent, there having been opened in 1900 "The Grand Hotel des Thermes," with three hundred rooms and fitted with all modern equipments in the way of sanitation and comfort. There are music, billiard, and reading-rooms, elevators and electric lighting, and the baths can be taken in the hotel itself, each floor being provided with special bathrooms for that purpose. The charges are not excessive. The season extends from April 1st to November, although July and August are the least desirable months in which to visit the spa.

Salsomaggiore is one of the two best-known spas in Italy, the other being Bagni di Lucca. The waters are what are known as muriated iodobromine, locally called "salso-iodic," and are furnished by numerous artesian wells. Their natural temperature is 57.2° F. For the "cure" either the "salso-iodic" or the mother water, made by extracting the salt by evaporation, is employed. The analysis of the water is as follows:

IN 1 KGM. OF WATER FROM SALSOMAGGIORE THERE IS:

	Gm.		Gm.
Potassium chloride...	0.000	Aluminum chloride....	0.0590
Sodium chloride......	153.990	Magnesium chloride...	.0057
Lithium chloride.....	.735	Magnesium bromide...	.3037
Ammonium chloride..	.637	Iodide of magnesium..	.0663
Calcium chloride.....	15.848	Borate of magnesium..	.0116
Strontium chloride...	.256	Bicarbonate of iron...	.0778
Magnesium chloride..	5.584	Sulphate of strontium.	.0033
Iron chloride.........	.033	Silicate................	.0230

Hot baths, mud baths, and inhalations are used in the treatment, which occupies from two to three weeks. The temperature of the baths is from 95° to 98.6° F., and the salso-iodic water is generally employed, although salso-iodic water mixed with the mother water can also be used. The duration of the baths is from fifteen to sixty minutes, and after the bath the patient goes to bed and rests. It is recommended that the cure be repeated again during the year, and followed up for two or three years. An after-cure in the mountains is advised.

There is an inhalation hall where this method of treatment is pursued for various affections of the respiratory tract, such as bronchitis, pharyngitis, laryngitis, etc.; for chronic eye affections, such as conjunctivitis, iritis, and keratitis; and for certain skin diseases. The diseases for which the baths are recommended are chronic rheumatism and gout; various gynæcological affections, such as metritis, salpingitis, ovaritis, perimetritis, and sterility; anæmia; convalescence from protracted illness; infantile rachitis; neurasthenia; bone and joint tuberculosis; tertiary syphilis, and some forms of neuralgia and neuritis. Massage and Swedish gymnastics, electricity, and various forms of douches are also employed. The mud baths, which are given in conjunction with and apart from the baths, are used especially for rheumatoid arthritis. The mud obtained from the deposit of the tanks at the well (rich in salt, iodine, bromine, lithium, and petroleum), is applied to the affected parts as hot as can be borne, and is left on for about twenty minutes. It is then removed and generally followed by a bath of medicated water.

Besides the arrangements for baths in the "Grand Hotel," there are bathhouses (*stabilimenti*) where every precaution is taken as regards cleanliness, sanitation, and disinfection. All laundry linen is carefully disinfected and sterilized after being used.

Salsomaggiore can be reached from London in about thirty hours. In going from Milan to Florence one alights at Borgo San Domino, and takes a half-hour's ride in a branch train to Salsomaggiore.

For a charming description of the excursions about this spa, one is referred to "Salsomaggiore and Its Surroundings," by Lady Colin Campbell.

Edward O. Otis.

SALT LAKE CITY, UTAH.—This city and the great region of the Salt Lake basin deserve consideration as a health resort of no mean degree, particularly as a place of residence for the consumptive. This basin of a former great inland sea, a huge remnant of which is the existing Salt Lake, has an average elevation of 4,300 feet, and is bounded on the east by a range of mountains and on the west and south by a desert. It is, then, a plateau of moderate elevation fed by the pure air from the mountains and the desert, and possessing a "maritime" quality from the presence of such a large body of salt water as the great Salt Lake, which covers an area of 2,360 square miles. Such an elevation, moreover, gives the peculiar climatic conditions incident to height above sea-level. The air is pure, cool, and dry; the sensible temperature is not oppressive, on account of the dryness of the atmosphere; the rainfall is small; high winds are absent, and the sunshine is abundant. Further, the softness of the air is a striking feature, very evident to one who first sets foot in this region, and giving a delightful sense of restfulness. The principal place of importance and resort is Salt Lake City, latitude 40° 45′ N., longitude 111° 50′ W., containing 53,531 inhabitants, and located 4,348 feet above sea-level. The city occupies an extensive area, is well built and attractive, with wide and well-shaded streets, and possesses an efficient sanitary system and excellent water works. The accommodations are good, there being several modern hotels. The soil is adobe. Irrigation is used, the water being carried in ditches along the sides of the streets.

"Salt Lake City," says Solly ("Medical Climatology"), "is one of the three Western cities of good size possible for the residence of those to whom a sunny climate is necessary and who desire to settle in an active business centre. The other two large cities are Denver, which shares with Salt Lake City the advantage of altitude, and Los Angeles, which is equally sunny but exposed to ocean influence."

At the Salt Lake Hot Springs Sanatorium sulphur and salt baths can be taken; and on the border of the lake, thirteen miles distant, reached by train, is the Salt Air Bathing Resort, well appointed, with nearly one thousand bathrooms. Here one can enjoy the strange experience of bathing in water containing nineteen per cent. of salt, and so buoyant that one can float in it with a

CLIMATE OF SALT LAKE CITY. LATITUDE, 40° 45′ N.; 111° 50′ W. ELEVATION, 4,348 FEET. PERIOD OF OBSERVATION, TEN TO SIXTEEN YEARS.

	January.	March.	May.	July.	September.	November.	Spring.	Summer.	Autumn.	Winter.	Year.
Temperature, Degrees Fahr.											
Average monthly temperature..........	29.0°	49.0°	57.5°	75.4°	64.3°	38.6°	49.5°	71.5°	51.3°	31.9°	51.3°
Mean of warmest..........	35.7	50.6	69.3	88.0	75.4	46.2	59.5	85.3	60.9	38.8	61.0
Mean of coldest..........	20.7	32.2	47.3	63.3	52.4	28.3	39.6	60.8	39.0	24.0	41.2
Average daily range..........	15.0	18.4	22.0	27.7	23.0	17.9	19.9	24.5	21.9	14.8	19.8
Highest or maximum..........	48.8	63.9	83.3	95.0	87.5	61.4	72.9	91.7	74.9	50.4	
Lowest or minimum..........	−6.1	21.6	35.6	51.6	53.1	18.8	28.9	49.2	30.0	0.2	
Humidity											
Average relative..........	61%	52%	45%	37%	37%	47%	49%	37%	43%	61%	48%
Precipitation											
Average in inches..........	1.49	1.74	2.08	.53	.36	1.40	6.36	2.16	3.82	4.39	16.73
Wind											
Prevailing direction..........	S. E.	S. E.	N. W.	N. W.	N. W.	N. W.	N. W.	N. W.	N. W.	S. E.	N. W.
Average hourly velocity..........	4.07	5.6	6.2	5.6	5.4	4.0	6.0	5.8	4.9	4.1	5.3
Weather											
Average number of clear and fair days..........	19.8	20.5	23.7	28.3	27.3	21.5	64.4	83.3	73.2	56.3	277.2

considerable portion of his body out of water. The lake is very shallow for a long distance from the shore, and it is a laborious task to wade to deep water. The temperature of the water is comparatively high.

Standart ("The Climate of the Great Salt Lake Basin," Transactions of the American Climatological Association, vol. vii., 1890) calls attention to the fact of the longevity of the inhabitants of this region, which he attributes to the influence of the climate; and he narrates the incident of a gathering of old folks representing three per cent. of the adult population of the great Salt Lake basin, where there were a thousand people who had attained the age of seventy years or over.

Good hunting and fishing are to be had in the mountains and streams round about, and there are many short excursions to mountain resorts lying on the banks of attractive lakes. A few miles from the city, reached by an electric road, is Fort Douglas, a military post, from which is an extensive view.

From the climatic table it will be seen that the temperature partakes of the characteristics of that of elevated regions. The diurnal range is large and it does not appear to be very cold in winter or excessively hot in summer. According to Solly, the average number of days above 90° F. is 30, and below 32°, 109. The average annual range as given by Standart is 93.5°. The average relative humidity is very low and the rainfall small, indicating a very dry atmosphere. The prevailing wind is from the northwest, and the average hourly velocity 5.3 miles for the year. The number of clear and fair days is 277, which means a large amount of sunshine.

Edward O. Otis.

SALT LAKE HOT SPRINGS.—Salt Lake County, Utah.

Post-Office.—Salt Lake City. Hotel and sanatorium. The springs are located in the northern outskirts of Salt Lake City. The water is conducted from thence to a sanatorium and bathing establishment in the heart of the city. This fine, commodious structure has a floor space of about fifty thousand square feet. The water, at a temperature of 112° F., is drawn from the springs through an eight-inch pipe, with a flow of about four hundred gallons per minute, and enters the establishment at a temperature of 110° F. Besides large separate swimming pools for men and women, there are twelve private pools and a number of elegant private bathrooms. A hotel and gymnasium are also connected with the enterprise in the same building. According to an analysis by H. Hirsching, analytical chemist, in 1893, the water contains rather more than three hundred grains per United States gallon of solid ingredients. This is largely composed of chloride of sodium (about two hundred grains), but the water also contains appreciable quantities of the chlorides of calcium and magnesium, the sulphates of sodium, calcium, and magnesium, the carbonate of sodium, and small amounts of several other compounds. It is also charged with sulphureted hydrogen in small quantities, as well as a considerable percentage of carbonic acid gas. The water is useful in the various ailments for which hot saline sulphur baths are prescribed.

James K. Crook.

SALTS, DISSOCIATION OR IONIZATION OF.—See The Appendix.

SALT SULPHUR SPRINGS.—Monroe County, West Virginia.

Post-Office.—Salt Sulphur Springs. Hotels.

Access.—Viâ Chesapeake and Ohio Railroad to Fort Spring, where carriages meet visitors for springs.

These well-known springs have been under the present management for many years, and have become justly esteemed as one of the most charming and homelike of the Virginia Mountain resorts. The location is two thousand feet above the sea level, and is surrounded by the usual beautiful scenery and wholesome climate of the Alleghanies. The hotel buildings are chiefly of brick and limestone. The largest, built of stone, contains seventy-two pleasant rooms, and has wide piazzas, two hundred feet long, overlooking the lawn. The parlor and great ball-room are also in this building. There are accommodations for three hundred guests. The springs are three in number, known as the "Old" or "Sweet" Spring, discovered in 1802; the "Salt Sulphur," discovered in 1805; and the "Iodine" Spring, known since 1821. We present analyses of the Old Spring and the Iodine Spring, the former by W. B. Rogers, the latter by D. Stewart.

One United States Gallon Contains:

Solids.	Old Spring. Grains.	Iodine Spring. Grains.
Sodium carbonate	....	10.80
Calcium carbonate	10.26	33.00
Magnesium carbonate	3.31	7.00
Potassium carbonate	....	2.33
Sodium sulphate	22.36	24.00
Calcium sulphate	84.90	68.00
Magnesium sulphate	18.21	20.00
Organic matter	9.24	....
Earthy phosphates, sodium chloride, calcium chloride, magnesium chloride, iron peroxide, alumina, silica, iodine, and bromine	2.00	7.35
Total	150.28	172.48
Gases.	**Cubic inches.**	**Cubic inches.**
Carbonic acid	13.28	34.56
Sulphureted hydrogen	3.44	19.12

These are valuable waters, containing as they do a large proportion of active mineral ingredients. Both contain a sufficient quantity of the purging sulphate to render them cathartic in their effects. The iodine spring contains a fair proportion of iron and appreciable quantities of iodine and bromine, rare ingredients of sulphur waters. This water resembles those of Challes, in Savoy, and possesses alterative properties. It proves especially beneficial in scrofulous and syphilitic diseases. The waters of both of these springs are useful in abdominal engorgement, chronic constipation, chronic metallic poisoning, functional hepatic disorders, rheumatism, gout, and scaly skin diseases. Cases of bronchial troubles and early phthisis also do well at this resort.

James K. Crook.

SALUBROL—tetra-bromo-methylene-di-antipyrin—is prepared by the action of bromine on methyl antipyrin. It is without odor, and is used as an antiseptic dusting-powder in place of iodoform. It is said to be a good hæmostatic like antipyrin.

W. A. Bastedo.

SALUMIN, aluminum salicylate, $Al_2(C_6H_4OHCOO)_6 + 3H_2O$, is a reddish-white powder, insoluble in water and alcohol, and soluble in alkalies. It is employed as an astringent dusting-powder in catarrhal conditions of the upper air passages. It is known as "salumin (insoluble)." With ammonia it forms aluminum ammonio-salicylate, $Al_2(C_6H_4ONH_4COO)_2 + 2H_2O$, which is readily soluble in water and is used in the nose and throat as an astringent spray or gargle. This compound is called "salumin (soluble)."

W. A. Bastedo.

SALVATOR MINERAL SPRINGS.—Brown County, Wisconsin.

Post-Office.—Green Bay.

This spring is the source of the Salvator Mineral Water. It does not appear to be used as a resort. An analysis by Professor Delafontaine, of Chicago, shows the following mineral ingredients: One United States gallon contains (solids): Sodium chloride, gr. 1.60; sodium bicarbonate, gr. 1.30; calcium bicarbonate, gr. 20; magnesium bicarbonate, gr. 17.16; iron bicarbonate, gr. 1.30. Total, 41.80 grains.

This analysis shows an excellent alkaline, diuretic, and mild laxative water, with ferruginous properties. It is valuable in the treatment of acid dyspepsia, sluggishness of the portal circulation, Bright's disease, diabetes, and irritable states of the bladder and urinary passages. The water is entirely free from organic impurities, and is well adapted for table and club purposes. It has a large sale in different sections of the country. *James K. Crook.*

SAMBUCUS.—ELDER. "The flowers of *Sambucus Canadensis* L. (fam., *Caprifoliaceæ*)," U. S. P. (but likely to be dropped from the next edition). This plant is a medium-sized or small shrub, with smooth, upright, rather simple stems, which are soft and herbaceous in the upper part. Their woody ring is very narrow; their pith very large, and much used for holding small objects for microscopical section cutting; leaves opposite, petiolate, pinnate, large; leaflets ovate-acuminate, serrate, rarely pinnate; flowers small, in large, compound, five-branched, flat-topped cymes, regular, pentamerous; calyx minute; corolla cream colored, urn-shaped, with spreading lobes; stigmas three; ovary inferior, ripening to a purple-black, shining, spherical, juicy, berry-like drupe, containing three minute nutlets. The elder is a common plant in moist places over a large portion of this continent, and is represented by nearly related species in many other parts of the world.

The flowers should be gathered in full bloom, and dried without heat. They then form a cream colored or very pale yellow mass, which grows darker with time. They have a peculiar, rather agreeable odor, and a sweetish and slightly bitter taste. Their important constituent is volatile oil, with which occur resin, gum, wax, and sugar.

The use of our elder was unquestionably derived from that of the black elder (*S. nigra* L.) of Europe, which is almost exactly like it in sensible properties. The American has tufts of microscopic hairs in the forks of the branchlets of the inflorescence and in the sinuses of the calyx teeth, while the *S. nigra* has not. Elder is slightly aromatic, and when given in hot infusion is also diaphoretic. Its employment is confined almost entirely to household medication. The twenty-per-cent. infusion may be given *ad libitum*.

The flowers are the least active portion of the plant. The fruits of this and related species, though used in pastry and largely in wine-making, are laxative in the uncooked state, and have been seen to intoxicate fowls. The young buds are powerfully cathartic or even emetic, as is the bark of the root. The leaves have been used for fly poison. The bark of the stem is a useful diuretic and hydragogue cathartic, emetic in over-doses. (See also *Poisonous Plants.*) *Henry H. Rusby.*

SAN ANTONIO, TEXAS.—The southwestern portion of Texas is regarded as the especial health resort region of this State, and San Antonio, occupying a central position in this region, can be taken as illustrating its climatic characteristics. San Antonio (elevation 650 feet) is the chief city of this district, and is situated in Lat. 29° 27' North, about one hundred and thirty miles inland from the Gulf of Mexico. It has a population of over 50,000, composed of Mexicans, Germans, and Americans. The Mexican element presents many attractive and picturesque features, in the architecture, street life, and suggestions of bygone days in the old missions. The historic incidents connected with the life of the city also enhance the charm and fascination of the place; for there is the famous Fort Alamo, the Thermopylæ of Texas.

The country is undulating, with no mountains nearer than thirty or forty miles, and the soil of the city is adobe. There is a pure water supply, and a more or less effective sewerage system. There are a number of hotels, boarding-houses, and restaurants, but the accommodations for invalids are said to be doubtful. Probably the most satisfactory plan would be to keep house in one of the more eligible suburbs of the city. There are many opportunities for outdoor life, in horseback riding, driving, etc. The climate is a mild winter one but uncomfortably hot in summer, although the nights are comparatively cool.

CLIMATE OF SAN ANTONIO, TEXAS. LATITUDE, 29° 27' N.; LONGITUDE, 98° 28' W. PERIOD EIGHT YEARS.

	January.	March.	May.	July.	September.	November.	December.	Year.
Temperature, Degrees Fahr.—								
Average or normal	51.5°	61.9°	74.9°	83.3°	77.5°	59.0°	54.9°	68.5°
Average daily range	19.8	21.8	19.6	22.1	21.2	21.1	20.5	
Mean of warmest	62.8	73.0	85.2	95.3	89.4	71.6	65.7	79.8
Mean of coldest	43.0	51.2	65.6	73.2	68.2	50.5	45.2	58.8
Highest or maximum	81.0	93.0	97.0	106.0	103.0	88.0	89.0	
Lowest or minimum	16.0	21.0	47.0	66.0	46.0	32.0	22.0	
Humidity—								
Average mean relative	65.6%	62.1%	69.6%	64%	68.8%	65.3%	62.8%	65.5%
Precipitation—								
Average in inches	2.03	1.42	2.85	.92	2.84	1.30	1.82	25.27
Wind—								
Prevailing direction	N.	S. E.	S. E.	S. E.	E., S. E.	N., S. E.	N.	S. E.
Average hourly velocity in miles	7.5	8.8	7.5	7.5	6.4	7.4	7.8	7.8
Weather—								
Average number of clear days	10.3	9.3	8.1	13.8	11	12.1	14.2	136.2
Average number of fair days	9.0	12.0	13.8	14.8	13	10.3	8.1	138.8
Average number clear and fair days	19.3	21.3	21.9	28.6	24	22.4	22.3	275.0
Average number of cloudy days	11.6	10.8	9.0	2.2	5	6.5	8.3	90.0

From the meteorological table we see that while the winters are mild, nearly as warm as the autumn at New York City, the diurnal variation is large; and also while the summer days are hot—many days above 90° F.—the nights, as has been said, are comparatively cool. The average annual rainfall for the eight years was 25.27 inches; and for twenty-one years, 30.6 inches (Solly, "Medical Climatology"). Occasional "northers" occur at San Antonio, but they do not last long. The average relative humidity is 65.5 per cent. for the year, which, considering the high temperature, means a moist atmosphere. The average number of cloudy days during the year is 90; and the average number of clear and fair days, 275.

Such a climate as this, while it is not an exceptionally excellent one in its various characteristics, yet affords an outdoor life in the winter in a mild and pure atmosphere. For the consumptive in good general condition, and with the disease not far advanced, and who, moreover, is willing and able to "rough it" more or less, this region can be recommended. It does not, however, in the writer's opinion, possess the advantages of Southern California or of many resorts in the southern pine belt, either in the matter of climate or in that of accommodations. Almost every resort has its enthusiasts, and the following quotation from an article upon southwestern Texas by Dr. T. K. Taylor in the Transactions of the American Climatological Association, 1888, may be said to have been written by one such. "For delicate children," Dr. Taylor says, "who require the invigorating influences of moderately cool weather and active outdoor life, that climate is all one could wish during the winter season, while the spring, with its multitude of flowers, its fragrant breezes, its genial sunlight, and its evenings with their soft sweet repose, give one a better idea of an earthly paradise than any place we have ever seen, or hope to see in this broad land."

San Antonio can be reached by three lines of railroad.

Edward O. Otis.

SANATORIA (for treatment of tuberculosis). See *Open-air Treatment, etc.*

SAN BERNABÉ SPRINGS.—Municipality of Dolores, Nuevo Leon, Mexico. These baths, known also as the *Topo Chico*, are situated 8 km. north of the city of Monterey, to which they are connected by a railroad. The water has a temperature of 105.8° F., and, according to an analysis by Gonzalez and Lambert, it contains the chlorides of sodium, calcium, and magnesium, the bicarbonates of calcium and sodium, sulphate of calcium, silicate of alumina, silicate of lime, and sulphuric acid. The gases escaping from the spring are composed of carbonic acid and nitrogen. A bathing establishment of considerable size has been constructed and is considerably resorted to, but as at most of the Mexican mineral spring resorts the accommodations are still very imperfect and in sad need of proper development. In Monterey these baths enjoy a high reputation in the treatment of rheumatism, diseases of the skin, certain nervous affections, and menstrual disorders. *N. J. Ponce de Léon.*

SAN BERNARDINO HOT SPRINGS.—San Bernardino County, California. These springs are fourteen miles from Arrowhead Hot Springs. They are picturesquely located at an elevation of sixteen hundred feet above the sea level. The springs vary in temperature from 100° to 175° F. The waters have acquired considerable reputation in the surrounding district. The following analysis was made by Prof. Oscar Loew: One United States gallon contains (solids): Sodium chloride, gr. 7.46; sodium sulphate, gr. 47.63; potassium sulphate, gr. 1.34; calcium carbonate, gr. 6.23; silica, gr. 11.95; magnesium, carbonate, and ferrous carbonate, traces. Total solids, 74.61 grains.

It will be observed that the waters are saline and calcic.

James K. Crook.

SANDAL WOOD, OIL OF.—(*Oleum Santali*, U. S. P., B. P., P. G.) A volatile oil distilled from the heart-wood of *Santalum album* L. (fam. *Santalaceæ*).

Sandal wood is the product of a small tree of the East Indies. It has been highly valued from the most ancient times for the manufacture of objects which retain the fine fragrance of the wood for a very long time, and for use as incense. The trunk is small and its product is still further limited by the uselessness of the outer or sap wood. This is removed, either by trimming or by leaving it exposed to the action of termites, which find it agreeable and nutritious, while the oleiferous heart wood is highly offensive to them. To discriminate between these two portions, the heart-wood is often known commercially as "pink" or "red" sandal wood. This custom leads, in turn, to some confusion between this and red saunders, which is also often called red sandal wood.

Sandal wood occurs in small billets of a brownish-yellow or reddish-yellow externally and of a more decidedly pinkish tinge internally. It is very hard and heavy, and of a tough and splintery fracture, and emits, especially when heated, the characteristic odor of the oil.

The tree, on account of its very extensive collection and the careless methods employed, was long ago placed under government protection and is now cultivated upon a great scale. The distillation of the oil has also been carried on under government supervision, with the express object of preventing adulteration. In spite, however, of all precautions, such great difficulties have been encountered in securing a pure article of native distillation that many firms prefer to incur the heavy expense of importing the wood and distilling it here or in Europe. The yield of oil from a wood of first quality is said to be about five per cent. The wood itself finds no employment in medicine.

The oil is thus described in the Pharmacopœia:

A pale yellowish or yellow, somewhat thickish liquid, having a peculiar, strongly aromatic odor, and a pungent spicy taste.

Specific gravity: 0.970 to 0.978 at 15° C. (59° F.).

It deviates polarized light to the left (distinction from *Australian Sandal wood oil* [specific gravity 0.953] and *West Indian* [specific gravity 0.965] *sandal wood oil*, which deviate polarized light to the right).

Readily soluble in alcohol, the solution being slightly acid to litmus paper.

If to 1 c.c. of the oil, at 20° C. (68° F.), there be added 10 c.c. of a mixture of three volumes of alcohol and one volume of water, a perfectly clear solution should be obtained (test for *cedarwood oil, castor oil*, and *other fatty oils*, etc.).

Oil of sandal wood belongs to that class of volatile oils commonly denominated "terebinthinate." Like copaiba, which it resembles in many respects, it is often called a balsam, though the term is very incorrect, neither benzoic nor cinnamic acid being contained. It is said to consist almost wholly of the alcohol $C_{15}H_{26}O$ and the aldehyde $C_{15}H_{24}O$.

Action and Use.—The absorption and elimination of this oil are rapid, the latter occurring chiefly through the kidneys and the lungs, so that it might be classed as a stimulating and disinfectant diuretic and expectorant, with some astringent properties also. Its administration is frequently followed by discomfort in the stomach and dryness of the throat, and occasionally by vomiting and colic.

Disagreeable eructations and its taste are complained of by some patients, but on the whole it is less unpleasant than copaiba. Its elimination by the kidneys, which is sometimes accompanied by a feeling of tension there, changes the odor of the urine, and causes it to become cloudy with acid, in the same way as copaiba does: alcohol, by clearing up this cloudiness, which is caused by a resinous precipitate, will distinguish it from albumen. The sandal-wood products in the urine exert upon vesical, and especially gonorrheal, inflammations a beneficial action very similar to that exerted by copaiba or cubebs. Sandal-wood therefore is frequently employed as an elegant substitute for these drugs. Reports differ widely as to the relative value, as antiblennorrhagics, of copaiba and sandal-wood oils, but the preponderance of evidence appears to be in favor of the former. Sandal-wood oil is especially serviceable in recent acute cases, with considerable discharge.

The oil is frequently given dropped upon sugar or shaken up with mucilage, but is far more largely taken enclosed in gelatin capsules, either pure or mixed with copaiba or cubebs. The dose is five to twenty minims four or five times a day, and its administration should be continued for a week or so after the symptoms have disappeared.

Allied Products.—Eight or nine species of *Santalum* are known, all natives of the East Indies. Various attempts have been made to utilize the products of several of these species, as well as somewhat similar products, though not of this genus, from the West Indies and South America; but none of them possesses the fine odor or other characteristics of the genuine, and it is doubtful if they now find their way into commerce.

Henry H. Rusby.

SANDARAC.—*Sandaraca. Resina Sandaraca.* A resin obtained in northern Africa from *Callitris quadrivalvis* Vent. (*Thuja articulata* Shaw.—Fam. *Pinaceæ* or *Coniferæ*), a small evergreen tree not distantly related to the cypress. The resin exudes spontaneously from the trunk and branches, and dries in tears resembling in form short, broad, blunt, simple or compound icicles, and rarely exceeding or even reaching an inch in length. They are dull on the surface and covered by a whitish powder produced by attrition, of a glassy fracture and transparent within. Occasionally insects are found embedded in them. Upon being chewed, the tears crumble to a fine powder which refuses to become plastic, whereas mastiche, which also occurs in small yellowish, though rounded tears, readily softens into a plastic mass. Powdered sandarac, which is non-adhesive and white, with a pleasant resinous odor and a resinous and bitter taste, is called "pounce," and was formerly used to rub over the surface of paper where an erasure had been made, to prevent the ink from running when it was written over again. Either alcohol or ether will dissolve sandarac completely, while turpentine, chloroform, or carbon bisulphide only partly dissolves it.

The volatile oil of sandarac exists in very small amount, as does the unstudied bitter principle. The resin consists almost wholly of sandaracolic and callitrolic acids, about ten per cent. of the latter and between eighty and ninety per cent. of the former. Sandarac is not used at present in medicine. *Henry H. Rusby.*

SAN DIEGO AND LITTORAL CALIFORNIA.—In a consideration of littoral California we select San Diego because there are few places in the United States with a more complete climatic record; it has an uninterrupted temperature and rainfall record extending back for over half a century. This station was also among the first to be equipped with self-recording apparatus, and it has a continuous automatic record of temperature, rainfall, wind velocity, wind direction, and sunshine for each moment of time, thus giving data that are absolutely reliable. It is on account of my familiarity with the excellent records of this station that San Diego and Coronado are selected as the type in this paper, but the statements and deductions apply almost equally to the coast of Southern California.

We must study a wide expanse of country when we are considering the climatic peculiarities of the coast of this region, as the coast has a marked influence on the interior, and it in its turn markedly influences the coast; indeed, further than this, the vast Californian coast line presents three distinct climates, while on the great inland plain there is a fourth type of climate. To quote from my recent paper before the American Climatological Association (*Philadelphia Medical Journal*, October 11th and 18th, 1902), we shall barely mention the northern climatic belt, the centre of which is at the junction of the mountain chains near the northern border of California, and which embraces also the country known as Oregon, Washington, British Columbia, and the coast of Alaska and its islands. The central climatic subdivision extends from a point below this northern junction of the mountains to Point Conception on the coast. It is about here that the mountain chains, by their junction, establish a transverse line of separation, thus warranting us in describing a Northern and a Southern California, each with its distinct topography and its very distinct climatic conditions.

Fig. 1141.—Map in Relief of the Topography of California. A comparison of this map with the temperature and rainfall charts of the State, will show how this topography exerts an influence upon the climate of California. (From California Section, Annual Summary, 1900, of Climate and Crop Service of the Weather Bureau, By Alexander G. McAdie.)

Southern California, then, embraces, so far as a study of its climate is concerned, all that part of the State which lies below the transverse high mountains about Point Conception. It is with this strip of coast that we are alone concerned, from Point Conception to Coronado.

At Point Conception the coast line changes its general direction and runs nearly east, the mountains run eastward for a sufficient distance to protect the country from the north; but afterward they again turn south, thus once more protecting the coast from the desert, which is east of it.

The arrangement of the mountains and the trend of the coast are the keynote of the delightful climate of littoral California. The Alaskan current is separated from the land by the curve in the coast, and the Kurosiwo, or great Japan current, leaves the land at Point Conception and never returns. This separation is materially assisted by the coast islands which are located between San Miguel and the Coronado Islands and by those lying farther south, off the coast of lower California, the Baja California of the Mexicans.

To understand fully the factors that make the coast climate so pleasant we must consider the formation of the country contiguous to the coast. The general topography of California, more marked in the north, is a double mountain range parallel with the long axis of the State, with large fertile plains and valleys, with enormous watersheds included between them. In the south this general plan is somewhat modified. While the eastern range, the Sierras, serve as a wall to protect the country from the great arid desert plains, the coast range is much lower and no longer shuts out the sea; indeed, at some points the whole interior is quite open to the sea, so that the Santa Clara valley, the valley of the San Buenaventura River, the San Fernando Valley, the San Gabriel Valley, the valley of the Santa Ana River, the San Jacinto River, the Los Angeles River and plains, and the San Diego country constitute a great open coast land backed and protected by the high Sierras. A newcomer from the eastern country will be somewhat surprised at the designation of plains as applied to these valleys, and he will also be somewhat disappointed at their size. The first effect will probably be one of smallness and narrowness as compared with the homeland valleys, but their size is greatly increased by the billy uplands into which they insensibly merge. This is most noticeable in the great upland plain of San Jacinto, south toward Coronado and San Diego.

As Lindley and Widney say: "The Sierra, which north of the Mojave Desert makes a great curve westward around the sound end of the San Joaquin plain of the central belt, turns southward again opposite Santa Barbara and Ventura counties, and doubling back upon its course walls in the west end of the desert, then turning directly eastward, separates the desert from the Los Angeles and San Bernardino plains. Turning southward again, it stands as a wall between the Colorado desert and that portion of Southern California lying west of its base."

The range varies in height from five thousand to seven thousand feet.

Unlike the northern and central portions of the chain, the range breaks down in the south at several points into low passes between the coast and the interior. "The pass, by which the Central Pacific crosses the Sierra, is 7,017 feet in elevation. Yet the Soledad Pass, by which the Southern Pacific crosses the Sierra in Southern California, is only 2,822 feet. The Cajon Pass, by which the Santa Fé enters, is of about the same height. There are numerous other comparatively low passes through the Sierras at the west end of the Mojave Desert, leading toward the sea in Ventura and Santa Barbara counties, and also through the range south of San Gorgonio. These passes through the Southern Sierra have a marked influence not only upon the climate of the coast portion of Southern California but also upon that of the deserts lying at the base of the Sierra."

The accompanying map in relief, prepared by Alexander G. McAdie for the California Section of the Climate and Crop Service of the Weather Bureau, 1901, if compared with the statements made above and with the temperature and rainfall charts of the State, will afford a graphic illustration of the influence of the diversified topography of California upon its climate.

*As I have said elsewhere, a great deal that is misleading has been written about the climate of Southern California. Its charms have been exaggerated and its drawbacks have either been passed over in silence or have been painted in glowing and attractive colors. The simple truth is quite good enough. It is a fact that in California of the South is to be found the best yearly climate in the world. Other localities have as good or perhaps a better climate than ours at their best, but certainly none of them has been blessed with this happy condition the year round as we have been on the coast.

A striking peculiarity, and one leading to much confusion, is the great diversity of climate in this country and the different climatic conditions which may be encountered in even a single day's journey.

At the lower stations the various climates have the

* "Two Health Seekers in Southern California," Edwards and Harraden. J. B. Lippincott Company, Philadelphia.

CLIMATOLOGY OF SAN DIEGO, CALIFORNIA.

By Ford A. Carpenter, Observer, Weather Bureau.

MONTHLY MEAN TEMPERATURES (DEGREES FAHR.) FOR A PERIOD OF TEN YEARS (1892-1901).

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1892......	55.1	55.0	56.0	57.8	61.0	62.0	64.9	67.8	65.4	62.7	60.9	54.2	60.2
1893......	57.4	54.4	54.2	57.5	61.0	63.4	67.4	70.0	64.6	62.7	57.6	57.4	60.6
1894......	49.5	50.5	52.6	56.4	58.6	61.4	64.8	67.0	65.9	62.8	57.1	54.8	58.4
1895......	53.2	55.5	55.4	57.8	61.9	65.0	65.6	61.7	67.4	64.4	59.4	55.0	60.5
1896......	55.5	57.7	58.2	56.5	62.0	64.8	68.6	69.4	66.7	64.2	59.7	59.0	61.9
1897......	55.8	54.7	54.2	59.8	60.9	63.4	67.0	69.9	68.1	62.4	60.2	55.0	61.0
1898......	50.8	55.2	54.5	59.1	58.8	63.8	66.7	70.6	68.5	62.3	59.4	56.6	60.5
1899......	55.5	53.4	56.4	58.2	57.7	61.4	65.6	65.8	65.5	62.7	60.8	58.7	60.1
1900......	57.8	57.6	59.2	56.8	60.9	64.4	67.6	66.2	65.6	63.1	64.6	60.4	62.0
1901......	56.2	57.5	60.0	57.4	60.0	62.5	65.6	68.2	64.8	62.8	60.8	57.8	61.2
Mean..	54.7	55.1	56.1	57.7	60.3	63.2	66.4	67.7	66.3	63.0	60.0	56.9	60.6

MONTHLY, SEASONAL, AND ANNUAL PRECIPITATION AT SAN DIEGO, CALIFORNIA (1892-1901.)

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.	Season of	Seasonal.
1892........	1.58	2.96	0.96	0.41	1.15	0.13	0.00	0.05	T.	0.22	0.91	0.69	9.09	1891-92	8.65
1893........	.78	.47	5.50	.22	.39	T.	T.	.00	.00	.11	.91	1.91	10.29	1892-93	9.21
1894........	.29	.49	1.05	.11	.09	.01	.00	.04	.01	T.	.00	2.26	4.35	1883-94	5.01
1895........	7.33	.53	1.43	.11	.19	.00	.00	.00	.01	.27	1.19	.27	11.33	1894-95	11.86
1896........	1.27	.02	2.89	.25	.03	.01	T.	.13	T.	.97	.98	2.18	8.73	1895-96	6.34
1897........	3.13	2.72	1.53	.02	.12	T.	.01	T.	T.	1.06	.02	.32	8.93	1896-97	11.66
1898........	1.71	.06	.91	.22	.66	.02	.00	.00	.07	.00	.15	.87	4.67	1897-98	4.98
1899........	2.34	.30	.85	.29	.10	.27	.00	.07	.00	.35	.86	.65	6.08	1898-99	5.31
1900........	.69	.03	.53	1.26	1.45	.08	.00	T.	T.	.30	1.43	.00	5.77	1899-00	5.90
1901........	2.08	4.77	1.07	.01	.77	.02	T.	T.	.06	.28	.41	.02	9.49	1900-01	10.45
General average	2.12	1.23	1.67	.29	.49	.08	.00	.01	.03	.46	.69	.92	7.87	....	7.93

MAXIMUM AND MINIMUM TEMPERATURES (DEGREES FAHR.) FOR A PERIOD OF TEN YEARS.

Year.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1891	76	35	70	34	76	41	77	44	67	53	78	53	88	58	85	60	89	55	84	50	82	44	72	32
1892	75	38	68	42	73	44	80	41	87	47	75	51	75	57	80	57	80	54	83	46	84	40	74	36
1893	80	38	75	40	75	40	78	43	88	49	75	53	79	57	81	59	77	53	88	50	83	40	82	38
1894	69	32	69	34	72	36	83	43	72	45	73	50	77	57	90	55	90	52	87	45	78	45	70	41
1895	77	36	82	39	74	38	81	44	80	51	77	51	74	57	78	54	90	54	84	54	85	38	79	34
1896	77	39	83	39	85	41	74	42	98	48	89	54	80	56	88	59	80	54	79	52	76	43	76	46
1897	73	40	76	38	70	40	88	46	67	50	70	54	79	59	89	60	83	58	76	51	83	45	80	36
1898	78	36	75	42	77	38	86	45	69	51	88	54	77	60	83	63	91	56	84	51	76	43	79	43
1899	74	43	76	34	86	44	93	46	66	48	70	55	78	57	76	58	92	55	93	48	81	50	80	46
1900	79	46	76	45	80	46	67	45	75	49	87	56	84	60	80	59	87	53	72	50	89	51	79	44
1901	75	40	83	41	82	47	66	46	67	51	86	53	74	57	79	58	72	56	96	51	80	49	76	35

TEMPERATURE AND WEATHER SUMMARIES FOR A PERIOD OF FIFTY-TWO YEARS.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Temperature, Degrees Fahr.													
Highest monthly mean and year	57.8 1900	58.5 1886	60.0 1901	63.8 1861	65.7 1861	69.1 1857-67	73.2 1852	75.1 1864	73.6 1852	68.8 1853	64.6 1900	63.3 1867	63.8 1867
Lowest monthly mean and year	49.5 1895	50.5 1894	52.1 1880	56 1872	57.7 1899	61.4 1894-99	63.4 1880	65.8 1880-99	63.1 1880	59.7 1886	56 1886	50 1856	58.4 1894
Absolute maximum and date	81 4, 1902	85 12, 1889	99 27, 1879	93 12, 1880	98 25, 1896	94 10, 1877	88 25, 1891	92 15, 1884	101 22, 1883	96 21, 1901	91 4, 1890	82 6, 1874	101 9-22-1883
Absolute minimum and date	32 .... * 4, 1880	34 .... 1-11-'94	38 6, 1880 14, 1898	39 .... 7, 1875	39 .... 7, 1875	50 14, 1884 13, 1894	54 .... 16, 1891	54 .... 29, 1879	50 .... 18, 1882	44 .... 30, 1878	38 8, 1881 24, 1895	32 .... 25, 1879	32 1-31-1880 12-25-1897
Greatest daily range	35	37	43	40	36	35	22	28	35	37	34	40	43
Mean daily range	16.9	13.7	14.2	14.2	12.2	12.1	11.6	11.4	13	14.1	17.7	16.2	13.9
Mean variability	2.4	2.1	2.3	2.2	1.6	1.6	1.7	1.7	2	1.8	2.3	1.9	2
Mean of three consecutive warmest days	65.7	69.2	71.3	74.3	72.1	75.8	78	81.1	82.9	79	75.6	75.6	82.9
Mean of three consecutive coldest days	40.2	41.9	44.3	50.5	52.6	55.4	59.5	60.8	57	49.8	44.9	42.8	40.2
Weather													
Average number of clear days	17	14	11	13	9	8	14	12	16	18	19	17	178
Average number of partly cloudy days	7	9	10	10	11	13	11	15	11	10	9	10	116
Average number of cloudy days	7	5	10	7	11	9	6	4	3	3	2	4	71
Average number of rainy days	6	8	7	4	3	1	0	0	0	2	3	5	39

* Also 21st, 1883; 7th, 1894.

peculiar charm of California's equability—an equability that is most remarkable. In San Diego, from 1875 to 1901—a total of 9,861 days, there were 9,545 days on which the temperature did not rise above 80° nor fall below 40° F.

Newcomers are often bewildered by the many varieties of climate, and make statements to far-away friends that add chaos to confusion in the minds of Eastern people. One traveller reports California all sunshine and flowers, another all fog and cold. Some complain of the dry desert winds with their exciting electrical conditions, while others dwell upon the excessive humidity; when the probable truth is that the critic has not selected the proper environment and has passed by what he is seeking, which is no doubt within a few short miles of the spot where he may happen to be.

There is little seasonal change in the extreme southern part of the State. I am accustomed to say to inquirers that our winters resemble September and October in the middle Atlantic States and that our summers are like April and May in the same region. The dividing line between summer and winter is more imaginary than real.

The greatest change in the temperature occurs at night, being more marked in the interior than on the coast. I wish to call particular attention to the apparent difference between sunshine and shade and midday and midnight. This change is more a subjective sensation than a reality and is true of all semitropical localities. It is less marked in California than in Italy, but it always appeals strongly to the newcomer, who is surprised at the immediate sense of chill which he experiences when he enters the shade from the direct rays of the sun. As the night advances the temperature decreases, and while this change may not cause the mercury to fall many degrees, still it is very noticeable to the individual. This is less marked on the coast in summer and more so at all seasons of the year in the interior. The days are characterized by a constant sea breeze which blows with astonishing regularity; it is rarely too warm for comfort, as is often the case at Cape May, Atlantic City, Long Branch, or other popular Atlantic coast resorts. Several times during the year the so-called desert spells occur. This is when the land breeze or wind from the desert, many miles in the interior, gain ascendency over the prevailing western or ocean breeze. During this time the thermometer is apt to show a very high registration. Under these conditions I have seen it at San Diego register 98° F., but for only a few hours. These hot winds may last two or three days. The nights at this time are always cool and pleasant. These are the only evenings on the coast upon which one may sit out of doors with comfort and without chill.

Rainfall.—Each rainy season has its own peculiarities. It may be one of constantly recurring rains, or the rains may be light, interspersed with long periods of almost constant sunshine. Hence the records do not help us much to predict for future rain probabilities. It is not altogether unusual to have a very deficient rainfall. Thus, for example, San Diego, with a normal rainfall of about ten inches, has had in the last fifty-two years a minimum of 3.02 and a maximum of 27.59 inches.

Fog.—The coast fog, about which so much has been written, is most frequent during the months of April, May, and June. The fog appears about nightfall and disappears after sunrise; by nine o'clock the coast is usually free from fog. Some days during the months mentioned are foggy until half-past twelve or one o'clock. The records show that Coronado and San Diego have nearly three hundred days a year that are recorded as clear. The East has its cloudy weather in the winter; we have ours in the summer. Again, the maximum sunshine in Southern California is in the winter time, in the East during the summer.

MONTHLY RELATIVE HUMIDITY (PER CENT.) FOR A PERIOD OF THIRTY-ONE YEARS. RECORD BEGAN JANUARY 1ST, 1871.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
A.M.	72.9	77.6	81.2	82.2	82.5	84.3	85.9	85.4	84.7	81.3	72.4	75.0
P.M.	73.0	73.5	73.9	73.4	71.8	75.9	76.4	76.4	78.0	76.2	72.8	72.9
Average	73.4	75.6	77.6	77.8	78.6	80.5	81.2	80.9	81.4	78.8	72.6	72.9

Humidity.—Carpenter, the weather observer at San Diego, very aptly remarks that the oft-repeated statement, "driest marine climate," as applied to San Diego, is not sufficiently explained. Why is our humidity so much less than that of Seattle or Santa Barbara, for example? We find the explanation in these two circumstances; distance from the average storm track and nearness to the desert. Our humidity is as constant as our temperature, and plays a very important part in the excellence of the climate. So long as the temperature is between 55° and 65° F. (and that is about half the time), the humidity is always seventy per cent. Whenever the temperature increases, the amount of moisture naturally decreases, for the capacity of the air for holding the vapor is correspondingly decreased. Strange as it may seem, this is also true of the other extreme in temperature in this desert-sea climate; the winter cold is a dry cold, just as the summer heat is a dry heat.

A general knowledge of the climate of Southern California is obtained, says Solly, if we remember that the coast is cool and moist and the interior hot and dry; "it should be thoroughly understood by the Eastern visitor, in his search for health, that if he seeks more days of sunshine and opportunities for outdoor life, with a more equable temperature and an average humidity a little greater than that of New York or Boston, he can find what he wants at Santa Barbara or San Diego" (or Coronado). The same writer adds that to those to whom the presence of dry air is not important, California offers many attractions from Monterey to Coronado, and he concludes that it can be said that the coast climate is delightful, equable, and healthful.

Wind.—The wind movement is moderate, the yearly average is about 5.6 miles an hour. During the day the wind blows from nearly every point of the compass. The coast clearly shows the phenomenon of land and sea breezes, for the air, warmed by the earth, rises and creates a draught from the cooler sea, so that by about nine o'clock the breeze commences and increases until about 2 P.M., at which hour it blows at about the average rate of twelve miles an hour. At or about sunset this westerly wind dies down, the land cools, and a current of air starts toward the warmer sea. *William A. Edwards.*

SAN DIEGO DE LOS BAÑOS.—The best-known and most-employed mineral springs of those abounding in Cuba are the springs situated in the town called San Diego de los Baños, in Pinar del Rio. This town is situated about ninety miles from the city of Havana and may be reached by railroad as far as Paso Real and thence by stages or carriages. This part of Cuba is not only one of the most picturesque on the island, but it is also the best known, for San Diego is surrounded by those tobacco estates which have made the name of Cuba so well known wherever the luxury of a good cigar is appreciated.

These springs have been known for over a century, tradition attributing their original discovery to an old negro, a runaway slave, who is said to have been cured of leprosy by bathing in these waters. During the last thirty years these springs have not enjoyed the vogue that they formerly had, but this has been due to the difficulties of transportation and to the disturbed political condition of the country. However, now that the island is at peace, there is no doubt that the springs of San Diego will develop with the rest of the country.

The population of San Diego during the closed season is about 1,500, and this increases to five times that number during the bathing period, which begins in the latter part of January and includes February and March. The temperature the year round fluctuates between 80° and 87° F. The River San Diego during the rainy season becomes a raging torrent, and in 1899 it swept away all the buildings connected with the bathing establishment.

Only three of the springs have thus far been utilized. One of these issues from the river-bed itself, the others are situated on the shore; the waters of the first have been isolated from the general body of the stream by means of dams and retaining walls.

The establishment at San Diego consists of three pools or tanks and twelve tubs with their corresponding buildings, such as dressing and waiting rooms for all the departments.

The Templado Spring.—This bath has, for women, a department measuring 8 metres long by 7 wide; it is lined with vitrified tiles and is furnished with a wooden floor. The tank on the men's side is larger and more comfortable; the pool has a depth of more than three feet and its temperature is constantly at 34° C. This is the largest and most important of the springs; it yields 860,000 litres in the twenty-four hours.

The next most important spring, from the point of view of the volume it yields and the curative properties of its water, is the *Tigre*. This pool is 8 metres in diameter, enclosed on all sides, thus allowing a concentration over the water of vapor and sulphurous acid gas. This has led people to believe that it is the stronger of the two baths, but experiments have proved that the two springs are really one and that the Tigre and the Templado are merely different outlets of the same spring. Years ago this pool was reserved for colored people.

The third spring, called the *Paila*, is certainly the most picturesque. The water issuing from the bed of the river itself reaches it after an admixture of fresh water from the river and the water from about thirty smaller springs. All these waters together collect into a pool about two hundred feet wide and in some places sixteen feet deep, thus allowing the bathers who are so inclined to add the exercise of swimming to the other attractions. From the above it can easily be understood that the temperature and strength of the water of this pool are subject to constant changes. In connection with this pool there is a dressing and waiting room 20 metres long by 6 metres wide, from which steps lead down to the baths.

The *chemical analysis* of these waters was made twenty-eight years ago by the brothers Aenlle. Since that time, however, there have been several earthquakes of more or less severity and the composition of the waters may have varied to a slight extent.

According to the analysis above mentioned one litre of the Templado or Tigre has the following composition: Hydrosulphuric acid, 0.152; sulphate of lime, 0.136; sulphide of calcium, 0.838; chloride of sodium, 0.032; bicarbonate of magnesium, 0.080; alumina, 0.006. Total solids 1.244 gram. Carbonic acid gas is present in slight amount.

Silicic acid, carbonate of iron, nitrogen, oxygen, organic matter, undetermined.

Density, 1.014.

The color of this water is bluish at the spring and in the bath, outside it is colorless and as clear as drinking-water. The odor is characteristic of hydrosulphuric acid. The taste is sulphurous and the temperature is 34° C. (93.2° F.).

The Templado spring yields 860,000 litres of water in the twenty-four hours, while the Tigre yields 240,000 during the same time.

The analysis of the Paila spring gives the following result per litre: Sulphide of calcium, 0.218; sulphate of lime, 0.850; sodium chloride, 0.022; bicarbonate of magnesia, 0.120; alumina, 10 012. Total solids, 1.222 gm. Carbonic acid gas is present in a small amount.

Undetermined quantities: Sulphurous acid, silica, carbonate of iron, nitrogen, and organic matter.

The temperature of this spring varies from 22° to 25° C. According to Dr. Cabarrony, medical director of the establishment, the physiological effects of these waters are as follows: "They stimulate or deaden the appetite according to individual idiosyncrasy, and act as a stimulant on the circulatory and nervous systems. The rapidity of the pulse is increased. They may cause headache, insomnia, and a general stimulating of the capillary circulation. Sometimes tachycardia of a transient nature is observed.

"On the respiratory apparatus the effect of the water is frequently at first to cause coryza, pharyngitis, and bronchitis, which rapidly subside. Upon the kidneys it seems to act as a stimulant, causing increased secretion of urine and a noticeably greater elimination of uric acid. It also stimulates the sexual organs. Like all waters of this nature it also stimulates the functions of the skin."

According to the same authority the use of these waters is beneficial in such diatheses as the herpetic, rheumatic, and scrofulous, especially so in the first two, in which the effect seems to be immediate. It is also of service in syphilitic affections.

By far the largest number of patients who visit San Diego are sufferers from rheumatism, and extraordinary results in the treatment of this disease are said to be obtained by the use of these warm baths. They are of great benefit in all the visceral manifestations of the disease, in endocarditis, pericarditis, cerebral rheumatism, sciatica, neuritis, chorea, etc.

N. J. Ponce de Léon.

SAN FRANCISCO, CALIFORNIA.—The metropolis of the Pacific coast is situated upon the northern end of a peninsula, in latitude 37° 47' N. and longitude 122° 23' W. On the west, north, and east the city is surrounded by water. The Pacific Ocean washes the extreme western side of the city, a fine ocean driveway extending from the Cliff House to the overflow basin of Lake Merced. The Golden Gate (the name was applied by General Fremont while looking westward from what is now Oakland) is a water passage about a mile wide, connecting the Pacific Ocean and the Bay of San Francisco. The harbor is generally conceded to be one of the beautiful harbors of the world. The bay extends twenty-five miles north and forty miles south of the city. There are numerous islands in the bay, and on some of these, as, for example, Belvedere, business men of San Francisco have elaborate summer homes. The coves and lagoons are favorite anchorages for house boats or arks.

The city of San Francisco has many hills, among the more prominent of which are Telegraph Hill, Russian Hill, Nob Hill, and Rincon Hill. In 1850 the city was nothing more than sand dunes and sand hills; and even at the present time in the extreme western end of the city these shifting sand stretches can still be seen. The climate is peculiar; the reasons for which are to follow. The winds are somewhat too rigorous for invalids, but for healthy people they are very stimulating. Overcoats and heavy wraps are worn in midsummer as well as in winter. Indeed heavy underclothing can be comfortably worn every day in the year.

age velocity of twenty miles per hour. From May until September little if any rain falls, and no matter how overcast or threatening the morning may seem, within a few hours, generally before ten o'clock, there is bright sunshine. Great banks of low fog roll in through the Golden Gate on summer afternoons. There is probably no other part of the Pacific coast where such a strange mixture of marine and continental climates can be found. The topography is so remarkable that marked climatic contrasts occur within short distances. Thus at any of the ferries one may see sealskin coats and white duck garments together, because the traveller needs warm garments crossing the bay and in the city; while at Sausalito, San Rafael, San Mateo, or any of the suburbs, summer clothing is necessary. It must be remembered that the great Sacramento-San Joaquin Valley, a basin five hundred miles in a north-and-south direction and fifty miles wide, lies due east of San Francisco, and that on summer afternoons there is often a difference of 55° F. in temperature in a distance of fifty miles.

Owing to the proximity of the Pacific the temperature in San Francisco is very equable. A native of San Francisco cannot say off-hand which is the warmest and which the coldest month of the year; because the range is very small. The mean annual temperature determined from the records of thirty-two years is 56.1° F. May and November have practically the same temperature. The mean temperature for July is 58.7° and for December 51.5° F. The highest temperature ever recorded was 100° and the lowest 29° F. Abnormally warm and cold periods last as a rule about three days. The mean for the three consecutive warmest days at San Francisco has never exceeded 76.3°; and of the three consecutive coldest days the mean temperature was not below 40.7°. The mean daily range of temperature is 12°.

The sunshine is less in San Francisco than at localities a few miles away, which is due to the prevalence of fog. The city is considered a very healthy one because it is washed by water and well ventilated by the strong winds.

CLIMATE OF SAN FRANCISCO, CAL. LATITUDE, 37° 47'; LONGITUDE, 122° 23' W. PERIOD OF OBSERVATION THIRTEEN YEARS, 1891–1902.

Furnished by permission of Chief of Weather Bureau, Prof. Willis L. Moore.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Temperature, Degrees Fahr.													
Average or normal	50.1°	52.2°	53.7°	54.9°	56.7°	58.7°	58.7°	59.8°	60.8°	59.9°	56.4°	51.5°	56.1°
Average daily range	10.0	11.0	11.5	13.0	11.0	14.0	13.0	11.0	13.0	13.0	11.0	10.0	12.0
Mean of warmest	59.2	62.5	62.7	65.1	64.8	68.5	66.2	69.3	71.3	69.0	67.2	56.7	
Mean of coldest	41.7	43.5	43.9	45.6	46.9	49.2	49.3	50.9	51.3	51.2	47.7	43.8	
Highest or maximum	78.0	75.0	80.0	87.0	91.0	100.0	90.0	92.0	94.0	94.0	83.0	72.0	100.0
Lowest or minimum	36.0	34.0	33.0	40.0	43.0	47.0	47.0	47.0	47.0	47.0	38.0	37.0	*33.0
Humidity													
Average relative	79%	78%	78%	78%	79%	80%	84%	86%	83%	80%	76%	80%	80%
Precipitation													
Average in inches	4.85	3.51	3.14	1.81	.72	.14	.02	.02	.23	1.05	2.75	4.80	+22.74
Wind													
Prevailing direction	N.	W.	W.	W.	W.	S. W.	S. W.	S. W.	W.	W.	W.	N.	W.
Average hourly velocity in miles	7.0	7.6	8.8	10.4	11.3	13.0	13.1	12.3	10.1	7.8	6.6	7.0	8.7
Weather													
Average number of clear days	11	12	14	15	12	21	18	15	15	17	12	12	
Average number of fair days	10	8	11	8	12	7	10	14	11	8	8	8	
Average number of clear and fair days	21	20	25	23	24	28	28	29	26	25	20	20	

* The lowest official temperature recorded in San Francisco was 29° on January 15th, 1888, preceding above record.
+ The rainfall has been recorded with great detail for fifty-three years.

The climate is a moist one, the mean relative humidity exceeding eighty per cent. During the morning hours, especially in summer, the sidewalks look as if a light shower had prevailed, but in reality the dampness is due to condensation of fog. The prevailing direction of the wind is from the northwest, and on summer afternoons the wind blows with great regularity. Between the hours of 1 and 7 P.M. the wind is from the west, with an aver-

It is worth noting that children escape the disorders incident to hot weather in Eastern cities. Women and children have as a rule ruddy complexions, bright eyes, and a good carriage. Natives of San Francisco are in general large and well-formed. The climate is, however, too moist for those affected with renal, rheumatic, and pulmonary troubles. The summer climate is bracing and acts as a tonic in cases requiring such treatment.

The residents of San Francisco go inland during May, June, and July to get warm; while strangely enough country people come to the city to get cool at this time.

The city is supplied with water by the Spring Valley Water Company, and notwithstanding the long period of dry weather each year there has never been any water famine. Nor has there ever been any epidemic traceable to the character of water supplied. The temperature is a little too cool for ocean bathing, but there are large bath-houses at the beach and in the city where salt-water bathing can be had every day in the year. Many of the clubs have large swimming tanks for the use of members.

The average rainfall is about 23 inches, and this falls chiefly from November to March. In the past fifty years there was one January when rain fell on twenty-four days; the average number of rainy days in a midwinter (or so-called rainy season) month is about ten. Physicians sending patients to the Pacific coast should remember that marked differences in temperature, humidity, air movement, and sunshine occur within short distances. Near the Bay of San Francisco this peculiarity of climate is particularly noticeable. Within one hour's ride by boat or rail, from San Francisco, there is often a difference of twenty degrees in temperature at the same moment of time and equally great differences in other climatic features.

San Rafael offers a pleasant shelter from the winds of the coast, while the cities of the Santa Clara valley have just enough of the sea breeze to be delightful summer abodes. Or one can, by going to Mount Tamalpais (elevation 2,500 feet), rise entirely above the fog belt and bask in sunshine with temperatures ranging from 80° to 90° F., while at sea level, under the fog, the temperatures are from 55° to 60° F. *Alexander McAdie.*

SANICLE. See *Umbelliferæ.*

SANITARY INSPECTION. See *House Sanitation.*

SANOFORM, di-iodo-methyl salicylate, $C_6H_2.I_2.OH.COOCH_3$, prepared by the action of iodine on oil of wintergreen, forms a colorless, odorless, and tasteless crystalline powder. It is insoluble in water or glycerin, and soluble in ether, chloroform, benzol, carbon disulphide, and petrolatum, and in ten parts of hot alcohol and two hundred parts of cold alcohol. Langaard states that it is non-toxic, has no harmful effect on the skin, and is not decomposed by exposure to air, light, or a heat of 200° C. (392° F.). It contains 62.7 per cent. of iodine, and is a substitute for iodoform. Its stability makes it suitable for antiseptic dressings, as they can be sterilized by heat. It is very absorbent, quickly drying up a wound, but forming with the secretions a pellicle which may retain the subsequent secretions and must therefore be soon removed. It is employed in the form of a dusting-powder, ten-per-cent. ointment, or collodion. Radziejewski and Jacobsohn recommend it in ophthalmic surgery.

W. A. Bastedo.

SAN REMO, ITALY.—This is an Italian town of about 18,000 inhabitants, seven and a half miles east of Bordighera and eighty-four miles west from Genoa. Express trains from Paris run direct to San Remo viâ Marseilles in about twenty-four hours. It is one of the most frequented resorts of the Italian Riviera, and lies upon a small bay formed by Capo Verde and Capo Nero. In the rear are a series of hills and mountain ranges, affording protection from the winds of the north and conducing to the warmth and equability of the climate.

The original town is old and quaint, with narrow, steep streets and picturesque architecture. To the east and west is the new town, where are situated the hotels and villas for the winter residents. The English and Americans frequent the west end, and the Germans the east; it was here that the late Emperor Frederick III. of Germany spent the last winter of his life at the Villa Zirio.

In both the east and the west portions of the town are attractive and extensive promenades along the water, shaded by palms, eucalyptus, and pepper trees, that to the west called the Corso dell' Imperatrice, and that to the east the Corso Federico. These promenades afford

FIG. 4142.—Shore Drive and Promenade at San Remo.

about the only level walks, for, immediately on leaving the sea, the ascent of the hills begins, so that an invalid is restricted to a limited space about the seaside, unless he rides or is strong enough to walk up hill.

The vegetation is varied and luxuriant and of a tropical and semitropical nature—here flourish the olive, lemon, fig, and a great variety of flowers and plants. One is especially impressed with the beauty and abundance of the roses and geraniums. The excursions among the hills and valleys are many and varied and through most attractive scenery, with olive, lemon, and orange groves and a profusion of flowers and plants on every hand. The drinking-water is excellent, and the natural drainage must, from the situation of the town, be good. There are also well-built drains running from the new town into the sea or to the mouth of the mountain torrents which flow through the narrow valleys to the sea. The soil is of clay, which renders it somewhat damp after a severe rain. The accommodations are abundant and good, although, as at most of the other Riviera resorts, they are somewhat expensive. There are competent physicians and all the other requirements of a first class health resort.

The so-called winter season extends from November to April. The chief characteristics of the climate during this winter season are mildness, dryness, and sunshine, with a brilliant blue sky and sea. There is more or less wind, as throughout all the Riviera, and it is sometimes cold. The hills and mountains afford protection from the north wind, but the east and the southeast winds prevail. Occasionally the northeast wind blows in winter, as does also the Mistral. Dr. Hassall ("San Remo, Climatically and Medically Considered," London, 1883) concludes his discussion of the winds by saying that "San Remo, and indeed the whole of the western Riviera, must be regarded as windy. The winds, doubtless on some occasions, interfere with the comfort and movements of some invalids, and they constitute a drawback of what is otherwise an excellent climate; but," he wisely adds, "one must remember that the winds play a very important part, particularly in warm climates, in purifying the air, and exert also for the most part tonic effects on the system."

CLIMATE OF SAN REMO, LATITUDE, 43° 48', FOR THE SEASON, NOVEMBER TO APRIL INCLUSIVE, FOR VARYING PERIODS.

	November.	December.	January.	February.	March.	April.	Season.
Temperature, Degrees Fahr.							
Average or normal	53.5°	49.2°	47.2°	50.1°	52.0°	67.0°	51.55°
Average daily range	10.7	10.4	10.0	7.8	12.1	12.2	11.1
Mean of warmest	61.4	55.5	53.0	56.8	60.5	64.6	58.6
Mean of coldest	50.7	45.1	44.0	49.0	48.4	52.2	47.5
Highest or maximum	66.4	61.9	58.9	62.3	67.1	71.3	
Lowest or minimum	44.2	43.0	36.4	37.0	41.4	45.6	
Humidity—							
Average relative	73.1%	66.1%	68.7%	68.8%	70.1%	69.8%	69.6%
Wind—							
Prevailing direction	N. E., N. W.	N. E., N. W.	N. W., N. E.	N. E., E.	N. E., W.	. . . W.	N. E., N. W.
Strong winds (average number days on which they prevailed)	2.7	1.7	3.7	5.7	3.0	7.0	21.7
Moderate winds (average number days on which they prevailed)	3.3	4.0	3.7	5.7	10.0	11.3	38.0
Precipitation—							
Average in inches	5.29	1.13	2.68	1.81	1.18	2.13	14.5
Sunshine—							
Days of sunshine	24.3	28.3	27.3	25.6	29.6	29.0	164.0
Mean daily sunshine	7 h. 45 m.	6 h. 46 m.	6 h. 26 m.	8 h. 11 m.	8 h. 50 m.	9 h. 12 m.	7 h. 56 m.

The accompanying meteorological table, compiled from data given by Hassall, will convey a fairly accurate idea of the various climatic data for the winter season. It will be seen that the average temperature is a high one, and varies but little from month to month, except in April, when it is appreciably higher. The average daily range is moderate, but in the shade and in the early morning and shortly after sunset the air by contrast is cold, and invalids must avoid either suddenly going from the sunshine into the shade or being out after sunset.

The relative humidity is the least—66.7 per cent.—at 3 P.M. The mean number of days on which rain falls is 30, and the mean rainfall 14.05 inches for the whole season. The days on which the sun shines are on an average 164 out of a possible 181, and the mean duration of the sunshine is 7 hours and 56 minutes. To the inhabitant of northern Europe or the northeastern portion of the United States such an amount of sunshine can hardly be appreciated until experienced. There are many winter resorts, however, in America which afford an equal or greater amount of sunshine, accompanied with a mild temperature. Such are found in Southern California, Arizona, New Mexico, Texas, and in various portions of the pine belt of the South.

The general effect of such a climate as that represented by San Remo is thus portrayed by Dr. Hassall (*loc. cit.*): "Owing to the mildness of the climate," he says, "there is less wear and tear and less strain. The several functions are performed in a more moderate and uniform manner. There being less expenditure of power and less waste, a smaller quantity of food is required, and the stomach has less work to do. The circulation, in particular the heart and its vessels, is exempt from the strains entailed by extremes of heat and cold, and which in themselves are often injurious and not unattended with danger." The action of the sun on the human body is very complex; the effects are not confined to the warmth derived from its calorific rays; the luminous and chemical rays all exert powerful effects. The sun acts as a stimulant to most of the bodily functions—to elimination, secretion, and absorption; it determines many chemical changes, and promotes sanguification and the coloration or bronzing of the skin."

With regard to the class of invalids likely to be more or less benefited by this climate, the following may be mentioned: those suffering from pulmonary tuberculosis in its inception or not far advanced, unaccompanied with fever; certain more advanced but very chronic cases, especially in persons past middle life, in regard to whom

FIG. 4163. San Remo as Seen from the Mediterranean.

the only hope is to prolong and make life comfortable; those suffering from chronic bronchitis, chronic laryngitis, emphysema, and asthma; cases of diabetes and Bright's disease; persons suffering from rheumatism and scrofula; the feeble and aged; convalescents from acute diseases or from an operation, and all that great army of persons who find existence in the cold changeable climate of the North a constant struggle. The plethoric and those who have a tendency to cerebral hyperæmia, those with atheromatous arteries, and those suffering from functional nervous disorders, such as neuralgia, insomnia, or hysteria, should not come here.

San Remo can now be easily and comfortably reached from America by steamer direct to Genoa from New York or Boston. Here, as in all health resorts, the selection of a residence and the manner of life to be pursued can be satisfactorily determined only by consulting a local physician, which should always be the first thing to be done by the invalid on arrival at any health resort.

Edward O. Otis.

SANTA BARBARA, CALIFORNIA.—Santa Barbara, a well-known health and pleasure resort of Southern California, a town of about 8,000 inhabitants, founded in 1782 by Franciscan friars from Mexico, under Father Junipera Serra, is situated in north latitude 34° 24′ 30.7″, and west longitude 119° 41′ 22″, on the shores of the Santa Barbara Channel, which body of water is separated from the main Pacific Ocean by the channel islands, Anacapa, Santa Cruz, Santa Rosa, and San Miguel, the average distance of these islands from the mainland being 30 miles. Santa Barbara is 110 miles northwest of Los Angeles and 373 miles southeast of San Francisco, from which points it is reached by the Southern Pacific Railroad and by the Pacific Coast line steamers. The time by rail from Los Angeles is about three and one-half hours, and from San Francisco about eleven hours by express. Santa Barbara lies at the foot of the Santa Ynez Mountains, which rise, on the north of the city, to an altitude of from 3,000 to 4,000 feet, upon an inclined plane having an area of about 3,000 acres and a maximum altitude of 260 feet. The inclined plane slopes in a southerly and westerly direction to the sea, at the rate of about 100 feet to the mile, thus insuring good drainage to the town. This inclined plane is bounded by the foothills of the Santa Ynez Mountains on the north, and on the south and southwest by a so-called "mesa," or tableland, about 400 feet high, which intervenes between the city and the channel, and on the southeast by the channel itself. The soil upon which the city rests is composed chiefly of clayey loam, and is generally very dry, owing to the difficulty with which rains penetrate beneath its surface.

Santa Barbara is noted for the elegance and refinement of its social life, whose leaders have migrated from older social centres, and is annually visited by thousands of travellers from all parts of the world. The facilities for amusement and recreation at Santa Barbara are numerous, embracing horseback riding over broad lowland roads, by the sea, or on mountain trails, pedestrian tours among the mountains, driving, polo, golf and tennis, for the cultivation of which sports special clubs exist. There are two city clubs and a country club, which generously extend many courtesies to visitors. The country clubhouse is delightfully situated by the sea in Montecito, a suburb of Santa Barbara, about three miles from the centre of the city.

There are numerous hotels and boarding-houses in Santa Barbara, offering accommodations commensurate with the means of all comers. The Hotel Potter, of immense proportions and fully equipped with every comfort and luxury, has been recently erected (1902) near the shore; and the Arlington, situated about a mile from the water front, affords suitable accommodations for those who do not wish to live in close proximity to the sea. There are numerous cottages and houses, furnished and unfurnished, which may be rented by those who desire to have private establishments of their own. A new bathhouse, located on the shore, at the Plaza del Mar, affords good facilities for bathing in both hot and cold sea water all the year round, and has dressing rooms for those bathers who prefer a plunge into the sea. During the summer the temperature of the sea water varies from 68° to 74° F., and it is rarely below 60° F. in the winter months. The Cottage Hospital, an institution for the treatment of all classes of medical and surgical cases, is situated at Oak Park, a quiet western suburb of the town. It is supported by voluntary contributions and has a training-school for nurses. The superintendent is a physician, but there is no regularly established corps of attendants, each patient being at liberty to be treated by his own physician. A well-known private sanitarium, Miradero, crowns the heights beyond the western end of the city, and is fully equipped with all modern appointments for the entertainment and the treatment of invalids and convalescents. The city is lighted by gas and electricity, and an electric street railway gives easy access to all parts of the town. Santa Barbara has three daily papers, a free public library, churches of the leading denominations, a chamber of commerce, and a good system of free schools, besides separate private schools for boys and girls and a manual training-school. The water supply of Santa Barbara is derived from the creeks in the mountain cañons and from artesian wells. The climate of Santa Barbara is characterized by remarkable mildness, notable uniformity of temperature, abundant sunshine, low relative humidity, and low average velocity of the wind, advantages which it owes to its low latitude, and its sheltered position, to the topography of the surrounding country and to the proximity of the sea. There is no governmental station at Santa Barbara for the study of climatic conditions, but competent and careful meteorologists have recorded their observations for the last thirty-two years, and the accompanying table embodies their results:

AVERAGES OF TEMPERATURE (DEGREES FAHR.) RAINFALL, RELATIVE HUMIDITY AND WIND MOVEMENT AT SANTA BARBARA, CAL., DURING THE PAST TWENTY-FIVE YEARS (ENDING 1902).

Month.	Average of highest temperature.	Average of lowest temperature.	Mean temperature.	Relative humidity. Per cent.	Average rainfall.	Average hourly movement of wind.
January	74.8	37.1	53.5	67	3.73	3.5
February	78.2	36.1	54.8	69	3.21	4.0
March	79.8	38.3	55.7	70	2.28	4.5
April	82.0	40.8	58.0	71	1.18	4.6
May	82.2	14.5	59.3	73	.36	4.5
June	85.4	47.9	62.5	74	.10	5.0
July	86.7	52.3	65.2	76	.02	4.2
August	87.0	53.5	66.7	75	.00	4.0
September	88.2	50.5	66.0	75	.22	3.6
October	87.9	47.3	62.6	72	.73	3.5
November	84.0	43.2	60.0	66	1.54	3.1
December	77.1	38.6	55.7	65	3.63	3.5
Means	82.7	44.1	60.0	71	17.00	4.0

This table is borrowed from an article by C. M. Gidney, Esq., secretary of the Santa Barbara Chamber of Commerce, in the *Santa Barbara Daily Press*, June 15th, 1902; it was compiled by him chiefly from the published statistics of Dr. C. M. Richter, of San Francisco, and of Hugh D. Vail, Esq., of Santa Barbara. The summer days at Santa Barbara are warm but very rarely uncomfortably hot, and the nights are so cool that blankets are regularly required for the sleeper's protection in the early morning hours. High fogs prevail throughout the summer months, making their appearance at nightfall or sometimes much later, and clearing away between eight and twelve o'clock in the morning. From November to May fogs are very rare. The most disadvantageous feature of the summer climate is the dust, which is abundant, owing to the absence of rain from April to October or November. The dust is combated by sprinkling with fresh or salt water, and recently by sprinkling with crude oil, which is very effective. The winter days at Santa

Barbara are generally clear, calm, sunny, and moderately warm. There is no snow except rarely on the mountain-tops, and no frost severe enough to destroy lemons, roses, violets, or heliotrope. Rain falls, at intervals of days or weeks, from November until April, but the rainy season is really such in name only. In the writer's residence at Santa Barbara, which has extended over a period of seven years, he has not seen a single winter during which an invalid would have been confined to the house more than ten days by rain. If we add to this sum the number of winter or spring days rendered too inclement by high winds and dust, we may safely assert that the health-seeker could advantageously remain out-of-doors during the daylight hours on all but fifteen or twenty days of the entire year. Many people sleep out-of-doors at Santa Barbara all the year round. The average number of absolutely clear and sunny days may be computed at about 250, the fair days at 50, the cloudy ones at 50, and the rainy days at 15. The foothill region of Santa Barbara, north of the town, Mission Cañon, one of the gorges between the Santa Ynez Mountains, and Montecito, an eastern suburb, offer essentially the same favorable climatic conditions presented by Santa Barbara proper, with even purer air, lower humidity, higher temperature, less violent winds and more abundant sunshine.

Renal diseases, cardiac affections, and neurasthenia are all favorably affected by the climate of Santa Barbara, while convalescents after acute diseases, old people, and little children thrive under the influence of its balmy air and genial sun.

Asthmatic patients do not do well at Santa Barbara, in the writer's experience, unless it be in the foothill region or on the heights of Montecito. Patients with bronchitis or with pulmonary tuberculosis do fairly well in the winter, but are unfavorably affected by the dust and fogs of summer. Some cases of tuberculosis have been cured at Santa Barbara under the writer's observation, but the majority do better farther from the coast and at an elevation greater than that of Santa Barbara.

William H. Flint.

SANTA BARBARA HOT SPRINGS.—Santa Barbara County, California.

POST-OFFICE.—Santa Barbara. Hotel and cottages.

These famous hot sulphur and soda springs are situated in the beautiful Santa Ynez Mountains, six and a half miles northeast of Santa Barbara city. The location is 1,450 feet above the sea-level, and unites many advantages of climate and scenery. The resort suffered from unwarranted neglect for a time. The springs are twenty-two in number, and range in temperature from 99° to 122° F. Analyses have been made by Oscar Loew and Winslow Anderson. We present Anderson's analysis as more recent and more complete than that of Loew: One United States gallon contains: Sodium chloride, gr. 1.74; sodium carbonate, gr. 2.17; sodium sulphate, gr. 14.92; magnesium sulphate, gr. 7.75; calcium sulphate, gr. 6.03; aluminum sulphate, gr. 2.90; arsenic, silica, sulphuric acid, and organic matter, very small amounts. Total solids, 36.69 grains. Gases: Free carbonic acid gas, 19.14 cubic inches; sulphureted hydrogen, 9.16 cubic inches.

Loew's analysis shows a slightly greater proportion of solid ingredients. It will be observed that the waters resemble those of the Arkansas Hot Springs. They have been found useful in the treatment of rheumatism, gout, and other joint affections, Bright's disease, and bladder irritation. Excellent results have been observed from the use of the baths in syphilitic and scrofulous contaminations, glandular enlargements, and chronic skin diseases.

James K. Crook.

SANTA CATALINA ISLAND, CAL.—This very attractive insular resort, with a delightful climate both winter and summer, lies off the coast of Southern California about twenty-five miles distant. It is reached in three hours and a half from Los Angeles by railroad to San Pedro Harbor, and from thence by steamer. The island is twenty-three miles long, and with an average width of four miles in the southern part and two miles in the northern. It is mountainous in character, rising to

FIG. 4111.—Avalon in the Island of Santa Catalina, California.

the height of three thousand feet, with deep valleys or gorges, and a great transverse depression running partly through it and forming a bay or anchorage on either side. The shores are bold, high cliffs, broken here and there by tiny bays or coves, with a sandy beach. Upon one of these coves, on the eastern side (called Avalon Bay), is situated the little town of Avalon, the only settlement on the island and the chief place of resort. Here are a number of good hotels, many boarding-houses, and, in the summer, tent villages with macadamized streets and rows of shade trees, where furnished tents can be rented—a popular mode of living at this season. There are also opportunities for camping in the many recesses of the island.

The climate exhibits the essential characteristics of that of the shore opposite, modified somewhat by local conditions; the rains here are said to be less frequent than on the mainland, the sea breeze is not so strong, and there is not so much fog. "They (the channel islands, of which Catalina is the principal one) are bathed in sunshine when the mainland opposite is enveloped in fog." The reader is referred to the article upon *Los Angeles* and the meteorological table therein contained for climatic details applicable in the main to the climate of Santa Catalina. The average July temperature at Santa Catalina is 65° F. In August the highest mean temperature observed at six in the morning was 72°; the highest at noon, 78°; the lowest, 69° F. The water temperature at noon, 76° F. The average relative humidity is 67 per cent. It is never uncomfortably warm in summer or too cool in winter. For both seasons it appears to be an admirable climate.

For a summer resort it is very popular and very much visited, and in the height of the season there are often five or six thousand people on the island; indeed, one of the objections to this resort for an invalid is the crowd of summer excursionists. As a genuine health resort it would appear to be more suitable and in many ways more attractive in the winter, for it is then "that the true beauties of this isle of summer are seen. The rains, which, curiously enough, are less than on the mainland, change the brown hills to a vivid green, and we have an emerald in an azure setting. Myriads of flowers spring up, and the face of the island is changed as if by magic. . . . In February and through the winter months Catalina is still an island of summer" (C. F. Holden, in *California Magazine*, December, 1892, quoted by Solly).

The outdoor attractions are many and varied. There are golf links in the Grand Canyon; various excursions among the mountains and valleys; a stage road across the island winding along the mountainside, affording delightful views of sea and land; boating, fishing, and bathing. The fishing is a feature of the place, and here are caught the large black sea bass, the leaping tuna, the yellowtail, and the barracuda. The water is so transparent that the bottom can be clearly seen at a depth of from fifty to one hundred feet, and for this purpose glass bottom boats are much in use, from which the most varied and fascinating sea vegetation, as well as a variety of fish life, can be seen. There is also wild-goat shooting from horseback in the fastnesses of the mountains.

Altogether, a region affording so many attractions of climate, scenery, water and land sport as that of Santa Catalina can hardly be imagined. Moreover, it has the great advantage of being an all-the-year-around resort. The sanitary regulations are said to be excellent, being under the supervision of a resident physician and health officer. Especial attention is paid to the sanitary condition and cleanliness of the tent villages. The bathing and swimming in the bay of Avalon are very delightful, both on account of the temperature of the water and on account of the absence of wind and surf.

Edward O. Otis.

SANTA ROSA WHITE SULPHUR SPRINGS.—Sonoma County, California. These springs are pleasantly situated about two miles from the town of Santa Rosa. The surrounding country is delightful in character and the climate very genial. There are good accommodations for visitors, and the resort is prosperous and thriving. The springs are mostly sulphureted and cold, having temperatures ranging from 59° to 62° F. The principal spring was found by Anderson to have the following composition: One United States gallon contains (solids): Sodium chloride, gr. 5.72; sodium carbonate, gr. 2.19; sodium sulphate, gr. 6.90; magnesium sulphate, gr. 9.07; and very small amounts of potassium carbonate, magnesium carbonate, calcium carbonate, calcium sulphate, ferrous carbonate, alumina, borates, silica, and organic matter. Total solids, 28.75 grains. Gases: Free carbonic acid gas, 4.16 cubic inches; free sulphureted hydrogen, 6.47 cubic inches. The action of this water is slightly aperient and diuretic. It is useful in congestion of the liver due to malarial poisoning, and in rheumatism, kidney and bladder troubles, and skin diseases. Excellent bathing facilities have recently been provided, the water being artificially heated.

James K. Crook.

SANTA YSABEL SULPHUR SPRINGS.—San Luis Obispo County, California. Hotel and cottages.

These valuable springs are located two and a half miles southeast of Paso Robles, on the line of the Southern Pacific Railroad, by which they may be reached. The location is a very delightful one, being in a small canyon about one mile east of the Salinas River. It is surrounded on all sides by the rolling hills covered with groves of gigantic oaks, towering pines, and clustering manzanitas. The atmosphere is sweet and balmy, and ranges from about 60° to 75° F. all the year round. The elevation is one thousand feet above the sea level, and the distance from the coast is about thirty miles. The soil of the neighboring land is exceedingly fertile, producing almost every known variety of fruit, as ascertained from the United States Experiment Station close by. The main warm sulphur spring flows twenty thousand gallons per hour. The waters are clear and sparkling, lightly sulphureted and freely carbonated. The waters are tonic, antacid, diuretic, aperient, and sedative.

The cold springs, being less densely impregnated with mineral ingredients, possess these qualities in a lighter degree than the warm. The waters have been found highly useful in a wide range of affections, embracing disorders of the liver, stomach, and bowels, catarrhal affections of the kidneys, chronic rheumatism, glandular indurations, obstinate syphilitic infection, and chronic cutaneous diseases. There are other valuable springs on the property, including a warm sulphur mud spring. This hot sulphurous mud is excellently adapted for bathing purposes. Extensive improvements are under way at this resort. Good roads and building sites have been laid out, and a depot landing selected. A small mountain lake is in course of construction; it will be from eight hundred to one thousand feet long by several hundred feet broad. On its waters will be several pleasure boats. About one hundred feet above the lake, on a pleasant plateau commanding magnificent views of the Salinas Valley, a spacious modern hotel and a number of cozy cottages will be reared. Thorough bathing facilities will also be provided. With its natural advantages of climate, soil, and surroundings, Santa Ysabel resort promises to be one of the pleasantest inland watering-places in that section of the country. It will be under the patronage of the Presbyterian denomination.

James K. Crook.

SANTONICA.—See *Wormseed.*

SANTONIN.—(*Santoninum*, U. S. P.; Br.; P. G.—$C_{15}H_{18}O_3$=245.43). A neutral principle obtained from santonica.

The source of this substance is described under *Wormseed, Levant.* It is extracted as a compound of lime by boiling in water or macerating in dilute alcohol to which lime is added. The calcium is then separated from the santonin by the addition of acetic or hydrochloric acid to the solution, and the santonin is purified by appropriate processes. Although now rarely intentionally adulterated, commercial santonin is very apt to be but imperfectly purified, and to contain artemisin. It is thus described by the Pharmacopœia:

Colorless, shining, flattened, prismatic crystals, odorless, and nearly tasteless when first put in the mouth, but afterward developing a bitter taste; not altered by exposure to air, but turning yellow on exposure to light.

Nearly insoluble in cold water; soluble in 40 parts of alcohol at 15° C. (59° F.), in 250 parts of boiling water, and in 3 parts of boiling alcohol; also soluble in 140 parts of ether, in 4 parts of chloroform, and in solutions of caustic alkalies.

When heated to 170° C. (338° F.), santonin melts, and forms, if rapidly cooled, an amorphous mass, which instantly crystallizes on coming in contact with a minute quantity of one of its solvents. At a higher temperature it sublimes, partly unchanged, and, when ignited, it is consumed, leaving no residue.

Santonin is neutral to litmus paper moistened with alcohol.

Santonin yields, with an alcoholic solution of potassium hydrate, a bright pinkish-red liquid which gradually becomes colorless.

From its solution in caustic alkalies, santonin is completely precipitated by supersaturation with an acid.

Its solution in cold, concentrated sulphuric acid is at first colorless (absence of *easily carbonizable, organic substances*), but after some time turns yellow, then red, and finally brown. If water be added, immediately after it is dissolved without color in sulphuric acid, it will be completely precipitated, and the supernatant liquid should not have a bitter taste, nor should it be altered upon the addition of potassium dichromate T.S. (absence of *brucine* or *strychnine*), or of mercuric potassium iodide T.S. (absence of *alkaloids in general*).

Action and Uses.—Although santonin produces very pronounced and in some ways remarkable physiological effects, it is very little used in those directions. It is actively diuretic, the action being dependent chiefly if not wholly upon local irritation, for it is excreted by the kidney. On this account it is occasionally employed as an emmenagogue. The urine is at the same time colored yellowish-brown, or, if decomposed, purplish-red. Upon the centres it acts as a motor excitor, this action being followed by depression, and there are evidences of cerebral congestion. Vision is most strongly and peculiarly affected, all objects appearing yellow or greenish-yellow, sometimes bluish at first.

It is occasionally administered in small doses, one-half to one grain, for correcting dimness of vision, especially that resulting from tobacco poisoning. With this exception, its sole use is that of an anthelmintic, destroying lumbrices and ascarides, especially the former. Advantages possessed by it over most other anthelmintics are its small bulk, freedom from bad taste, and availability for use in the form of confections, which are easily administered to children. Also in its favor is its slight solubility, on account of which it remains in the intestine sufficiently long to act upon the parasites and is then dejected without entrance into the circulation. This property cannot, unfortunately, always be depended upon, since, for reasons but little understood, it sometimes becomes unexpectedly absorbed, with poisonous effects. It must therefore be given with caution, and its effects should be kept under observation by the physician. Its administration should in all cases be followed by a cathartic, chiefly in this case as a precaution against poisoning. Unlike some poisonous substances, its absorption is not favored, but rather inhibited, by fats. Great caution should be observed in administering it to very young children. The dose of santonin for a child of five or six years is 0.03 to 0.06 gm. (gr. ss. to gr. i.). Adults may take from 0.12 to 0.25 gm. (gr. ij. to gr. iv.). The official preparation is the troches (*trochisci santonini*), each containing 0.03 gm. (about gr. ss.) of powdered santonin, with sugar and tragacanth, and flavored with a little stronger orange-flower water. *Henry H. Rusby.*

SANTONIN-OXIM.—A derivative of santonin, obtained by the action of hydrochlorate of hydroxylamine, in alcoholic solution, upon santonin. Its chemical formula is $C_{15}H_{18}O_2NOH$, that of santonin being $C_{15}H_{18}O_3$. It is a white crystalline substance, having a melting-point of 323° F. It is scarcely soluble in water, but soluble in alcohol and ether, and in weak alkaline or weak acid solutions.

Santonin-oxim is recommended as a substitute for santonin, as it is said to be free from any toxic properties. This is explained by the statement that it is not absorbed from the alimentary canal, its anthelmintic action being effected, therefore, without any influence on the general system. The dose for children of two or three years is one grain; for those from four to six, one grain and a half; for those from six to nine, two grains; and for adults, five grains. This quantity is to be given in two portions, an hour intervening between them. The dose should be repeated daily for two or three days, and should be followed by a purgative. *Beaumont Small.*

SANTONIN, POISONING BY.—Santonin is a neutral, crystalline principle obtained from the unexpanded flowers of the *Artemesia pauciflora* Weber. The formula $C_{15}H_{18}O_3$ has been assigned to it. It is but slightly soluble in cold water; more so in alcohol. Its principal use is as a vermifuge, and for this purpose it is given to children in doses of about half a grain; adults may take from two to four grains. Serious symptoms have arisen in children from as little as two grains, and one fatal case is believed to have been due to six grains. It has a marked bitterness, which is, however, not at once perceived owing to the slight solubility of the drug. The symptoms produced by overdose are dizziness, stupor, paleness, and subnormal temperature, followed by vomiting, dilatation of pupil, and unconsciousness. Occasionally convulsions involving the trunk muscles occur. Disturbances of color-vision often occur, objects appearing usually yellow, but sometimes green or blue. The drug is eliminated in part by the urine, which will acquire a distinct red tint on adding an alkali, or spontaneously on standing owing to the formation of ammonium carbonate from the urea.

There is no specific antidote. A few grains of potassium permanganate in a tumblerful of water might be of service. If this is given, no coffee, milk, or other organic matter should be added. Washing out the stomach might be of some use. Hot applications to the extremities are advisable. *Henry Leffmann.*

SAPOCARBOL is an aqueous solution of crude carbolic acid and potash soap, intended as a substitute for lysol. It is said to contain from thirty-seven to forty-four per cent. of phenol. *W. A. Bastedo.*

SAPODERMIN is a soap containing 0.2 per cent. of mercury in the form of caseinate; though the soap is alkaline, the mercury salt retains its solubility. Sack says that it is not only non-irritating, but in prolonged use acts as a preservative of the skin. In aqueous solution (1 to 1,000) it inhibits the growth of streptococci, and is best applied in bacterial and fungous skin diseases by letting the concentrated lather dry upon the skin.

W. A. Bastedo.

SAPOLAN consists of 2.5 parts of crude naphtha, 1.5 parts of lanolin, and three or four per cent. of anhydrous soap. It is a brownish-black salve, preferred by Lesser to the tar preparations because of its non-irritating properties. Mracek has used it with excellent results in eczema of different kinds, in favus, herpes, tinea tonsurans, etc., and he considers it distinctly bactericidal.

W. A. Bastedo.

SAPROL is a dark-brown oily substance, consisting of a forty-per-cent. solution of crude cresols in the lighter petroleum hydrocarbons (benzin, etc.). It is immiscible with water and is very inflammable. It is used as a disinfectant. *W. A. Bastedo.*

SARANAC LAKE. See *Adirondacks.*

SARATOGA SPRINGS.—Saratoga County, New York. Post-Office.—Saratoga. Hotels, boarding-houses, and cottages.

Access.—Saratoga is a station on the Delaware and Hudson Railroad, 38 miles north of Albany and 183 miles north of New York. The trip may be made by steamers on the Hudson River to Albany or by two lines of railroads, the New York Central and the West Shore to Albany, thence viâ Delaware and Hudson Railroad. Through trains run daily from New York during the season. From Buffalo and the West Saratoga is reached by way of the Delaware and Hudson Railroad and its Western connections, and from Boston and the East viâ the Fitchburg Railroad to Albany and thence viâ the Delaware and Hudson Railroad.

This famous resort is perhaps the most celebrated watering-place in the United States, as it is undoubtedly in the Northern States, and, with the exception of Berkeley Springs in Virginia, the oldest in the country. The village is situated toward the eastern border of the State, at the southern termination of the Adirondack range of mountains, and at about the centre of a valley extending from Ballston to Quaker Springs. The altitude of Saratoga is about 300 feet above the sea level, and the population varies from about 11,000 in the winter to 35,000 during the season, which lasts from the middle of June to the middle of September. The accommodation for visitors of all classes is ample and excellent. The name Saratoga is derived from the Iroquois tribe of Indians, and there is ample evidence to show that some of the springs here were known to and used by the aborigines many years prior to the advent of the European settlers. The well-known High Rock Spring on Willow Walk was apparently the first of these springs to be used by the whites. It is said to have been resorted to by Sir William Johnson as early as in 1767. The first real impetus given to the resort, however, was in 1789, when Gideon Putnam, of Sutton, appeared at the springs, leased three hundred acres of land, and thereafter was the leading spirit of improvement. In 1802 he built a portion of Union Hall upon the site of the present magnificent Grand Union Hotel, and this may be regarded as the starting-point of the Saratoga which we know to-day. Since those days many new springs have been added to the list, and the number at the present time will exceed fifty. As late as May 10th, 1897, the New York *Sun* contained an account of a new spring which had been struck at the Geysers on the preceding day by workmen who were drilling for the Carlsbad Company.

Saratoga presents many attractions beside the mineral springs and the grand hotels. The village has numerous elegant private residences, densely shaded streets, attractive walks, and beautiful drives. "The grounds of the different fountains are picturesquely adorned and shaded, and each hotel has its embowered court, where pleasing music is discoursed at intervals through the day and evening. Congress Park, at the southern extremity of Broadway, is a favorite resort where during the morning hours visitors congregate at the spring, drink of the waters, and stroll along the beautiful walks beneath the shade of ancient forest trees" (Walton). Among the numerous attractions in the neighborhood are the Saratoga Lake, nine miles long and four or five miles wide; Prospect or Waring Hill, said to rise two thousand feet above the sea level; Chapman's Hill, Hagerty Hill, etc. Bemis Heights, the scene of the surrender of Burgoyne to General Gates, is in the town of Stillwater, fifteen miles distant. All these points and many others may be easily reached from Saratoga by carriage drives or by bicycles.

The predominant ingredients of the Saratoga waters, as will be seen from the analyses, are the chloride of sodium, the alkaline carbonates, and carbonic acid gas. Some of them are, furthermore, quite heavily impregnated with iron. All contain one or more of the salts of lime. They are properly described as muriated alkaline-calcic carbonated waters. The further designation of chalybeate may be applied in many instances. Owing to lack of space we shall be able to give the analyses of only a few of the better known springs:

1. Congress Spring—(C. F. Chandler).

One United States Gallon Contains:

Solids.	Grains.	Solids.	Grains.
Sodium carbonate	10.77	Sodium chloride	400.44
Calcium bicarbonate	143.40	Potassium chloride	8.05
Magnesium bicarbonate	121.76	Sodium bromide	8.56
Strontium bicarbonate	Trace.	Calcium fluoride	Trace.
Lithium bicarbonate	4.76	Sodium iodide	.11
Iron bicarbonate	.34	Alumina	Trace.
Barium bicarbonate	.93	Silica	.84
Potassium sulphate	.89		
Sodium phosphate	.02	Total	700.90
Sodium biborate	Trace.	Carbonic acid gas	392.30

2. Empire Spring—(C. F. Chandler).

One United States Gallon Contains:

Solids.	Grains.	Solids.	Grains.
Sodium bicarbonate	9.02	Potassium chloride	4.29
Calcium bicarbonate	109.66	Sodium bromide	.27
Magnesium bicarbonate	42.96	Calcium fluoride	Trace.
Strontium bicarbonate	Trace.	Sodium iodide	Trace.
Lithium bicarbonate	2.08	Alumina	.42
Iron bicarbonate	.79	Silica	1.46
Barium bicarbonate	.07	Organic matter	Trace.
Potassium sulphate	2.77		
Sodium phosphate	.02	Total	680.44
Sodium biborate	Trace.		
Sodium chloride	506.63	Carbonic acid gas	344.67

3. Hathorn Spring—(C. F. Chandler).

One United States Gallon Contains:

Solids.	Grains.	Solids.	Grains.
Sodium bicarbonate	4.29	Sodium bromide	1.53
Calcium bicarbonate	170.65	Calcium fluoride	Trace.
Magnesium bicarbonate	176.46	Sodium iodide	.19
Strontium bicarbonate	Trace.	Alumina	.13
Lithium bicarbonate	11.45	Silica	1.26
Iron bicarbonate	1.13	Organic matter	Trace.
Barium bicarbonate	1.74		
Sodium phosphate	Trace.	Total	888.40
Sodium biborate	Trace.		
Sodium chloride	509.97	Carbonic acid gas	375.75
Potassium chloride	9.60		

4. High Rock Spring—(C. F. Chandler).

One United States Gallon Contains:

Solids.	Grains.	Solids.	Grains.
Sodium bicarbonate	34.89	Sodium bromide	0.73
Calcium bicarbonate	131.74	Calcium fluoride	Trace.
Magnesium bicarbonate	54.92	Sodium iodide	.08
Strontium bicarbonate	Trace.	Alumina	1.22
Iron bicarbonate	1.48	Silica	2.26
Barium bicarbonate	Trace.	Organic matter	Trace.
Potassium sulphate	1.61		
Calcium phosphate	Trace.	Total	627.56
Sodium chloride	390.13		
Potassium chloride	8.50	Carbonic acid gas	409.46

Kissingen or Triton, now Arondack Spring—(Professor Sharples).

One United States Gallon Contains:

Solids.	Grains.	Solids.	Grains.
Sodium bicarbonate	67.62	Sodium bromide	1.80
Calcium bicarbonate	140.26	Calcium fluoride	Trace.
Magnesium bicarbonate	70.47	Sodium iodide	.01
Strontium bicarbonate	Trace.	Alumina	Trace.
Lithium bicarbonate	5.13	Silica	1.28
Iron bicarbonate	1.56		
Barium bicarbonate	.99	Total	644.63
Potassium sulphate	Trace.		
Sodium chloride	338.50	Carbonic acid gas	361.50
Potassium chloride	16.98		

It will be observed that all the waters contain large quantities of carbonic acid gas, ranging from about 212 cubic inches per United States gallon in the Saratoga Alum Spring to 465 cubic inches in the Champion Spouting Spring. All contain the chlorides of sodium and potassium, the former salt ranging from 702 grains per United States gallon in the Champion Spring to 108 grains in the Flat Rock Spring. The bicarbonate of sodium is also present in each of the springs, the Vichy Spring leading with 82 grains and the Kissingen follow ing with 67 grains per gallon. All contain magnesium salts, the Champion Spring being first with 193 grains of magnesium bicarbonate per United States gallon. All the springs analyzed according to the more recent methods of examination are found to contain lithium, the Hathorn having 11 grains and the Geyser, Pavilion, and the New Putnam each about nine grains of the bicarbonate to the United States gallon. Most of the other springs contain an appreciable amount of lithium. Iron is always present in all of the waters, from the merest trace in some to 1.62 grains per gallon in the Hamilton, 5.88 grains in the Columbian, and 7 grains in the Putnam springs. All of the springs also contain calcium, while many of them contain the iodide and the bromide of sodium. The Putnam Spring contains the bicarbonate of magnesium. Several well known springs are not included in the above list, but recent analyses show that they possess the same general characteristics as those of which we have given the analyses.

The Saratoga waters have been recommended in a wide range of disorders and diseases, in many of which they have been found useful, while in others their influence has been pernicious. It can be laid down as an axiom that waters of this strength should not be taken at random; the consumer should invariably give himself the benefit of the advice of a physician of skill and experience before entering upon a course of the waters, either in his own home or at the springs. We cannot in this place enter into a detailed discussion as to the indications and contraindications for the Saratoga waters, but it may be said in a general way that their best application has been found in dyspepsia, engorgement of the liver and portal system, and chronic constipation. The chalybeate waters have been found beneficial as a tonic and reconstructive in general debility, in neurasthenia, and in anæmic states. The springs containing lithia may be counted upon to exercise the same influence upon the protean uric acid states as is to be expected from the widely advertised lithia waters. Many of the waters are also capable of producing a very appreciable alterative effect when taken for a considerable period of time.

There are three bathing establishments at Saratoga: the Saratoga Baths, recently opened and luxuriously appointed; the Red Spring bathhouse, and the misnamed Magnetic Baths. There is also a bathhouse at the White Sulphur Spring, south of Saratoga Lake. All are well conducted. *James K. Crook.*

SARCOMA.—The term sarcoma is loosely applied to the individual members of a large group of cellular, rapidly proliferating tumors of mesenchymal origin. It is applied more specifically to the members of that subdivision of these tumors in which the tumor cells secrete intercellular substances. The latter are usually small in amount, but they are similar in character to the intercellular substances found in ordinary connective and myxomatous tissues, cartilage, and bone. The tendency is more and more to restrict the name sarcoma to this single class of tumors.

The sarcomata, like other simple tumors, consist of two parts—of the tumor cells which may or may not secrete an intercellular substance, and of a stroma furnished by the tissue in which the tumor grows, in consequence of a physiological demand for nutrition and support made by the tumor cells. The stroma consists of blood vessels which may or may not be accompanied by a varying number of connective-tissue cells and fibrillæ. The blood vessels are often of the simplest type and may consist of endothelium only.

The sarcomata may be divided into several groups, according to the production or not of intercellular substances, and the form, arrangement, and differentiation of the cells. These groups can be further subdivided according to the kind of intercellular substance produced, and the size, shape, pigmentation, or other peculiarities of the cells.

The several groups adopted here and the subdivisions under them are as follows:

Group A. Sarcomata Characterized by the Production of an Intercellular Substance.—1. Spindle-cell sarcoma. 2. Myxosarcoma. 3. Chondrosarcoma. 4. Osteosarcoma. 5. Giant cell sarcoma. 6. Malignant leiomyoma.

Group B. Sarcomata Possessing a Reticulum.—1. Malignant lymphoma. 2. Chloroma. 3. Myeloma.

Group C. Sarcomata having an Alveolar Structure.—1. Melanoma. 2. Alveolar sarcoma.

Group D. Endotheliomata.—1. Hemangioendothelioma. 2. Lymphangioendothelioma. 3. Endothelioma of dura.

GROUP A. SARCOMATA CHARACTERIZED BY THE PRODUCTION OF AN INTERCELLULAR SUBSTANCE.—The mesenchyma of the embryo gives rise to a series of tissues of which the most closely related are ordinary fibrillar connective tissue, myxomatous tissue, cartilage, and bone. The tumors arising from these tissues, or, in the case of cartilage and bone, from the tissues which produce them, are, in their most actively proliferating types, owing to a lack of differentiation, indistinguishable; but the cells almost always preserve, to some extent at least, the property of differentiating in cell or intercellular substance like the cells of the tissue from which the tumor has arisen. For example, the periosteum gives rise to spindle-cell sarcomata with fibrillar intercellular substance; certain parts of such tumors frequently cease to grow rapidly, the fibrillar intercellular substance increases in amount, and is transformed into a hyaline material (osteoid tissue) in which lime salts may be deposited. In other words, some of the tumor cells have gone far enough in their differentiation to betray the nature and properties of the tissue from which the tumor originated.

It is usually claimed that sarcomata starting from ordinary connective tissue never produce bone, but this may not be a correct assumption. A few sarcomata containing bone have been described as arising in situations where no bone ordinarily exists. They may have arisen from misplaced periosteal tissue, but the simpler explanation is that ordinary connective tissue may give rise to tumors containing bone just as we know it often does under inflammatory conditions, as, for example, in the healing of wounds.

In this group are included those sarcomata which produce intercellular substances, such as the fibrillæ of ordinary connective tissue, the mucus of myxomatous tissue, and the hyaline substances of cartilage and bone. The amount of intercellular substance varies considerably and often is quite small, but even in the most cellular tumors, where mitotic figures are very numerous, proper staining of tissues carefully fixed while perfectly fresh always shows a certain definite and often large amount of intercellular substance.

The tumors of this group are subdivided chiefly according to the character of the intercellular substance produced, to some extent, however, according to the character of the cells. The whole group of tumors is, however, so closely related that the division is largely artificial. Combinations of almost any two or more of the varieties recognized is not at all uncommon. They are really classified in accordance with the amount of differentiation shown by a part or all of the cells. For example, if a spindle-cell sarcoma produces in places a mucoid intercellular substance, it is called a myxosarcoma; if cartilage, a chondrosarcoma; if bone, an osteosarcoma. If, on the other hand, giant cells are present in it, the tumor is called a giant-cell sarcoma.

Sarcomata grow by multiplication of their own cells. They do not infect surrounding tissue cells and cause them to turn into tumor cells. On the other hand, a certain amount of reactive proliferation of normal tissues may take place at the advancing edge of a sarcoma, but the cells preserve their normal characteristics. As a sarcoma enlarges it either simply shoves the neighboring tissue back on all sides by expansive growth, or infiltrates and destroys it. No tissue, not even bone, is able to withstand it.

The various sarcomata have the common characteristics of rapid growth, a tendency to ulceration, to local return after extirpation, and to early and extensive metastases. The metastases may be local by discontinual peripheral growth, or regional by way of the lymphatics, or general by means of the blood-vessels. As a result of local metastases sarcomata often have a lobulated form. As a result of the frequent extension of sarcomata into blood-vessels, general metastases are common; multiple nodules occur in the lungs, liver, spleen, and bone marrow, and occasionally in other organs. Regional metastases are rare except with certain varieties of sarcoma.

Retrograde changes are frequent in sarcomata, especially fatty degeneration, necrosis, and calcification. With some forms hemorrhage is common and may give rise to pigmentation simulating that present in melanotic sarcomata.

The form of the cells in the different sarcomata can be studied best in teased preparations of fresh or macerated tissues, while the intercellular substances are best demonstrated by means of the aniline blue connective-tissue stain.*

1. *Spindle-Cell Sarcoma.*—Of the sarcomata of which the cells produce an intercellular substance, the most common and typical example is the spindle-cell sarcoma (Fig. 4145). The cells are elongated and terminate at each end in a process which may be long or short. In the swollen centre of the cell is an oval or elongated nucleus; occasionally two or more nuclei are present. When the cells are seen in cross section they look like small round cells. The arrangement of the cells is fairly regular: they overlap each other so that the slender ends of one cell come opposite the middle of the cells adjoining it. The cells tend in a general way to run parallel with the blood-vessels; in this way are formed the bundles of cells which in a mounted section are seen to run in different directions. The bundles of cells may be large, or small and closely interwoven.

FIG. 4145.—Spindle-Cell Sarcoma showing the Connective-Tissue Fibrillæ Between the Cells.

The cells vary considerably in size and shape in different tumors; they may be large or small, and short and plump with oval nuclei, or very long and slender with rod-shaped nuclei. The two extremes of size are recognized as the large and the small spindle-cell sarcomata.

Mitotic figures vary considerably in number in different tumors and in different parts of the same tumor, but

FIG. 4146.—Sarcoma Composed of Large Cells, Round to Spindle in Shape, with Connective-Tissue Fibrillæ Between the Cells. Two mitotic figures of which one is compound. One very large cell contains lobulated nuclei and hyaline droplets. This sarcoma started in the uterus and probably originated in smooth muscle fibres.

usually they are comparatively numerous. The number of them in a given area affords the best means of judging of the rapidity of growth of the tumor.

Running between the cells and in the same direction as their long axes are very delicate connective-tissue fibrillæ, which are produced by the tumor cells. In the more slowly growing sarcomata, and often in certain parts of those which are proliferating rapidly, the fibrillæ are more numerous and tend to unite into coarser fibres.

As a rule, the blood-vessels are very delicate and usually are lined with endothelium only.

All spindle-cell sarcomata do not grow at the same rate of speed. Some contain great numbers of mitotic figures and little intercellular substance; others have fewer proliferating cells and more intercellular fibrillæ. It is not always easy to draw the line between them and the more slowly growing connective tissue tumors to which they are intimately related. When the cells and fibrillæ are about equal in quantity and the tumor is growing rather slowly, it is called a fibrosarcoma. When the fibrillæ greatly preponderate and the growth is very slow, the tumor is called a fibroma. Names are assigned to but these three rates of speed, and all tumors of this nature are arbitrarily classed under one or another of them.

The spindle-cell sarcoma has its prototype in young connective tissue which it sometimes very closely resembles. I have recently found that young connective tissue cells of inflammatory origin produce two kinds of fibrillæ—the ordinary delicate wavy fibrillæ which stain blue by the aniline blue connective-tissue stain, and delicate refractile straight fibrillæ which stain intensely red by the same method, provided the staining with acid fuchsin be prolonged for twenty four hours, and which have about the same relation to the cell protoplasm that the neuroglia fibres have. These red-staining fibrillæ do not stain by Weigert's method for elastic fibres, but can be brought out sharply by a method which has not yet been published. These same fibrillæ occur in spindle-cell sarcomata.

Although the spindle cell sarcoma is the typical and most common example of the tumors which produce a fibrillar intercellular substance, certain other sarcomata occur in which some or all of the cells may be oval, polymorphous, or even round (Fig. 4146), but they must be carefully distinguished from those tumors in which the cells lie in a reticulum or have an alveolar arrangement.

2. *Myxosarcoma.*—The tissue (Wharton's jelly) of

* *Aniline Blue Connective-tissue Stain.*—This method, slightly modified from the original, is as follows:

1. Fix thin sections (2 to 4 mm. thick) of perfectly fresh tissue in Zenker's fluid for twenty-four hours. Wash in running water twenty-four hours. Dehydrate in ninety-five-per-cent. alcohol.
2. Stain celloidin or paraffin sections in a one-half-per-cent. aqueous solution of acid fuchsin for five minutes.
3. Wash off quickly in water (not over five seconds).
4. Place in a one-per-cent. aqueous solution of phosphomolybdic acid for ten to twenty minutes.
5. Wash off quickly in water (not over five seconds).
6. Stain in the following aniline blue solution five to ten minutes. Aniline blue soluble in water (Grübler), 0.5; orange G (Grübler), 2.0; oxalic acid, 2.0; water, 100.0.
7. Wash very quickly in running water (not over five seconds).
8. Wash in several changes of ninety-five-per-cent. alcohol.
9. Absolute alcohol, xylol, xylol balsam.

Water extracts the acid fuchsin very quickly. Alcohol has little effect on the acid fuchsin but extracts the aniline blue rather quickly.

which the umbilical cord is composed has always been held up as the type of myxomatous tissue. It is usually said to be composed of delicate irregular cells united by protoplasmic processes between which is a fluid or gelatinous ground substance containing mucin. Such a tissue composed of delicate protoplasm and fluid would tear

FIG. 4147.—Osteochondrosarcoma. An area where the fibrillar intercellular substance shows partial transformation into the hyaline matrix of cartilage and bone.

with the greatest ease; the umbilical cord is unquestionably rather tough. As a matter of fact, proper staining of the umbilical cord, even in the very smallest embryos, shows that innumerable exceedingly delicate connective-tissue fibrillæ run in parallel strands everywhere between the cells. Myxomatous tissue is, therefore, to be defined as connective tissue in which the individual fibrillæ are more or less separated from each other by a fluid containing an excess of mucin. The ordinary staining methods do not bring out these fibrillæ distinctly. Myxomatous tissue differs from œdematous connective tissue chiefly in the amount of mucin present in the fluid.

A myxosarcoma is to be defined as a sarcoma which produces a fibrillar intercellular substance together with a fluid containing an excess of mucin. The amount of fibrillar material varies with the rapidity of growth of the cells, just as it does in a spindle-cell sarcoma. A pure myxosarcoma is rare; its cells are irregular, more or less stellate, with branching processes. As a rule, only parts of a tumor are myxomatous and the stellate cells grade off into others of the spindle type and the intercellular fibrillæ are closer together and more evident.

3. *Chondrosarcoma.*—The chondrosarcoma is a sarcoma, usually of the spindle cell type, in which in places the fibrillar intercellular substance has become homogeneous and transformed into a hyaline material having the appearance and chemical properties of cartilage. The change is perfectly analogous to that which takes place under normal conditions in the repair of injuries to cartilage, where the new cartilage is produced by a proliferation of the perichondrium which forms young connective tissue; this is then transformed into cartilage. At the same time the spindle cells change their form and become more or less round or irregular. A chondrosarcoma is, therefore, a sarcoma of which a part of the cells have differentiated far enough to produce cartilage (Fig. 4147).

4. *Osteosarcoma.*—The osteosarcoma is a sarcoma, usually of the spindle-cell type, in which in places the cells have been transformed into bone corpuscles and the intercellular fibrillæ into a homogeneous substance in which lime salts have been deposited (Fig. 4147). This process is analogous to that which takes place in the repair of bone, the periosteum and endosteum produce young connective tissue which is transformed into bone.

If lime salts are not deposited in the osteoid tissue, the tumor is called an osteoid sarcoma. Osteosarcomata usually arise from the periosteum and endosteum.

5. *Giant-Cell Sarcoma.*—It is a question whether or not sarcomata containing giant cells should be put in a class by themselves. Giant cells occur in spindle-cell sarcomata which have no relation with bone (in one case they were present in a primary sarcoma of the left auricle of the heart), they occur in fibrosarcomata, in tumors which grow so slowly and are so benign that they must be regarded as fibromata, and most frequently of all in osteosarcomata. Many writers seek to restrict the term to those tumors which arise from bone, but this seems hardly justifiable. A tumor should be classed by what it contains and itself shows, not by the tissue from which it is supposed to have arisen.

Large cells containing several nuclei, or a large lobulated nucleus, occur in many rapidly growing tumors. These cells are usually, perhaps always, the result of irregular mitoses; that is, the mitotic figure is compound and the nucleus divides into several or even into many nuclei; the nuclei may remain more or less connected together and form a large lobulated nucleus. It is not customary to speak of these cells as giant cells. The term is reserved for cells which contain usually many more nuclei, often a hundred or more; and so far as known these giant cells are not the result of mitoses but of direct division and possibly also of fusion of cells. They have been regarded by many as foreign-body giant cells, but Ribbert looks upon them as attempts at the formation of osteoclasts; that is, they represent on the part of the tumor a certain form of differentiation of the cells. In favor of the foreign-body irritation view is the fact that the protoplasm of these cells usually contains clumps of minute elongated fissures which may have been filled in the fresh state by fat or other crystals. The nuclei do not have the bipolar or mural arrangement so characteristic of the giant cells in tuberculous lesions, but are generally grouped together, usually centrally, but sometimes toward one end of the cell. They never extend to the periphery of the protoplasm.

Giant cell sarcomata arise most commonly from the endosteum of the long bones and from the periosteum of

FIG. 4148.—Giant-Cell Sarcoma, showing Connective-Tissue Fibrillæ Between the Cells.

the jaw, but they may occur in other organs, as, for instance, the breast, where they are not so exceedingly rare. The naked-eye appearance of them is characteristic. The cut surface is almost always brownish red over a considerable extent, in consequence of previous hemorrhages, as a result of which the tumor cells often contain much pigment.

While the cells associated with the giant cells are usually spindle-shaped in type (Fig. 4148), they may be polymorphous or even round, although the latter form is rare. The formation of bone in these tumors is common, but may be absent even where the growth develops from endosteum.

The term *epulis*, applied by the clinician to all tumors growing on the jaw, is sometimes employed clinically as practically synonymous with giant-cell sarcoma, because most tumors of the jaw are of that nature.

6. *Malignant Leiomyoma.*—It has been a much disputed question among pathologists whether or not a sarcoma ever arises from smooth muscle tissue. A number of writers claim to have demonstrated the transformation of a myoma of the uterus into a sarcoma, but each later writer doubts the work of his predecessors, and it has been the tendency of pathologists in general to doubt the conclusions of all of them. It is probable that many of these tumors were of smooth-muscle origin, but perfectly satisfactory proof was not offered.

I have recently studied a tumor of the uterus which seems without much question to be a malignant leiomyoma. It was of the size of a cocoanut and was situated in the posterior wall of the uterus. From its inner side a nodule as large as an orange projected into the uterine cavity. The nodule on section was grayish, homogeneous, rather soft, and friable; it cut and looked like a sarcoma. The main tumor mass was in general of the same appearance, but there were scattered through it, especially at the periphery, areas of a tough fibrous character resembling a myoma. The diagnosis made at the time was "large mixed-cell sarcoma."

Smooth muscle fibres have two sets of fibrillæ: those in the periphery are known as the coarse or border fibrillæ; the others are situated between these and the nucleus, and are known as the fine or "binnen" fibrillæ. It is possible to stain the coarse fibrillæ differentially by means of the aniline blue connective-tissue stain and by other methods, so that they stand out in sharp contrast to other tissues. Benda has recently studied these fibrillæ by means of a modication of Weigert's neuroglia stain. He finds them comparable in many respects to neuroglia fibres and names them myoglia fibres. They are probably a supportive tissue for the smooth muscle fibres, for they pass without break from cell to cell.

The tumor in question would naturally be classed as a large spindle-cell sarcoma, although in some places where the cells are largest they are round in shape. Multinucleated cells also occur and mitotic figures are exceedingly numerous. Yet, in spite of its rapid growth, there is between and around all of the cells an abundant fibrillar intercellular substance which has the staining reactions of ordinary connective tissue. In addition, however, all of the spindle cells over large areas have another set of fibrillæ (Fig. 4149), which stain differentially like the coarse fibrillæ of smooth muscle fibres. These cells differ considerably from smooth muscle fibres; they are much larger and have abundant protoplasm; the nucleus is large and oval in shape; the fibrillæ are usually finer; but every gradation between them and typical smooth muscle cells can be found; in other words, some of the tumor cells tend to differentiate into perfect muscle cells. Where the cells are largest, and oval to round in shape, no differentiated fibrillæ can be demonstrated, although the ordinary intercellular fibrillæ are numerous. The tumor seems unquestionably to be a very cellular, rapidly growing, malignant leiomyoma, which probably developed in a myoma. Some parts of the tumor show invasion of smooth muscle tissue; the tumor cells either press between strands of muscle fibres, or infiltrate them and cause the muscle cells to degenerate.

So far as I know, there is only one source of error in the above diagnosis. Young connective-tissue cells of inflammatory and tumor origin produce, besides the ordinary intercellular fibrillæ with which we are acquainted, a second kind of fibrillæ which stain differentially in the same way as the border fibrillæ of smooth muscle fibres; but the two kinds of cells look very different, and the fibrillæ of connective-tissue origin are usually much finer. Moreover, as the connective-tissue cells differen-

FIG. 4149.—Malignant Leiomyoma, showing One Cell in Mitosis and many Differentially-Staining Coarse Fibrillæ Characteristic of Smooth Muscle Cells. The ordinary connective-tissue fibrillæ between the cells are not stained by the method employed and hence do not show.

tiate and produce an increased amount of intercellular substance, the red-staining fibrillæ diminish in number. In smooth muscle tissue under the same conditions they increase in number.

I have had the opportunity of studying but three other sarcomata of the uterus; two were typical spindle-cell sarcomata derived without doubt from connective tissue; of the third only a small piece projecting into the vagina was obtained. Histologically it closely resembled the most cellular portions of the malignant leiomyoma just described, but no differentially staining fibrillæ could be found in it.

The large amount of ordinary fibrillar intercellular substance in this tumor, in spite of its rapid growth, makes one wonder if it also, as well as the differentially-staining coarse fibrillæ, may not be the product of the cells. Probably the simpler explanation is that the tumor cells, like ordinary smooth muscle fibres, make a demand on adjoining connective tissue for an abundant supply of connective-tissue fibrillæ to surround and support each cell.

GROUP B. SARCOMATA POSSESSING A RETICULUM.—Lymphoid tissue throughout the body, in lymph nodes, spleen, and elsewhere, is composed, aside from blood-vessels, of three different kinds of elements—of a connective-tissue reticulum with the cells which produce it, of endothelial cells which line the reticulum in places, and of lymphocytes (*i.e.*, the different cells of the lymphocyte series) which fill the spaces in the reticulum.

When a tumor develops from these lymphocytes, new blood-vessels and reticulum are formed and there may be more or less proliferation of the endothelial cells, but these are all secondary or reactive processes. The essential part of the tumor is the cells derived from the lymphocytes. They alone give rise to metastases, and, wherever they lodge and proliferate, blood-vessels and reticulum are provided for them.

The lymphocytes of lymphoid tissue are in part undifferentiated lymphocytes such as fill the germinative centres of Flemming, in part the typical differentiated small lymphoid cells such as are met with in the circulation, and in part the more or less differentiated cells, including the plasma cell, between these two extremes of the lymphocyte series.

The undifferentiated lymphocyte corresponds with and is probably identical with the undifferentiated cell of the bone marrow. Dominici has shown that, in the rabbit at least, the undifferentiated lymphocyte in the spleen under the influence of various toxins can give rise to cells which are identical with the orthobasophilic myelocytes of the bone marrow, and from these cells ordinary polynuclear leucocytes may be produced.

It is evident, therefore, that the tumors arising in lymphoid tissue will not necessarily all show exactly the same type of cell. As a matter of fact, the cells vary considerably. Sometimes they resemble the typical lymphoid cell, sometimes the undifferentiated lymphocyte, sometimes they differ more or less from both.

The normal bone marrow contains undifferentiated cells identical with those in lymphoid tissue. From them develop not only lymphoid and plasma cells, but also the amphophile and other myelocytes. Tumors can evidently arise, therefore, in the bone marrow identical with those originating in lymphoid tissue; but as the cells of the bone marrow under normal conditions undergo much greater differentiation than the cells in ordinary lymphoid tissue, it is not surprising that tumors arise in the bone marrow which are peculiar to that tissue.

This group of tumors arising in lymphoid tissue and in the bone marrow agree in two points: the cells are more or less spherical and are embedded in the meshes of a connective-tissue reticulum. It is difficult to define and classify them exactly, because there is comparatively little that is known positively about them. They unquestionably should be classified according to the differentiation of the chief cell of which they are composed.

The clinical history of this class of cases is always of the greatest importance, and yet even with that, if only material obtained at a surgical operation is available, a final diagnosis may not be justifiable unless the subsequent history also is obtained and in case of death a careful post-mortem examination is made. Various causes can lead to great enlargement of lymph nodes. The difficulty is to know when the enlargement is due to true tumor formation and when to other causes, when the tumor is primary and when secondary.

The inflammatory lesions of the inguinal lymph nodes secondary to gonorrhœa are fairly characteristic and should lead to no trouble in diagnosis, especially with a history of infection. The same is true of many other acute enlargements. The chronic enlargements are more difficult. Some are due to tuberculosis, others to syphilis, and still others to causes not yet fully understood. Hodgkin's disease is a clinical picture which has not a definite pathology. The name is best limited probably to those chronic enlargements of the lymph nodes which at present have no known etiology. Such enlargements are characterized by thickening of the reticulum, the

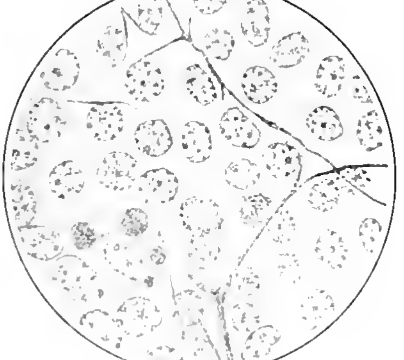

FIG. 4150. Malignant Lymphoma, showing the Characteristic Reticulum, One Cell in Mitosis, and One Large Phagocytic Cell.

presence of many eosinophiles and of numerous large cells with multiple nuclei or with a large lobulated nucleus. These large cells are probably derived from the endothelial cells which normally line the reticulum in places. The enlarged nodes remain discrete; the sinuses and lymph nodules usually do not disappear.

The most difficult question remaining to be settled in connection with these tumors is their relation to the leukæmias. If the latter, as seems not impossible, should prove to be true tumor formations with metastases growing in the circulating blood because the cells are highly enough differentiated to find the best conditions for their growth there, the relation would be a simple one, and they could readily be classified. If, on the other hand, the leukæmias are simply the expression on the part of the bone marrow of a reaction to toxins or other definite causes, they would have no relation at all to the class of tumors under discussion. The term pseudoleukæmia should probably be given up. The cases diagnosed as such should be included under malignant lymphomata or under the chronic inflammatory processes (Hodgkin's disease).

1. *Malignant Lymphoma.*—The term lymphosarcoma is often used for this class of tumors, but malignant lymphoma is probably better. It is applied to a rapidly growing tumor, of which the actively proliferating cells are of the type of the cells in the lymphocyte series and are embedded in the meshes of a delicate reticulum (Fig. 4150). The small round-cell sarcoma and probably some of the large round-cell sarcomata belong under this same heading. It may be possible later to subdivide this group according to the differentiation of the cells, which are not always of the same character. In the majority of the cases they resemble more or less closely the undifferentiated lymphocyte, but apparently cases occur, although I have seen none, in which the cells are of the type of the differentiated lymphoid cell.

The nuclei of these cells are in general round, although irregular and indented forms are common. They are vesicular in type and contain one to several coarse chromatin granules, but no differentiated nucleolus. Mitotic figures are as a rule numerous. The protoplasm is almost always small in amount, non-granular, but sometimes finely reticular. The cells vary more or less in size in different cases. As a rule they are about as large as the undifferentiated lymphocyte, but occasionally cases occur in which the cells are considerably larger, although otherwise agreeing with them in all respects.

Phagocytic cells are always present in these tumors, so far as my experience goes. They vary greatly in different cases both in size and in number. Often each phagocyte will contain half a dozen or more inclusions. They are unquestionably derived from the endothelial cells lining the reticulum.

Eosinophiles, although generally few in number or altogether absent, occasionally occur in great numbers. In one case at the Boston City Hospital, in a man fifty-five years old, the tumor started just over the symphysis pubis and reached the size of "two fists" in the ten months preceding operation. It extended into the scrotum, along the left vas deferens, and infiltrated the skin. It recurred within a few weeks in the skin covering the dorsum of the penis, in the corpora cavernosa, in the left inguinal lymph nodes, and in the left hypogastrium. The cells were of the type of the undifferentiated lymphocyte. Unquestionably the case was one of rapidly growing malignant lymphoma, and yet polynuclear eosinophiles were present in great numbers everywhere in the tumor, and in places formed one-fourth to one-half of the cells present.

The reticulum is fairly abundant and usually quite delicate, but may sometimes in places be dense and even hyaline.

A malignant lymphoma may arise anywhere where there is lymphoid tissue, but originates most commonly in lymph nodes and in the lymphoid tissue of the pharynx and intestine. Although when the tumor starts in lymph nodes several of them almost always appear to be affected together from the start, it is probable that the growth starts in one node and rapidly spreads to others.

Sometimes the invasion of a lymph node is distinctly visible to the naked eye on section. At other times it can readily be made out on microscopic examination. The normal tissue is rapidly invaded and destroyed, so that the sinuses and lymph nodules disappear. The tumor cells also early infiltrate the connective, fat, and other tissues outside of the lymph nodes, and sometimes extend into blood-vessels and occlude their lumina.

Metastases are frequent. In the great majority of cases they occur only in lymphatic tissue, especially in other lymph nodes, or in the lymph nodules of the intestine where large prominent nodules may arise. The tumor cells spread to the rest of the body by direct infiltration, by way of the lymphatics, and through the blood-vessels. It is by the last method chiefly that they get to the organs where they become fixed in the capillaries, and proliferate, compress, and destroy the cells between the capillaries. In the larger lymph nodes the metastases take place mostly in the peripheral parts near the capsule, where at first more or less circumscribed nodules are formed.

The gross appearance of a malignant lymphoma is more homogeneous and uniform than that of a lymph node, because there is no division into lymph nodules, sinuses, and trabeculæ. The cut surface is grayish-white and juicy, and the consistence usually soft, but hard malignant lymphomata occur in which the reticulum is coarse. This difference in consistence may occur in different cases or in the same case; if in the same case, the older nodules are the harder, the younger the softer.

2. *Chloroma.*—In its histological structure the chloroma corresponds in all respects to the type of the malignant lymphoma; it is composed of mononucleated lymphocytes embedded in the meshes of a reticulum. Its distinctive and characteristic feature is its color, which may vary from grass green to dirty green. The nature of the color is not known. Certain nodules in a given case may be green, while others are colorless. Von Recklinghausen thinks the color is due to the cells, while Huber and Chiari claim that the color is contained in very fine fat droplets. Against this latter view is the fact that the color is not extracted by alcohol (Dock), although it readily disappears on exposure to air.

In all but one case the bones of the skull were the primary focus affected, and the metastases were chiefly in bone tissue or in the periosteum. Only about twenty cases of the disease have been reported. In most of the cases double or unilateral exophthalmus was one of the earliest symptoms due to the development, behind the eyeball, of tumors which soon became palpable.

3. *Myeloma.*—The myeloma is also closely related to the malignant lymphoma. It consists of small round cells embedded in a delicate reticulum. The cells closely resemble plasma cells in certain respects. The protoplasm is basophilic, and the nuclei, of which there are often two or three in a cell, are more or less excentrically situated. The chief point of difference is that the cells have a very distinct nucleolus, which can be stained differently from the chromatin of the nucleus and which has a clear space around it. The chromatin granules are not so coarse as in a plasma cell.

The tumor affects chiefly the flat bones of the skull, the sternum, ribs, bodies of the vertebræ, less often the bones of the pelvis. It always starts from bone tissue, and metastases occur in other bones but not in other organs. The individual nodules are not sharply limited. The growth causes destruction of bone tissue, so that fractures, as, for example, of the ribs, take place easily. Albuminosuria is a fairly characteristic but not absolutely diagnostic symptom of the disease, as it has been found rarely in certain other conditions.

GROUP C. SARCOMATA HAVING AN ALVEOLAR STRUCTURE.—The structure of these tumors is more or less like that of a carcinoma; they consist of a connective-tissue stroma in the meshes of which the cells are embedded.

In this group belong the melanotic sarcomata of which the origin is now pretty definitely settled, and certain other tumors about which but little definite is known.

1. *Melanoma, Chromatophoroma, Melanosarcoma, Melanotic Sarcoma.*—The melanoma is a sarcoma which owes its distinctive name to its color: in the most characteristic cases this is a very dark brown, but it may be a clear brown, or only a light-brownish tint. The tumor is frequently irregularly pigmented, in some parts brown, in others light-colored, in still others colorless. Sometimes only small areas are colored, so that the pigmentation might easily be overlooked.

According to Ribbert, melanomata occur primarily only in the skin, in the mucous membranes arising from it, in displaced parts of the skin, and in the eye. They

FIG. 4151.—Melanoma of Skin, showing Alveolar Arrangement of Cells with Deep Pigmentation of a Few of Them.

arise from pigmented cells or chromatophores, certain differentiated cells of mesenchymal origin which produce pigment but probably no intercellular substance. These cells occur normally in the choroid and iris of the eye, and in certain situations in the pia and skin. They are also present more or less abundantly in the congenital soft warts or nævi of the skin. As it is from these nævi that melanomata of the skin almost invariably arise, some account of their structure is important. They consist of groups of medium-sized cells having more or less of an alveolar arrangement. The cells are round or irregular in shape and often have short processes. Within the cell groups the pigmentation is usually slight or even wanting, but at the periphery, especially adjoining the epidermis, the cells are usually larger, much more irregular in shape with branching processes, and deeply pigmented. These cells are typical chromatophores; the other cells are to be regarded as young forms produced in excess.

Two types of melanomata occur. In one the cells are more or less round or irregular in type, and are arranged in fairly distinct alveoli (Fig. 4151). This form is spoken of as the alveolar melanoma and is the common type in melanomata arising from the skin. The other form, the spindle-cell melanoma, is much rarer; it is composed of long spindle cells, and occurs most commonly in the eye. It bears a close resemblance, except for its pigmentation, to the ordinary spindle-cell sarcoma, but the vessels run between the bundles of cells instead of in the centre of them. Unless it be demonstrated that these spindle cells produce an intercellular substance, this form of melanoma is best regarded simply as a modification of the ordinary alveolar melanoma; *i.e.*, its groups or alveoli of spindle cells are large and rather indefinitely separated from each other by delicate blood-vessels accompanied by a very slight amount of connective tissue. Rapidly growing carcinomata sometimes show an equally indefinite alveolar arrangement. This view is favored by the fact that all gradations between the two types of growths are said to occur.

It is very important, in the study of the forms of the cells in melanomata, to examine teased fresh specimens, because they cannot be made out nearly so well in stained sections. The cells may be round, irregular, spindle-shaped, or have short or long, simple or branched processes. The latter forms are more evident in the melanomata of the eye.

The pigmentation is fairly uniform only in the dark-brown tumors. In the others it affects only a part of the cells or a few of them, or may be lacking in whole sections. The cells in the separating strands are usually deeply pigmented. The pigment occurs in the form of brown angular granules and is an essential product of the cells. It is termed melanin, contains no iron, and is probably derived from albumin because it contains sulphur. Melanomata may contain pigment which gives the iron reactions, but this is secondary to hemorrhage which is not infrequent in this class of tumors.

The melanoma is prone to recur after extirpation and to give rise to metastases. This is probably to be explained in part by its tendency to extend along the lymphatics. It usually affects first the neighboring lymph nodes, but soon spreads throughout the body by means of the blood. It develops in the form of nodules of all sizes in all organs, but usually most abundantly in the liver. The color of the metastases may be like the original growth, or darker or lighter. Black and white nodules may occur side by side.

As the melanoma is derived from the chromatophores, Ribbert suggests the term chromatophoroma for them. The only objection to the term is its length, which renders it somewhat undesirable. Melanoma is simpler and calls attention to the important characteristic of the tumor. The terms melanosarcoma and melanotic sarcoma are in good usage, but might be considered to apply also to tumors colored by iron containing pigments.

2. *Alveolar Sarcoma.*—Under this heading have unquestionably been grouped in the past a variety of tumors of which some at least do not belong here. Many have unquestionably been carcinomata, others endotheliomata. Ribbert has called attention to the fact that melanotic sarcomata are sometimes so slightly pigmented that their real nature might easily be overlooked. Under such conditions they might readily be put into this class. It has been suggested but not proved that alveolar sarcomata may arise from striated muscle cells. For the present this group of tumors must be regarded with suspicion. Many, perhaps all, belong under other titles.

GROUP D. ENDOTHELIOMATA.—The endotheliomata form a group of tumors which are very difficult to characterize so that they can be recognized with ease and certainty. In recent years it has been the custom to call almost every tumor which did not fit in readily with the well recognized tumors an endothelioma. This has been particularly true of certain tumors called cylindromata, which although of various origin (epithelial, mesothelial, and mesenchymal) have the one common characteristic of producing, in some by cell secretion, in others by hyaline transformation of vessel walls, round and cylindrical hyaline masses which are especially noticeable in fresh-teased preparations. At present there is a strong reaction against this tendency.

Endothelial cells normally line blood-vessels and lymph vessels. The cells lining the pericardial, pleural, and peritoneal cavities, and the sac of the tunica vaginalis are now generally recognized as mesothelial in origin and the tumors derived from them are classed with the carcinomata. The space between the dura and the pia is formed by a split in connective tissue, and is lined by connective-tissue cells which become flat and endothelial-like. The tumors arising from these cells are at present classed with the endotheliomata, but further researches may decide that they should be put in a class by themselves.

Endothelial cells possess few characteristics by which they can be recognized with surety; in other words, they do not possess a high degree of morphological differentiation. They are relatively large, thin, flat or curved cells with lightly staining oval nuclei, in which occur usually one or more somewhat coarse chromatin granules but no differentiated acidophilous nucleolus. They line vessels or spaces and are not supposed to secrete an intercellular substance. They are joined to each other at the edges by cement substance along an irregular line, which can be demonstrated in the fresh condition by staining with nitrate of silver. Under certain conditions endothelial cells may become very phagocytic for other cells.

None of these properties is sufficiently marked by itself to characterize with certainty tumors derived from endothelial cells, and yet it is on these more or less characteristic properties that the diagnosis of endothelioma must be based.

The diagnosis in the past has been made largely in two ways: by the process of exclusion and by the demonstration of actual connections between the tumor and blood- or lymph vessels. If a tumor resembled an epithelial growth but originated in a place where epithelium did not normally occur, it was diagnosed as an endothelioma. For example, the cholesteatoma was at one time regarded as a typical example of an endothelioma. The second line of argument used, that a tumor must be an endothelioma because actual connection between vessels or cell masses of the tumor and the blood or lymph vessels of the surrounding tissue can be demonstrated, has been shown by Ribbert to be absolutely untenable. Tumors grow by proliferation of their own cells, not by causing the cells in the tissues around them to multiply and join the tumor mass. Tumors may and often do form connections with surrounding blood- and lymph vessels and with epithelium, but that does not prove that they arose from them. The demonstration of the origin of a tumor from a given cell or tissue is possible only when it is just starting, at a stage when it is rarely or never possible to see it. As a result we are compelled to base our diagnosis on the properties or differentiation of the cells of which the tumor is composed.

Three types of endotheliomata are recognized: one arises from the endothelium of blood-vessels, a second from that of lymph vessels, and the third from the cells lining the dura. The attempt has recently been made to add a fourth, the perithelioma, as a variety of the endothelioma arising from lymph vessels.

1. *Hemangioendothelioma.*—This tumor is derived from the endothelium of blood-vessels and is rare. It grows in the form of narrow or broad anastomosing vessels of a capillary type, which may become filled up with endothelial cells so that solid anastomosing columns of cells are formed. Connective-tissue fibrillæ gradually grow in between the cells, so that the older parts of the tumor resemble more or less closely a spindle-cell sarcoma.

I have recently studied one of these tumors in which all stages of its development could be followed. The primary growth occurred on the back of a boy, sixteen years old, and was followed by three recurrences in the course of the following twenty-one months. Each time the tumor appeared in the form of a group of discrete nodules, from the size of a millet seed to masses 3 or 4 cm. in diameter. The original growth seemed to be attached to the head of a rib, which was resected, but it was not adherent to the skin, and in the recurrences the nodules could always be easily dissected out. The nodules varied from a soft, elastic, almost diffluent to a cartilaginous consistence. On section they varied from reddish to gray; the cut surface was smooth and homogeneous, like a sarcoma.

The earliest appearance of the lesions and the evident source of the recurrences were to be found in the fat and connective tissue outside of the nodules. Here occurred irregular, often long convoluted masses of capillary vessels containing red blood corpuscles and leucocytes, and lined with prominent endothelium. The capillaries ran in the connective tissue often along large blood-vessels and in places invaded fat tissue, gradually causing it to disappear and giving rise to miliary tumor nodules. In all of these small areas and nodules the capillaries were pervious, contained blood, and mitotic figures in endothelial cells were numerous.

In the large, more distinct tumor nodules the appearances were not so simple. Capillaries and larger blood-vessels were very numerous, but there were in addition solid anastomosing columns of cells and a cellular tissue resembling to some extent young connective tissue or a spindle-cell sarcoma. Both of these were found to arise from the capillary vessels in the following way: Mitoses were very numerous in the larger nodules, not only in the capillary endothelium, but also in the cell columns and in the sarcoma-like tissue. Proliferation of the capillary endothelium often led to occlusion of the lumen and the formation of a mass of cells which often assumed a more or less concentric arrangement. Proliferation of cells beyond the point of occlusion produced anastomosing columns of cells. Hemorrhages and other causes which interfered with the circulation in the young vessels probably also led to the same result.

The second stage in the development of these tumors was, therefore, due to the occlusion of a certain number of capillaries. Continued proliferation of the endothelial cells led necessarily to the formation of clumps and anastomosing columns of cells. At this stage the tumor to some extent resembled a carcinoma, but both the cell masses and the stroma showed differences.

The third stage was due to a still further change. The aniline blue connective-tissue stain showed that the very youngest of the newly formed tumor capillaries quickly become backed by connective-tissue fibrillæ. As the vessels get older the fibrillæ increase in number. In the same way the fibrillæ surround and invade the cell masses formed after the capillaries become occluded. They gradually separate the cell masses so that each individual cell is separated from its neighbor by fibrillæ. But even here small concentrically arranged clumps of cells are often found where rapid proliferation has taken place and separation of the cells has not yet been effected.

Whether or not these endothelial cells produce the fibrillæ, I am not prepared to say. The process probably is analogous to that seen in acute desquamative glomerulo-nephritis where connective-tissue fibrillæ soon extend in between all the desquamated epithelial cells, probably in consequence of a physiological demand for them.

2. *Lymphangioendothelioma.*—This form of endothelioma is derived from the endothelial cells lining lymph vessels and lymph spaces. It usually grows in the form of tube-like or slit-like anastomosing canals, but may form solid anastomosing rows and frequently also concentric masses of cells.

In a case which I have had, the tumor was situated in the lumbar region behind the kidney. It measured over 7 cm. in diameter and was made up entirely of freely anastomosing round, irregular, and slit-like cavities of various size, lined with low, endothelial-like cells (Fig. 4152). In a few areas the lumina of the vessels and the cells to some extent approached a cuboidal form. An occasional endothelial cell in mitosis was found. All of the vessels were backed by a small amount of connective tissue which in places was very œdematous and contained numerous plasma cells.

The term *perithelioma* is applied to a tumor which grows in such a way as to form a sheath around blood-vessels. It is supposed to originate from the endothelial cells (the so-called perithelium) lining the perivascular lymph space. The most typical example is found surrounding the vessels of the brain. If this supposition is true, then a perithelioma is a special form of lymphangio-endothelioma.

Sarcomata frequently grow around blood-vessels in such a way as to form a sheath to them, but this manner of growth is rarely or never entirely perithelial. Parts of the tumor or even the greater portion of it may show the picture of an ordinary melanotic, alveolar, or even spindle-cell sarcoma.

The perithelial form of growth is probably largely accidental, and dependent more or less on nutrition. The cells nearest the vessels are best nourished; those farthest away, least so. If necrosis takes place the cells around the vessels are often preserved. The necrotic portions are in time more or less completely absorbed, with the result that the cell sheathed vessels are but lightly bound together, and in the fresh condition can often be pulled out like the tubules of a normal testicle. It is often possible in a single tumor to trace the entire development of a perithelial growth from a sarcoma of an ordinary type.

It is probable that hemorrhage may act like necrosis in giving rise to the perithelial type of growth.

3. *Endothelioma of the Dura.*—This is the best known of the endotheliomata. It occurs usually as a circumscribed, flat, or more or less hemispherical, occasionally pedunculated tumor. The size varies greatly, but is rarely greater than that of a walnut. The tumor is very lightly attached to the dura by blood-vessels and a slight amount of connective tissue.

The structure of the tumor varies greatly; it may be cellular like a sarcoma or more or less fibrous like a cellular fibroma. The cells may have an alveolar arrangement with the cells often grouped in whorls or the cells may be more or less uniformly distributed in the stroma.

Two cases at the Boston City Hospital illustrate well the two extremes of type. The first measured 5 x 4.5 x 4 cm., and was situated in the right cerebral hemisphere 3 mm. from the longitudinal fissure and 3 mm. posterior

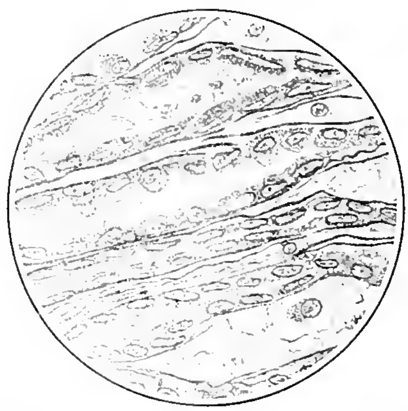

FIG. 4152.—Lymphangioendothelioma, showing Spaces Lined with Flattened Cells and Œdema of the Connective-Tissue Stroma.

to the fissure of Rolando. It was sharply circumscribed, everywhere separated from brain tissue by pia, and presented a cauliflower-like surface. Microscopically it showed dense masses of cells arranged for the most part in whorls, between which ran a stroma consisting of blood-vessels surrounded by a small amount of connective tissue, which showed little tendency to extend out between the cells. The nuclei were oval, vesicular, finely granular, with one or more coarse chromatin granules but no differentiated nucleolus. Numerous mitotic figures showed that the tumor was growing rapidly. In places were many hyaline concentrically-layered bodies often containing the faint remains of nuclei.

The second case occurred in the right occipital lobe and measured 8.5 x 6 x 6 cm. It was slightly lobulated and was separated from the brain tissue by the pia. On section it was almost homogeneous in appearance; the surface was grayish, only moderately translucent, and slightly granular. The tissue could be very easily teased apart.

Microscopically the tumor might readily on casual inspection be mistaken for an odd form of spindle-cell sarcoma. Apparently it consisted of numerous spindle and oval nuclei embedded in a fairly abundant connective-tissue stroma. Careful study, especially of sections stained by the aniline blue method, showed that the connective-tissue fibrillæ and the cells were disposed in layers. The layers of fibrillæ ran in parallel planes, which bent and twisted in various directions and often surrounded the blood-vessels. Both surfaces of each layer of fibrillæ were lined by large flat cells, which sometimes piled up two or three cells in thickness. The nuclei were oval and flat, stained lightly, and contained one, sometimes two or more, coarse chromatin granules. No mi-

... ...ats could be found. A few concentrically lay ...ed bodies were present.

Apparently just as the endothelial cells lining blood- and lymph-vessels attempt in tumor formation to form vessels, and, failing in this, give rise to solid columns of cells, so the endothelium lining the dura tends, sometimes at least, in the new growths to which it gives rise to form spaces lined with endothelium. The connective-tissue fibrillæ may be produced, as Ribbert claims, by the endothelial cells, but I prefer to regard them as produced by true connective-tissue cells which grow in with the blood vessels and extend in between the endothelial cells because there is a physiological demand for them.

F. B. Mallory.

SARSAPARILLA, U. S.—The root of *Smilax medica* Chamisso et Schlechtendal (Mexican, Vera Cruz, or Tampico sarsaparilla), *Smilax ornata* Hooker f. (Jamaica, Central American, Costa Rica, or Lima sarsaparilla), *Smilax papyracea* Duhamel (Brazilian, Para, or Rio Negro sarsaparilla), or a species known commercially as *Honduras* sarsaparilla (fam. *Liliaceæ*). Fruiting specimens just received by the writer from Honduras indicate that the last mentioned is from *S. grandifolia* Regel. Various other species than those here named have been recorded as yielding sarsaparilla, but it is doubtful if any appreciable amount of the present article of commerce so originates. The genus *Smilax* L. is large, being credited with some two hundred species. Its habits and characters are well illustrated by our ordinary cat briars, greenbriars, or bread-and-butter vines, the green, tough, spiny, tendril-bearing stems of which constitute the principal element in dense thickets of the Eastern United States. Apparently, the Northern species do not possess the medicinal properties of those of the tropics. The aerial stems of the latter grow from excessively long slender rhizomes, which run just underneath the loose forest mould, and send down from each joint a fascicle of from few to many tough, elongated roots, which, dried, constitute the drug sarsaparilla. They are collected at

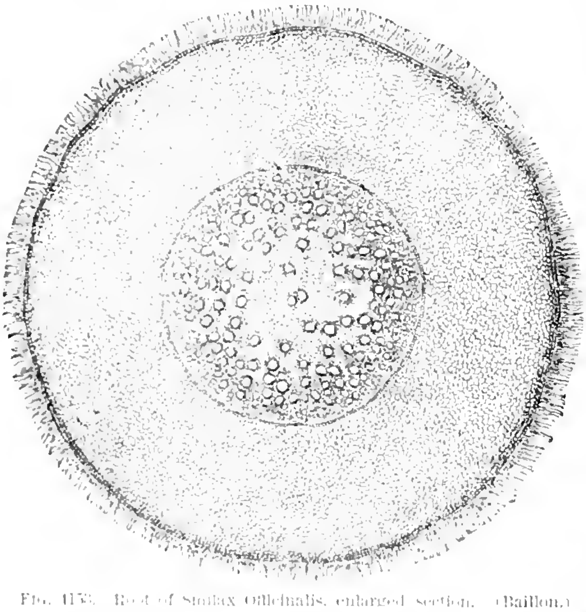

FIG. 4153.—Root of Smilax Officinalis, enlarged section. (Baillon.)

about the close of the rainy season, probably chiefly with the idea of saving labor, since the ground is then soft and the roots are more easily torn out. After being collected and dried, they are packed in various ways, as explained below, these different forms of packing being characteristic and aiding in identification, although the practice of packing a cheaper article to imitate a more expensive one is not unknown. Other forms of sophistication are not common, though other roots, sticks, and even stones are occasionally found in the interior of the packages.

DESCRIPTION.—Mostly more than a metre (more than a yard) in length, and 4–6 mm. ($\frac{1}{6}$–$\frac{1}{4}$ in.) thick, with few or many fine roots adhering; externally varying from light-gray-brown and smooth, with few deep and sharp wrinkles, to dark- or orange-brown and less smooth, and with more and smaller wrinkles; internally whitish, with a thick, mealy, or sometimes horny cortex, a circular wood-zone and a thick pith; fracture tough; nearly inodorous; taste mucilaginous, somewhat sweetish and bitter, slightly acrid.

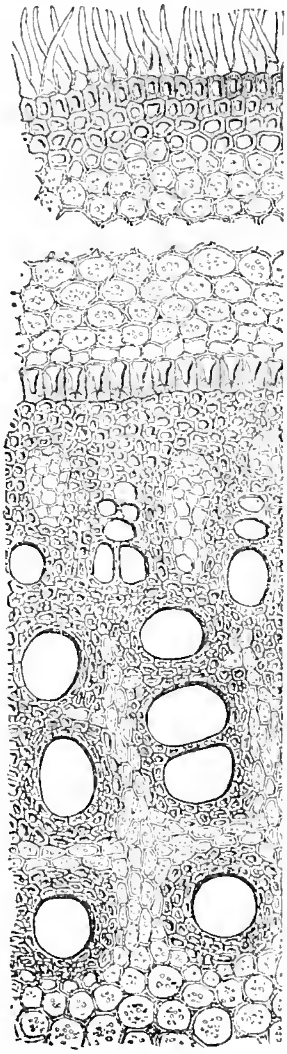

FIG. 4154.—Magnified Section of One-Half Diameter of Root of Smilax Officinalis. (Baillon.)

The thick, woody, knotty rhizome, if present, should be rejected.

As a rule, Honduras and Brazilian sarsaparillas have the cells of the parenchyma more densely crowded with starch grains, so that they are termed "mealy sarsaparillas," the other two being denominated "non-mealy." It is probably due to this excess of starchy contents that the mealy sarsaparilla wrinkle less deeply in their drying, their wrinkles, however, being usually much more numerous than those of the non-mealy varieties.

Honduras Sarsaparilla consists of the roots separated from the rhizomes, folded back and forth to a length of about two feet, and very closely and tightly wound from end to end with one or more of its own roots, the folded ends not cut off, but projecting slightly beyond the winding at either end. These rolls have usually a diameter of about two and a half or three inches. This variety is generally of a rather light brown color. It varies greatly in its tendency to bear rootlets, though as a rule these are not numerous. A transverse section made near to the rhizome shows the diameter almost equally divided between the cortex, wood, and pith. The cells of the endodermis are rather thin-walled, the thickness of the outer and inner walls nearly equal, and the form of the cells nearly square.

Brazilian Sarsaparilla also consists of roots freed from the rhizomes, but it is differently packed. The rolls are very large, a yard or more in length and a foot in diameter. They are rolled with extreme tightness, and closely wrapped with a thin tough vine. The folded ends are cut squarely off and the trimmings enclosed in the centre of the roll next packed, the rolls thus possessing a swollen middle portion. This root is of a very dark-brown color and bears a large number of branching rootlets. It is finely wrinkled. The transverse section shows the woody zone much narrower than the cortical and the pith large. The cells of the endoderm are radially elongated, with an oblong aperture, and the inner portion of the wall is thicker.

Mexican Sarsaparilla has the roots of each node still attached to a short portion of the hard woody rhizome. They are loosely folded into somewhat flattened bundles, much thicker at one end and loosely tied with a root which passes several times around in an irregularly spiral manner. The root is of a pale drab-brown, often a little shining, almost free from rootlets and bearing but a few wrinkles, which are exceedingly deep and sharp. The transverse section shows very small pith and wood zones, with a very broad cortical layer. The endodermal cells quite closely resemble those of the Brazilian.

Jamaica Sarsaparilla presents two distinct forms. The plant named above is native of Central America, whence the most of our supplies are received. This root is of a dark gray-brown color, rather thin, sharply wrinkled, and very abundantly supplied with branching rootlets. It is always separated from the rhizome and may come either pressed into square bales or tied into rolls with folded ends, like those of the Honduras, but usually thicker, looser, and with a much scantier and looser winding. The other form is known as "native Jamaica" (species of Smilax undetermined), and is the product of plants which have been introduced into the island named. This root is usually much thicker and cleaner looking, and is almost invariably of a bright orange-yellow or orange-red color. It is packed either in bales or in short, thick, lightly tied bundles. The endodermal cells are radially elongated and their walls heavily thickened.

The widest differences of opinion exist as to the relative values of the different varieties of sarsaparilla, and the predominant opinion is not constant, one variety maintaining its position as a favorite for a time, and being then displaced by another. On the whole, Honduras sarsaparilla probably enjoys a wider preference than any other, though the native Jamaican is mostly preferred in Great Britain.

Constituents.—Most earnest attempts have been made to find a tangible and useful active principle in sarsaparilla, but with only partial success. From three to fifteen per cent. of starch, according to the variety, a trace of volatile oil, a small amount of resin, pectin, etc., are unimportant. The activity appears to reside in a mixture of three saponin-like bodies, amounting in the specimens examined by Otten to nearly three per cent. Some confusion of ideas has arisen regarding the relations of these substances to one another, on account of the variety of names assigned them by different investigators. Both *parillin* ($C_{26}H_{44}O_{10}$) and *smilasaponin* ($C_{20}H_{32}O_{10}$) have been called "smilacin," and on account of this indefiniteness the last name has been dropped from scientific literature. The third body, *sarsasaponin* ($C_{22}H_{36}O_{10}$), is about three or four times as active as either of the preceding. Like parillin, it is crystallizable, while smilasaponin is not. These constituents are all more or less soluble in water or alcohol, more so upon the application of heat. Either the decoction or a preparation with a warm mixture of alcohol and water well represents the drug. The constituents are fatal to animals, with the general symptoms of poisoning by the sapotoxins.

Action and Use.—Sarsaparilla was first carried to Europe about 1536–45, and first or early employed as a cure for the same disease with which it has been since most generally associated, and for which another smilax, "China" had previously been used. The use in numerous other slow diseases, especially in eruptions and as a "blood purifier" in general, followed, and has continued extensive until the present time. Although now it has been nearly discarded as a serious medicine by physicians, it is still a much-prized popular remedy, and is extensively used, the world over, for syphilitic and scrofulous diseases. Its reputation is doubtless greatly and unduly enhanced by the enormous popular advertising of numerous proprietary articles bearing its name, but in reality quite different substances. On the other hand, there can be no doubt that the judicious use of sarsaparilla by physicians should be extended. The valuable depurative effects of the saponins, not only by promoting excretion by the intestines, but through most other channels, requires no argument, and the timely use of a laxative dose of sarsaparilla, perhaps at the soda fountain—if only a genuine article could be there expected,—may well prevent the necessity for more violent treatment later on. The dose of any preparation should represent from 4 to 8 gm. (ʒ i. to ij.). The Pharmacopœia provides a fluid extract; a compound decoction of ten-per-cent. strength, with two per cent. each of sassafras, guaiac wood, and liquorice root, and one per cent. of mezereum; a compound fluid extract of seventy-five-per-cent. strength, with twelve per cent. of liquorice root, ten per cent. each of sassafras and glycerin, and three per cent. of mezereum.

Allied Product.—China root, from *Smilax China* L., in large, hard, jalap-like tubers, is used in the East for the same purposes as sarsaparilla.

Henry H. Rusby.

SARSAPARILLA, FALSE. (*Aralia nudicaulis* L.) See *Araliaceæ*.

SASSAFRAS, U. S. P.—*Sassafras bark.* The dried bark of the root of *Sassafras Sassafras* (L.) Karsten. (*S. variifolius* [Salisb.] Kuntze—fam *Lauraceæ*). Although all parts of the sassafras tree are aromatic, the bark of the root is selected for official purposes because its aromatic properties differ in kind from those of the leaves and branches, and are far stronger than the similar properties of the bark of the trunk and the wood of the root and trunk. The British Pharmacopœia makes the root,

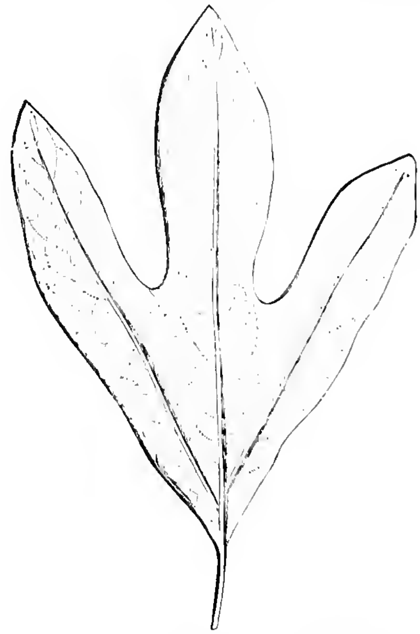

Fig. 4155.—One of the Three-Lobed Leaves of Sassafras. (Baillon.)

the German Pharmacopœia the wood of the root, official, while certain others include, or even specify, the wood of the trunk or at least of its lower portion. There can be no question that the official article of the United States Pharmacopœia is very superior to any other part of the plant. The sassafras tree grows very abundantly in light soil and exposed or partly exposed situations from eastern Canada southward, being collected chiefly in the coast region. It occasionally reaches a height of seventy feet or more and a trunk diameter of upward of three feet, though usually its height is from twenty-five to forty feet and its trunk diameter little more than a foot. The root is much and irregularly branched. When it is freshly dug, its outer color is whitish and its wood yellowish or brownish-white, but the former soon turns gray and the latter of a rusty red or brown after collection. Annual rings are apparent in cross-section, though less conspicuous than in most trees of the same region. The bark of the trunk is ashy gray and deeply fissured externally, whitish within, soon turning rusty brown, though not so deeply as does that of the root. The wood of the trunk is similar to that of the root, though less deeply colored. The young twigs are at first deep green and smooth, gradually becoming brownish warty, then brown and fissured with age. The large pith of the branches is described below. The form of the leaf is displayed in the accompanying cut, though often not lobed or with a lobe on only one side. The leaves are thin and downy when very young, soon becoming thickish and smooth. The diœcious, small, yellowish flowers are borne in umbels or corymbs, and appear somewhat before the leaves. All parts of the tree are aromatic, bitter, and strongly mucilaginous.

The drug is thus described:

In irregular, warped, chip-like fragments, 5 mm. (⅕ in.) or less in thickness, the thicker pieces deprived of most of the gray corky layer; light rust-brown, or with more or less of the gray-brown cork adhering and exhibiting its outer surface softly and rather finely scaly, from numerous short, intersecting, shallow fissures; inner surface obscurely short-striate; light, soft, and fragile, with a short, weak fracture which exhibits a broad, irregular, whitish layer between two rust-brown ones; strongly and peculiarly fragrant; taste sweetish and bitterish, aromatic, mucilaginous, and slightly astringent.

The stem-bark is in strips or elongated pieces, with a lighter-gray, more deeply and longer fissured outer surface, and is less aromatic, more mucilaginous and bitter.

The most important constituent of sassafras is its volatile oil, of which there is sometimes nearly ten per cent. When fresh, the bark contains a large amount of a peculiar tannin, which, after collecting, gradually becomes converted into the peculiar granular yellowish brown substance, *sassafrid*, which is readily dissolved in alcohol. A large amount of starch, much gum, and an unstudied bitter principle also exist. The properties of sassafras are almost wholly referable to its volatile oil. No preparation of it is official, but it is largely used in the household, and to some extent by physicians, as a stimulating diaphoretic and as a deobstruent or alterative ("blood purifier"), stimulating the excretions of the kidney and skin. For these purposes, the infusion is commonly employed. It should have a strength of five per cent., and may be taken in wineglassful doses.

Oil of Sassafras (*Oleum Sassafras*, U. S. P.) is defined as a volatile oil distilled from sassafras, and it is directed to be kept in well stoppered bottles, protected from light. Although thus defined as obtained from official sassafras, it is really obtained from the entire root, the wood of which yields from one and one-half to two per cent. It is thus described by the Pharmacopœia:

A yellowish or reddish yellow liquid, having the characteristic odor of sassafras without the odor of camphor, and a warm, aromatic taste. It becomes darker and thicker by age and exposure to the air.

Specific gravity: 1.070 to 1.090 at 15° C. (59° F.).

Soluble, in all proportions, in alcohol, the solution being neutral to litmus paper; also soluble, in all proportions, in glacial acetic acid, and in carbon disulphide.

If to five drops of the oil five drops of nitric acid be added, a violent reaction will take place, producing at first a red color, and finally converting the oil into a red resin.

If to a few drops of the oil a drop of sulphuric acid be added, a deep red color will be produced at first, which soon becomes blackish.

The oil consists chiefly of *safrol* ($C_{10}H_{10}O_2$), with a small percentage of *safrene* ($C_{10}H_{16}$) and a very small amount of eugenol. Safrol fully represents the properties of the oil.

Oil of sassafras differs but little in its action and uses from ordinary stimulating volatile oils, for example, oil of peppermint. Although an active carminative, it is scarcely so efficient as oil of peppermint or oil of anise in that direction. On the other hand, it appears to be rather more freely excreted through the skin and a more efficient diaphoretic. It is also distinctly laxative and its reputation for stimulating the excretory functions appears to be justified. The dose of this oil is one to five minims. There is no official preparation.

Sassafras pith (*Sassafras medulla*, U. S. P.) is defined as the dried pith of the sassafras and is thus described:

In cylindrical, straight, curved, or coiled pieces, one to several inches in length and 3 to 8 mm. (⅛ to ⅓ in.) in diameter, or in split portions of the same; white, very light, and spongy; inodorous or with a slight odor, as well as taste, of sassafras; very mucilaginous.

Macerated in water, it forms a mucilaginous liquid, which is not precipitated on the addition of alcohol.

Its aromatic content is entirely insignificant and it is valued wholly for its gum, which readily forms a mucilage upon maceration with water. This mucilage possesses the important property of mixing with alcohol without precipitation, and it becomes a useful vehicle for the administration or application, especially to the eye, of active substances. Its properties in general are merely those of mucilages. Its mucilage is official and is directed to be made freshly, when wanted, by macerating 2 gm. of the pith in 100 c.c. of water for three hours and straining.

Several other vegetable products are called sassafras in other countries, but none of them is of interest in our Materia Medica. *Henry H. Rusby.*

SASSY BARK.—*Mancona Bark.* The bark of *Erythrophlœum Guineense* Don. (Fam. *Leguminosæ*), a good-sized, acacia-like tree, growing in tropical Africa, and employed by the tribes of the west side like Calabar beans, as an ordeal. It was made known in Europe and America about forty years ago, and was revived as a medicine about ten years since. It is a ponderous bark, heavier than water, of a dull red color, a fissured external surface, and a short fracture. Odor slight, taste astringent. The active principle of sassy bark is *erythrophlœine*, a crystalline alkaloid, first obtained by Gallois and Hardy. It is an active heart-poison of the digitalis kind, producing slowing of the pulse, increase of blood pressure, and in experiments upon animals death, with the heart in systolic contraction. The powdered drug is a powerful sternutatory. But little use has been found for this potent medicine. It is sometimes used like digitalis, in doses of one to three grains, of the bark, in the form of a tincture, but is far less certain and regular and even more inclined to upset the stomach. It is said to be employed at home in dysentery, etc., with benefit, as well as in intermittent and other fevers. In full doses it is nauseating and emetic, as well as somewhat narcotic.

ALLIED PLANTS, ETC.—See *Senna*. *W. P. Bolles.*

SAUNDERS, RED.—*Santalum Rubrum*, U. S. The heart-wood of *Pterocarpus santalinus* L. f. (fam. *Leguminosæ*).

This article, often called ruby wood or red santal, is the product of a small tree of India, collected chiefly in the Madras Presidency, and now mostly from cultivated plants. The wood is imported in billets three or four feet long and from two to eight or nine inches in diameter, the bark and sapwood having been removed. It is of a bright blood-red color within, but darker upon the surface, becoming at length nearly black with age and exposure. For pharmaceutical use, it is usually cut into chips or rasped into powder. It is almost odorless and has only a slight astringent taste. Its coloring matter is santalin or santalic acid, crystallizing in minute red prisms, soluble in alcohol, ether, alkalies, and a few essential oils, but not in water, which is scarcely colored by red saunders. The article is essentially a dye-stuff, being without physiological or medicinal power and used purely for coloring purposes, as in the compound tincture of lavender, which contains about one per cent. of it.

W. P. Bolles.

SAVILL'S DISEASE. See *Dermatitis Epidemica.*

SAVINE.—*Sabina,* U. S. P. The leaves and young twigs of *Juniperus Sabina* L. (fam. *Pinaceæ* or *Coniferæ*). This is a compact, horizontally spreading, evergreen shrub or small tree, resembling our common red cedar on a small scale, and bearing similar berries. It is widely distributed through the north temperate zone of the Old World, and is also met with in the Northern United States (in the Great Lake region) and in Canada. The medical supply comes from Europe, chiefly from Switzerland, in "short, thin, subquadrangular branchlets, the leaves in four rows, opposite, scale-like, ovate, lanceolate, sessile, more or less acute, appressed, imbricated, bearing on the back a shallow groove containing an oblong or roundish gland; odor peculiar, terebinthinate; taste nauseous and bitter."

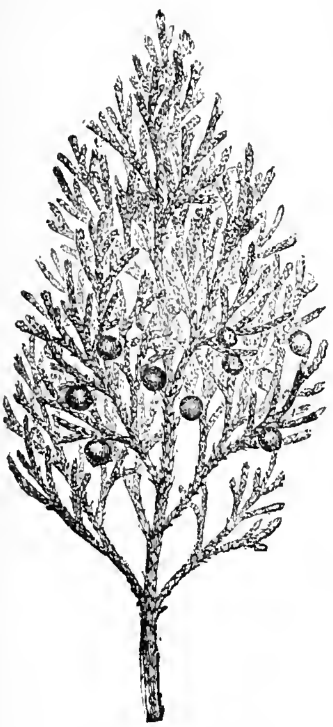

FIG. 4156.—Savine, Fertile Branch. (Baillon.)

The odor and taste of savine are mostly due to from two to four per cent. of essential oil (*Oleum Sabinæ,* U. S. P.), a pale-yellow, terebinthinous liquid, becoming thicker and darker by age, colorless if redistilled, of a specific gravity of about 0.910. It has the odor of savine, a sharp, bitter, camphoraceous taste, and is more rubefacient and irritating to the skin than others of its class. Tannin and resin are less important constituents of savine.

ACTION AND USE.—Savine and its oil are essentially like, but more intense than, oil of turpentine in physiological and therapeutical properties; irritating to the skin and mucous membranes, to the urinary apparatus by which they are eliminated, and to the uterus, which they may cause to abort. Besides these effects, convulsions and coma may follow. Vomiting, diarrhœa, gastro-intestinal inflammation, strangury, with or without convulsions or unconsciousness, these are the usual symptoms of savine poisoning; abortion may or may not take place. This potent drug is not much employed. It has been given as an emmenagogue, also as a hæmostatic, for leucorrhœa and other purposes mostly connected with the uterus. It is not infrequently used with criminal intent to produce abortion, usually without success, unless it nearly or quite kills the mother also; externally it is the basis of some moderately useful stimulating ointments, liniments, and "hair-restorers."

In this country, the oil of juniper, which is milder, is perhaps generally substituted for oil of savine. Oil of turpentine is also often substituted for or mixed with it. Oil of savine can be distinguished by the fact that it does not form a solid mass with hydrochloric acid; also by the fact that very little of it distills under 200° C.

The dose of savine (leaves) is about 0.5 gm. (gr. viij.); of the oil, from one to four or five drops. A fluid extract of the former (*Ex. Sabinæ Fluidum,* U. S. P.) is an eligible preparation and the basis of the cerate (*Ceratum Sabinæ,* U. S. P.), strength about 25 to 100 savine.

W. P. Bolles.

SAVORY, SUMMER. See *Labiatæ.*

SAW PALMETTO.—This palm, *Serenoa serrulata* forms the common palmetto scrub of South Carolina, Georgia, and Florida. The whole plant has marked demulcent and nutritive properties, and is extensively used as a local remedial agent in all forms of disease of the mucous membranes, especially when associated with debility and wasting. Its use is followed by an improved digestion, increased strength and flesh, and a soothing influence on any irritable state of the membranes. It is used in catarrh, ozæna, and bronchitis, and has a special value in diseases of the bladder and reproductive organs. Reginald Harrison[1] has found it very beneficial in irritable states of the bladder, and compares its action to pareira. It is also reported to be of benefit in affections of the prostate gland. Another property that is claimed for it is its vitalizing and strengthening action upon weakened and wasted glands of the generative organs. It is said to cause a rapid development of the mammæ, ovaries, and testes, when these organs are debilitated as the result of masturbation and sexual excesses of all kinds.

The berries and seeds contain a large percentage of a fixed oil, upon which the medicinal properties are said to depend.[2] The fluid extract of the seeds is the most convenient form for administering the drug; it is given in half-drachm to one-drachm doses, repeated three or four times a day.

Beaumont Small.

[1] London Lancet, 1890, 414.
[2] Phar. Review, 1897, 113.

SCABIES (Latin, *scabies,* an itching eruption, from *scabo,* I scratch).—Synonyms: The Itch; German, *Krätze*; French, *Gale.* Scabies is a contagious disease of the skin, wholly local in character, due to the presence of an animal parasite—the *acarus* or *sarcoptes scabiei* (see Arachnida, in Vol. I.) in, and upon, the skin. The eruption present may vary from the smallest amount imaginable, a few papules, up to the most severe development of inflammatory lesions, even such as to render the patient helpless; the subjective sensations may vary from a slight pruritus, which is described as not unpleasant when relieved by scratching, up to an itching which is almost unendurable, causing restless nights and distressing days.

The most common sites for the lesions of scabies are the hands, especially about the wrists, in the soft skin between the fingers, and on the sides of the hands. But in many cases the eruption is entirely absent from this locality and is well marked elsewhere. In males the penis seldom escapes, and in females the region of the nipples is very apt to be affected; the anterior fold of the axilla is a very common seat of the lesions, and the elbows and extensor surface of the forearms are sometimes most severely affected. In those who sit a great deal the buttocks often present an abundant eruption. In infants and children the softer parts of the feet and ankles generally exhibit lesions. It may be said that the head is never affected by scabies.

The eruption of scabies exhibits the greatest variety of lesions, from the smallest papules and vesicles to large pustules, often ecthymatous in character, and in weakly children pustular bullæ may form on the hands. The bulk of the lesions is papular, although small vesicles can generally be seen on tender portions of the skin during some period of the disease. Mingled with these primary lesions there are generally found the results of scratching, viz., abraded surfaces and those covered with crusts.

The only single pathognomonic sign of scabies is the *cuniculus*, furrow, or burrow (German, *Milbengang*; French, *sillon*), which is caused by the penetration of the female beneath the epidermal layer of the skin in the search of a place where she may lay her eggs; the male seldom, if ever, goes beneath the skin. This cuniculus consists of a minute, dark-colored line, generally somewhat beaded in appearance and curved, appearing much as if a bit of dark sewing-silk had been run beneath the surface; rarely, it is as long as a fourth of an inch, more often half that length; and generally it may be seen to terminate at one end in an inflamed papule or vesicle, or sometimes to run over a pustule. The female insect will be found at that end of the furrow, and the dark line is her track, which is found to be filled with eggs in various stages of development, and, among them, black particles of fæces. If the skin is washed these dark lines, instead of being removed, become more apparent; but in recent cases, or in individuals who are very cleanly or have undergone treatment, it is often impossible to discover any of these cuniculi, although the disease may still exist, and, if left alone, it will increase and may be communicated to others.

Scabies is not a very frequent disease in this country, forming only about 1.5 per cent. of a large number of skin cases analyzed. In other countries it is more common, and in Glasgow it formed twenty-five per cent. of ten thousand cases analyzed by McCall Anderson.

DIAGNOSIS.—Considerable care is often required to diagnose a mild or unusual case of scabies, and cases sometimes go unrecognized for a long time. The disease most commonly confounded with it is eczema, which may present almost identical appearances, except that there are no cuniculi; when these latter are positively found the diagnosis is certain. The location and distribution of the eruption, the history of contagion, and the multiform character of the lesions are generally sufficient to establish the diagnosis. Scabies may also be confounded with lichen, pityriasis, prurigo, pruritus, and urticaria papulosa.

ETIOLOGY.—There is but one cause of scabies, the presence of the parasite (acarus or sarcoptes scabiei), whose removal or destruction is followed by the cessation of the disease. It often occurs, however, that the treatment employed may occasion an amount of artificial eruption or dermatitis which may mask the true affection, and may even remain after the real cause of the disease has been destroyed; this second eruption may require a very different treatment, of a soothing character.

PATHOLOGY.—The only pathologial lesions, aside from the presence of the cuniculus, are those connected with inflammation of the skin. The lesions are simply inflammatory areas of greater or less size, caused either by the direct irritation of the burrowing insect, or by the scratching or other measures employed for the relief of the itching, or by both. When the local irritation is removed the eruption ceases; if the acari could all be removed mechanically, picked out, there would be no eruption. In patients who are paralyzed on one side, or who have been unable to scratch, there is very little eruption on the portions of the skin which are out of reach.

TREATMENT.—The treatment of scabies is purely local and consists in such measures as destroy the life of the parasitic insects and their eggs. The patient first takes a warm bath, using plenty of strong soap rather alkaline in character, such as the sapo viridis or the common laundry soap, and rubbing the affected parts so as to break the burrows as much as possible. After drying, the affected parts, or even much of the body, should be well rubbed with an ointment of which sulphur is a chief ingredient. The ordinary sulphur ointment diluted once, with the addition of a drachm of liquid storax to the ounce, answers as well as anything. After thorough friction with this for at least half an hour, the patient puts on underclothes which are to remain on night and day until the end of treatment. The ointment should be freshly rubbed in twice daily for several days, and a bath is to be taken on the third day, the ointment being again rubbed in and a fresh suit of underclothes put on. After three days more of treatment another bath may be taken, and it is then to be expected that the cure is complete. But frequently some of the cuniculi will be found to have escaped being broken, or new infection may come from the clothing or elsewhere, and in such case the treatment must be repeated. Sometimes an artificial eruption is excited by the treatment, when soothing remedies are required. The clothing should always be treated; the underclothes should be boiled a long time and very thoroughly ironed; the outer garments may be baked or very thoroughly ironed on the wrong side. Patients should be more or less isolated, although when they are under treatment the chances of communicating the disease are very small.

PROGNOSIS.—The prognosis is, of course, favorable; there can never be the slightest harm in curing even the most inveterate or severe cases of scabies. In the hospitals abroad it is claimed that a cure is effected in a few hours, but it is questionable if, in the large majority of cases, the relief is more than temporary, a portion only of the parasites being killed. Practically, cases require treatment for a number of days, or even weeks, to make the cure certain; when the skin is delicate the active parasitic treatment may have to be interrupted, owing to the dermatitis excited, and occasionally it will be found difficult to use remedies strong enough to effect a cure.

L. Duncan Bulkley.

SCAMMONY.—(*Scammonium*, U. S. P., B. P.) A resinous exudation from the living root of *Convolvulus Scammonia* L. (fam. *Convolvulaceæ*). This is a perennial herb of the Levant, having a long, thick, cylindrical, several-headed, but otherwise usually simple, milky-juiced root, and numerous twining stems, resembling those of an ordinary morning-glory vine. The root, which is official in the British Pharmacopœia, is up to a metre in length, and a decimetre in diameter, at the crown, light brownish-yellow without, white within, fleshy, and resinous. The scammony is collected by cutting off the living root at the crown and either scraping off the exudation as it appears or placing some receptacle, commonly a mussel shell, at the lower side to receive it as it runs down. It may dry at once, a very high grade of the drug thus resulting; or, as is more usual, the separate collections are laid aside until enough is accumulated to make a "cake," when it is all moistened and kneaded together. In this way the bubbles and sour odor of what is known as "Virgin scammony," are produced.

Scammony is in irregular, angular pieces, or circular cakes, greenish-gray or blackish, internally porous and of a resinous lustre, breaking with an angular fracture; odor peculiar, somewhat cheeselike; taste slightly acrid; powder gray or greenish-gray. The porous, bubbly texture and the sour, cheesy smell are results of fermentation during the process of drying. It is soluble to the extent of three-fourths in ether. The costliness and opaque color of scammony render it especially liable to adulteration. Lime, flour, ashes, gum, etc., are among the common admixtures. The proportion of resin is the best test of purity. This resin (*Resina Scammonii*, U. S. P.) is obtained by digesting the drug with alcohol and evaporating the tincture so obtained, or by treating the root in the same way. It is a brown, translucent brittle resin, with a sweet fragrant odor if obtained from the root; but, as is usually seen, from crude scammony, it is more greenish and dirty in color, and has the odor of scammony itself. In action and value the two products are about the same.

COMPOSITION.—The peculiar resin of scammony, unfortunately called *jalapin*, and now known as *scammonin*, first obtained in a state of purity by Johnston, in 1840, differs from the *convolvulin* of jalap by its solubility in ether.

When purified, it is a colorless, translucent, brittle non-crystalline resin, tasteless and odorless, of nearly neutral reaction, and freely soluble in ether. It is a glucoside, and resolvable into *scammonic acid*, a crystalline substance, and sugar. Good scammony contains eighty or ninety per cent. of this resin.

Action and Use.—Scammony and its resin are to be counted among the very active drastics, excelled only by croton oil and elaterium. Their action is similar to that of jalap, but considerably more intense. They are used as derivatives and hydragogue cathartics in cases of cardiac and renal troubles associated with dropsy. The action of scammony resembles that of jalap, but is more intense. Aromatics and carminatives are appropriate adjuvants. Dose, of good scammony, half a gram or so; of the resin, 3 or 4 dgm. The compound extract of colocynth contains fourteen per cent. of resin of scammony

W. P. Bolles.

SCAPULA, SURGICAL AFFECTIONS OF THE.—Diseases of the Scapula.—Acute periostitis and osteomyelitis of the scapula are rare. When present they are usually the result of traumatism followed by infection, and affect most commonly prominent portions of the bone, such as the spine.

Tuberculous osteomyelitis of the scapula is much more common and may give rise to extensive caries and necrosis. Cold abscesses may form and reach the surface at some distance from the focus in the bone. In rare cases the shoulder-joint may become involved.

The treatment of tuberculous disease will depend upon the extent of the local process. Small foci may be scraped out with the Volkmann spoon and treated later by iodoform injections. Larger foci may require resection of a part of the bone, such as a portion of the body or the spine. Complete excision of the scapula is seldom indicated.

Tumors of the Scapula may be either benign or malignant, the latter being the most common. A recent collection of 64 cases made by Langenhagen showed the following relative frequency: Exostosis, 8; chondroma, 14; fibroma, 5; carcinoma, 23; sarcoma, 12; uncertain tumors, 2.

The tumor may reach an enormous size, and in case of the malignant varieties the surrounding parts may become invaded. Some tumors grow into the axilla, others spread to the adjacent muscles, and may eventually ulcerate through the skin. Metastases may occur in the pleura, lungs, vertebræ, or some other internal organ.

The treatment of malignant neoplasms consists in excision of the scapula provided that the tumor has not involved the arm. In the latter case removal of this as well may be indicated (interscapulo-thoracic amputation).

Benign tumors, when circumscribed, may be removed by partial resection of the portion of bone involved. The usual incision for excision of the scapula begins over the acromion, runs along the spine to its inner border and there descends to the angle. Through this incision the muscular attachments are divided close to the bone, and the whole bone is removed. If possible that part of the acromion should be preserved which receives the insertions of the trapezius and deltoid muscles. Otherwise the function of these muscles will be lost.

Fractures of the Scapula.—These are comparatively rare injuries (according to various authors from one to four per cent. of all fractures), and occur chiefly in adult males.

The following varieties of fractures occur:

1. Fracture of the body of the scapula (including one of the angles).
2. Fracture of the glenoid cavity.
3. Fracture of the neck.
4. Fracture of the acromion and spine.
5. Fracture of the coracoid process.

1. *Fractures of the Body* are the most common. They occur usually in the infraspinous fossa, and the line of fracture is most commonly transverse. The cause is blunt violence, such as a blow or fall, and there may be considerable contusion of the overlying soft parts. In case of multiple fractures, there may be several fissures radiating from a central point. Fractures of the lower angle form a comparatively common group of fractures of the body, and may be accompanied by considerable displacement of the small lower fragment. Fractures of the upper angle are far less frequent.

The objective symptoms of fractures of the body are, as in other fractures: crepitus, false motion, and localized tenderness. These signs are not always easy to make out, especially in muscular subjects or in case of marked swelling. The scapula can be brought into prominence and thus be easier to palpate if the elbow is drawn inward in front of the chest or the arm carried backward and inward. Dislocation of the fragments is most marked in fractures of the lower angle, and is then due to the combined action of the teres major and serratus magnus muscles upon the lower fragment.

The prognosis of these fractures is good. Bony union usually takes place promptly under proper immobilization, and the function of the arm is not impaired. In the rare cases of compound fracture suppuration may occur, and the pus may burrow downward between the scapula and the muscles of the back.

The treatment consists in immobilization of the shoulder and scapula in that position which overcomes the deformity. The arm can be kept in this position by means of a Velpeau bandage to which may be added some turns of a plaster-of-Paris bandage. In about four weeks the fracture should be solid and movements of the arm may be begun. König recommends in some cases suture of the fragments.

2. *Fractures of the Glenoid Cavity.*—These are rare fractures which may involve chipping off of some portion or of the whole of the articular surface (fractures of the anatomical neck). They are sometimes associated with dislocation of the humerus. The symptoms are very obscure, and it is doubtful if a diagnosis can be made. As a dislocation of the humerus is often present, the treatment would be that of the dislocation.

3. *Fractures of the Neck of the Scapula* are of considerable practical importance. The line of fracture runs downward from the incisura scapulæ. The causes are usually some form of direct violence applied to the shoulder region, such as a blow or fall.

The symptoms resemble somewhat those of dislocation of the head of the humerus. There are a flattening of the shoulder and abduction of the arm; the acromion is prominent, and the axis of the arm is not directed toward the shoulder-joint. The chief point of difference is that the fractured piece can be felt in the axilla as an irregular object not resembling the smooth head of the humerus. By grasping the coracoid process with the middle finger and the posterior aspect of the shoulder with the thumb, crepitus can be felt on rotation of the arm. Crepitus can also be felt by palpation in the axilla. The deformity of the shoulder can be readily overcome by upward pressure on the fragments within the axilla, but recurs again as soon as pressure is stopped. In dislocation of the shoulder, on the other hand, the deformity is made to disappear only by special movements for reposition of the head of the bone.

The treatment consists in replacing the fragment by upward pressure and maintaining it in place by a pad in the axilla. The arm is secured to the body by means of a Velpeau bandage. Plaster bandages may be applied as an outside dressing. The fracture sometimes requires as long as from ten to twelve weeks for consolidation.

4. *Fractures of the Acromion and Spine* are produced by direct violence upon these prominent portions of the bone. The line of fracture is usually transverse. The most important symptoms are the irregularity in the outline of the bone, localized tenderness, and occasionally crepitus. In case of the acromion, the fracture lies either in front of the acromio-clavicular joint or near the base of the acromion. The outer fragment may be displaced downward from the weight of the arm. The treatment of fractures of the spine consists in immobilization of the arm in a flexed position. In fractures of the acromion the outer fragment is elevated by pressing the humerus upward. It is retained in position by means of a bandage

bound around the shoulder and body or by an adhesive plaster strip supporting the elbow and crossing itself over the point of fracture.

5. *Fractures of the Coracoid Process.*—These are very rare and are usually combined with some other fracture or dislocation in the vicinity. The fracture is usually near the base of the process, and results most commonly from direct violence, although muscular contraction has been known to produce it.

The chief symptoms are local swelling, ecchymosis, abnormal mobility, and crepitus. Pain can be elicited by flexion of the forearm in a supinated position, as this brings the short head of the biceps muscle into action.

The treatment consists in immobilization of the arm in a flexed position by means of a Velpeau bandage.

Benjamin T. Tilton.

SCARLET FEVER.—Synonyms: *Scarlatina* (English and Italian); *Scharlach* (German); *Scarlatine* (French); *Escarlatina* (Spanish).

Definition.—Scarlet fever is an eruptive contagious fever. Its incubative period is brief, rarely less than twenty-four hours, usually lasting for from four to six days, and not often exceeding this duration. This period is succeeded by a period of invasion, which is ushered in by fever, usually of considerable intensity, and by sore throat. A scarlet eruption begins to appear before the end of the second day, and marks the end of the prodromal, and the beginning of the eruptive, period. The eruption rapidly becomes general, and the tongue becomes stripped of its coating and assumes a raspberry-red color. The eruption slowly fades after the first few days. The fever persists until the sixth, seventh, or eighth day, or longer. As the eruption fades, desquamation begins and continues for from eight to fourteen days or more. It is peculiar in being lamellar, sometimes occurring in very large shreds and exfoliations. During the attack, and for weeks subsequently, there is an especial predisposition to renal inflammation. Scarlet fever attacks children more especially. It usually affects an individual but once.

History.—Scarlet fever is probably a disease of very ancient origin, though until three centuries ago medical writers had not recognized it; indeed, definite knowledge of it as a specific, independent affection dates back hardly two hundred years, although as early as 1589 an epidemic, which we now presume to have been scarlet fever, was described as having occurred in Sicily in 1543 (Paulus Restivas).[1] It was not until 1676 that Sydenham definitely separated this malady, as "*febris scarlatina*," from measles, and gave it an established position. The observations of writers had already been leading them toward similar views, and within a few years scarlatina became recognized all over Europe. Although its place of origin can never be known, it is probably of European birth; for it is a remarkable fact that scarlet fever has never succeeded in gaining a firm foothold in Asia or Africa. According to Hirsch, in whose most valuable work these facts have been recorded, the coast of Asia Minor is the only Asiatic district which is frequently visited with scarlatina in its severe forms. In nearly all other parts of Asia it occurs not at all, or only sporadically. Wernich, in 1871, declared the disease to be quite unknown there. In Africa, Hirsch states that it is only in Algiers and in the Azores that it is at all common. Following the carefully recorded data of Hirsch, scarlet fever appeared first in America, in New England, in 1735. It extended as far south as Philadelphia in 1746, and penetrated to Ohio in 1791. Not until 1851 was it seen in California. In 1830 it began to be generally observed in South America. In the West Indies it was first observed in 1802, in Martinique, as a mild epidemic. Greenland has heretofore escaped with but a solitary case. Australia and Polynesia appear to have escaped until 1848. In the Polynesian islands, except Tahiti, scarlatina has not been known. It is unquestionable that scarlet fever has never occurred in some localities only because the inhabitants have not been exposed to its influence; but there can be no doubt that in other countries influences prevail that oppose the development of the disease. Whether these are climatic or racial, or due to other causes, is at present unknown. The American Indian is not exempt from its ravages, nor can any different degree of susceptibility be observed in the negro race in the United States. Frick,[2] however, noted a somewhat more pronounced tendency in the negro to scarlet fever.

In the epidemic in Baltimore, between the years 1850 and 1854, of every ten thousand inhabitants 13.8 whites and 10.8 negroes died. This would indicate a relatively greater predisposition in the negro, as in the total population the whites were largely in the majority. Frick's observations were too limited to secure an unhesitating acceptance of his conclusions. It must be noted, however, that in this country the negro is rarely of unmixed African descent. He may have inherited from white progenitors some of their especial liabilities to disease. Drake and others have shown that scarlet fever prevails less in the Southern than in the Northern States. It is also probably true that the disease is more frequent in cold than in hot countries. Yet it cannot be determined that the differences depend upon temperature; Greenland has remained without an epidemic, while Algiers has experienced them frequently. In 1873–75 a severe epidemic of scarlet fever appeared in the Faroë Islands, among people who for at least fifty-seven years, and possibly never before, had not been exposed to scarlet fever.[79] The study of this epidemic, to which reference will frequently be made, gives one interesting data as to the natural course of the disease in a community in which each individual may reasonably be presumed to have been exposed, and in which immunity, due to previous attacks, can be excluded.

Frequency of Epidemics.—Scarlet fever at once shows differences from smallpox and measles in not sweeping over localities in great periodic waves. It may, it is true, sometimes invade very wide areas of territory with astonishing rapidity, but the intervals between epidemics are often very great. Without obeying any well-defined periodic law, measles is often known to prevail with noticeable violence every third or fourth year, frequently disappearing completely in the interim; so, too, smallpox usually exhibits unwonted activity at intervals of from five to ten years, or as soon as popular neglect of vaccination renders a large portion of a community susceptible to it. It is not thus with scarlatina. Hirsch has collected very valuable information upon this point. At Münster fifty years elapsed without the disease appearing. At Ulm there was only one small epidemic in seventeen years. At Tuttlingen scarlet fever had not been seen for thirty-five years previous to the epidemic of 1862–63. A number of writers, however, *have* observed an epidemic cycle in scarlet fever. Thus Fleischmann,[3] at St. Joseph's Hospital, in Vienna, observed one of four years. In Dresden, according to Gerhart, there is an epidemic cycle of from four to five years; in Munich, according to Ranke, one of three years. On the other hand, scarlet fever often prevails sporadically for a long time in a locality, finally to disappear or to spread suddenly far and wide. Mayr[4] states that in Vienna the register shows that scarlatina has never absolutely died out in fifty years. Scarlet fever is remarkable in the varying intensity of cases occurring during a given epidemic, and in the differing severity of epidemics. At one time it was regarded as an insignificant disorder, almost never proving perilous to life. Even now epidemics of an exceedingly mild type are frequent. Graves has told how, between 1800 and 1834, whenever scarlet fever prevailed in Dublin, it was so uniformly mild that medical men attributed the bad results of their predecessors to improper methods of treatment, and flattered themselves upon their superior skill, until a change in type brought their death rate quite up to that of former times.

Etiology.—There is presumptive evidence that scarlatina is due to a specific micro-organism, but the direct and positive proof is so far lacking. Authorities admit the constant presence of the streptococcus, which may be the direct cause of the inflammatory lesions of the mouth and pharynx, cervical lymph nodes, and probably of the secondary complications, as the heart, kidneys, and other tissues. It is possible that a streptococcus is the specific organism. With the streptococcus, the staphylococcus pyogenes aureus and the pneumococcus are frequently associated. In the light of our present knowledge it is impossible to state whether the toxins which undoubtedly are present are due to the activity of these secondary organisms or to some specific cause.

Class,[79] in a recent paper on the subject, has described a diplococcus, discovered by him, which he believes to be the primary infectious cause of scarlatina. He finds it invariably present in the throat secretions, blood, and scales. He differentiates it from the other micro-organisms because it produces in the pig a disease closely resembling scarlatina, because the blood of patients convalescent from scarlet fever inhibits the growth of the organism, and because it produces nephritis in guinea-pigs. He also shows that a guinea-pig injected with the blood of a patient convalescent from scarlatina may be protected from the pathogenic action of his diplococcus. The coccus in question closely resembles the staphylococcus albus. It is very sensitive to environment and at times is so modified in form as to appear as a diplococcus, a streptococcus, or a streptobacillus, the three forms sometimes being present in the same culture. Its size varies from that of a small point just to be distinguished by a one-twelfth oil-immersion lens to a coccus one-third of the diameter of a red blood corpuscle, as seen in old cultures. For routine work cultures are made in the same way as in diphtheria. It is impossible at present to state the importance of this organism in the diagnosis of scarlatina. The results of animal experimentation are not, however, conclusive.

Recent bacteriological investigations by Pearce[80] and others have not added materially to our knowledge of the specific primary cause of the disease. While we may assume the exciting cause of the disease to be an as yet undetermined germ, in the presence of which alone scarlatina is possible, the question of the predisposing causes is a much wider one and demands careful consideration.

Predisposing Conditions.—There is a widespread impression that scarlet fever prevails more especially during the fall and winter months. There is, indeed, some difference in favor of these seasons, but by no means to the extent that is generally supposed. Hirsch has tabulated the records of 435 epidemics. These prevailed 178 times in the winter, 157 times in spring, 173 times in summer, and 213 times in autumn. The same relative prevalence is shown in his tables of deaths from scarlatina. Of more than 55,000 deaths from scarlet fever in London, from 1838 to 1853, 32.1 per cent. occurred in autumn, 25.2 per cent. in summer, 24.6 per cent. in winter, 22.1 per cent. in spring. These figures, however, cannot be accepted with perfect confidence, as they must have been influenced by the mildness or severity of the several epidemics. Hirsch's data show also the season of prevalence and the severity of type for two hundred and sixty-five epidemics.

Of 77 winter epidemics	42.2 per cent. were mild. 55.8 per cent. were severe.
Of 50 spring epidemics	54.0 per cent. were mild. 46.0 per cent. were severe.
Of 66 summer epidemics	45.5 per cent. were mild. 54.0 per cent. were severe.
Of 72 autumn epidemics	48.6 per cent. were mild. 51.4 per cent. were severe.

The maxima of malignancy fall in winter and summer; but, as Hirsch remarks, the difference is unimportant. It may be concluded, however, that in the spring epidemics are usually less frequent and milder.

Scarlet fever is chiefly observed in young persons, because older people are generally protected by a former attack. Nevertheless, adults who have never had scarlet fever are less liable to take it than children similarly circumstanced. This is not attributable to differences of age, but to feeble individual susceptibility, which probably held as well during the childhood of these persons. The greatest susceptibility appears to exist between the ages of three and six years. Nearly four-fifths of all cases occur in the first ten years of life. In McCollom's table of 1,000 cases of scarlet fever treated in the contagious wards of the Boston City Hospital,[77] 50 per cent. of all cases occurred between two and six years, 78 per cent. in the first ten years, and 90 per cent. before the age of twenty years. It is certain that a not very small percentage of persons successfully resist exposure to the scarlet-fever contagion throughout life. In the epidemic at Thorshavn, Faroë Islands, in 1873–75, from a total population of 930 inhabitants, comprising all ages and not protected by a previous attack against scarlatina, only 38.3 per cent. was infected by scarlet fever. Holt is authority for the statement that not more than one-half of the children exposed take the disease. While, then, it is not difficult to understand why adults seldom take scarlet fever, it is more difficult to account for feeble predisposition observed during the early months of life. Infants less than a year old are rarely attacked, and often escape even when exposed directly and frequently. They do not, however, possess absolute immunity; indeed, scarlatina during fœtal life has been reported. Leale observed such a case, as did also Tourtual. Thomas records several cases occurring in the practice of others. Veit noted scarlet fever in a child fourteen days of age. Numerous similar observations, more or less trustworthy, have been recorded. On the other hand, Murchison saw two new-born infants remain healthy while their mothers suffered from scarlet fever. New-born children are so subject to cutaneous and other disorders that may readily be mistaken for scarlatina, that we may well demand the most definite testimony. Scientific exactness should require that a new-born child must be proven either to have served as the medium of contagion for others, or to have developed characteristic symptoms in the midst of predisposing surroundings. Both sexes are equally susceptible to infection.

The predisposition to scarlet fever is much less universal than that to measles and smallpox. While the two latter diseases will almost certainly attack all unprotected persons exposed to their contagion, scarlet fever often leaves unscathed persons who have been brought into the most intimate personal relations with it. In the epidemic at Thorshavn referred to above, only 38.3 per cent. of the total population proved to be susceptible to scarlatina, whereas in the same population in an epidemic of measles in 1875, 99 per cent. of those not protected by a previous attack was shown to be susceptible to measles. It is consequently much easier to practise isolation with the hope of success. However, the immunity possessed by an individual, as shown by repeated exposures, may not prove perpetual, and well-marked, even fatal, scarlatina may follow a final exposure. A degree of immunity from scarlatina is sometimes exhibited in families, the members of which escape altogether, or have only light attacks. Unfortunately, on the other hand, a decided family predisposition to the disease is occasionally encountered, one member after another falling a victim to its virulence.

Careful observation has failed to show that predisposition to scarlet fever is especially favored by the nature of the soil or the state of the weather; neither can it be proven that the type of the disease is especially influenced by any ordinary surroundings, further than that conditions of life prejudicial to the maintenance of good health diminish the powers of resistance to the onset of the disease. It is important to remember that in the absence of the contagious principle no degree of filth, deprivation, dampness, bad ventilation or drainage, or exposure, no matter how injurious to general healthfulness, can serve as the starting-point for scarlet fever. Indeed, it is remarkable, considering the bad hygienic environment of the poorer classes, that between them and the rich there should be so small a difference in the degree of predisposition to, and in the relative mortality from, scarlatina.

Mode of Infection.—To develop scarlatina an individual must, of necessity, receive into his body the *materies morbi* derived from one who has, or who has had, the disease. In all cases the contagion must be communicated by the air, or in solids or fluids received into the body. It is probable that physical contact occurs but rarely between infected and unprotected persons, and that when it does occur, the danger of infection is due rather to the increased liability of intercepting emanations from the body. Scarlet fever appears to be not contagious at the very beginning. In this respect it differs markedly from smallpox and measles. In the prodromal stage the contagion is probably not set free as readily as at a later period. Girard, however, has asserted that it is contagious only on the first day. This hardly needs a refutation. Longhurst also claims that it is most contagious during the pre-eruptive stage, and not at all during desquamation. These and similar opinions of individuals are negatived by the almost universal experience of observers. Scarlet fever develops its highest properties of contagion during its period of eruption, and, still unlike measles, retains its contagiousness until desquamation is far advanced. Two children, at the Netherfields Institution at Liverpool, were believed to have been centres of contagion six and a half weeks after the beginning of their illness.[6] Cameron[7] reports a case in which, nearly nine weeks after the beginning of her own attack, a child communicated the disease to her sister by contact. It seems probable that the power of communicating scarlet fever is retained, gradually diminishing in intensity, until the end of desquamation, which may not be completed for six, eight, even ten weeks. Thomas mentions cases in which children, even after the completion of desquamation, while suffering from scarlatinal dropsy, probably served as centres of contagion. The agency of the atmosphere as a contagion-bearer does not seem to extend beyond a few yards. Thus, it often happens that the disease does not spread beyond the sick-room, provided mediate contact can be avoided. Possibly the contagion is of too great gravity to be wafted for any distance. Yet it is certainly, under certain conditions, very tenacious of life, and may be conveyed long distances and preserve its properties for prolonged periods. It has often been carried by a healthy person, who has been exposed to the malady, to persons at a distance. There are authentic accounts of physicians, nurses, attendants, and visitors serving thus to carry infection. Such unfortunate occurrences are not very common, and probably happen only when the carrier of contagion passes directly from the sick-bed to the unprotected person, without due regard to the proper disinfection of the person and clothing. A pernicious custom is the habit of putting on over clothing and wraps over the dress in which the patient has been visited without proper exposure to the free circulation of fresh air. The tenacity with which the contagion clings to inanimate substances is most remarkable. Articles of clothing, bed-linen, furniture, wall-paper, hangings, and the like, frequently serve to communicate the disease, and often after almost incredibly long intervals. Richardson gives an example of this. Four children lived with their parents in a thatched cottage. One child was taken with scarlet fever, and the others were sent away. After three weeks one of these was permitted to return. It took the disease on the first day and died. The walls of the cottage were now cleaned and whitewashed; everything was thoroughly scrubbed, and all wearing apparel was washed or destroyed. After four months another child returned. The next day he was seized with the disease and died. Here the thatch was thought to have retained the contagion. The germs of the disease may be shut up in a letter and conveyed a long distance. Woollen clothing, put away and brought out after many months, pillows, cushions, toys, books, have all been known to preserve the contagion in full vigor. The dissemination of the virus in the atmosphere has been stated to be very limited, but the same cannot be said so confidently concerning the agency of fluids. The spread of scarlet fever has never been directly traced to the water-supply, but there is abundant reason to attribute its occasional extension to the medium of milk. Thomas quotes two examples of this. One, reported by Bell, leaves it an open question whether the milk, its receptacle, or the boy who carried it, was the medium. The other came under the observation of Taylor, who noticed "that one of the first severe cases which initiated an epidemic occurred in the house of a milkman whose wife milked the cows, the milk being supplied to about twelve families in the city. In six of these scarlatina occurred in rapid succession, at a time when the disease was not epidemic, and without any communication having taken place between those who were affected and the person who brought the milk. It is very probable that in this instance the milk was the carrier of the contagion, as, previous to its distribution, it had stood in a kitchen which had been used as a hospital for scarlatina patients." More recently, Airy, in eighteen families, consisting of thirty-five persons, reported twenty-four of these sick with scarlatina within thirty-six hours. Every one of these patients received milk from the same source. Neighbors who had milk from other sources were not attacked. It was found that a person who milked the cows lived with a child in full desquamation from scarlatina. Several observations of this kind make it hardly doubtful that milk may serve as the vehicle for the scarlatina virus, and that it, indeed, may be considered a favorable culture-fluid for it. But until recently it has not appeared that the virus-bearing milk received its contamination otherwise than through human sources. Later investigations seem to throw much light upon the possible origin of scarlatina in man, and upon one of the paths for its dissemination previously unrecognized. An outbreak of scarlatina among persons who received their milk supply from a dairy in Hendon, in England, in 1885, seemed to be traceable directly to a disease of the cow. The cows of this farm were affected with a peculiar affection, among the symptoms of which were a shedding of the hair and the formation of vesicles and ulcers upon the teats and udders. The nature of the disease in this case is, however, doubtful. Crookshank held that it was cowpox and had nothing to do with scarlet fever. In 1900, Kober[31] collected records of 99 epidemics of scarlet fever, and of these there was scarlet fever at the farm or dairy in 68; in 17, employees themselves were infected, and in 10 they acted as nurses; in 6, persons connected with the dairy either lodged in or had visited infected houses; in 2, infection was brought by cans or bottles from the houses of patients suffering from scarlet fever; in 3, the milk was stored near or in the sick-room; in 1 case milk utensils were wiped with an infected cloth. The existence of scarlet fever in animals has been claimed by such authorities as Salmon and Peters; other writers maintain that the disease is not identical with scarlatina as seen in man. In this connection it is an important fact that inoculation of cows, especially when in milk, with the virus of scarlatina, results in the production of definite symptoms.

The scarlatinal virus gains access to the blood through the respiratory tract, and is also conveyed in solid and liquid food to the stomach, whence it is absorbed. Though it is unlikely that absorption can occur through the sound skin, the disease is said to have been inoculated by artificial deposition of contagion-bearing material upon the abraded cutis. Miguel d'Amobise claimed to have inoculated children successfully with blood taken from scarlatinous patches. Stoel and Harwood have been reported as having conducted successful inoculations. On the other hand, Petit-Radel failed in his experiments. New observations upon this point are required. The contagion probably resides in the epidermis, and becomes diffused as this is exfoliated; also in the buccal and faucial mucous membranes, and probably in the secretions, in the lymph, and in the blood. In the absence of reliable inoculation experiments we have no fixed knowledge upon these points.

Incubation.—Scarlet fever has a shorter and much less definite period of incubation than the other eruptive

Scarlet Fever.

fevers. In determining the interval between infection and the outbreak of symptoms, it is much easier to reach correct conclusions when the fever has followed a single exposure than when the exposures have been repeated or prolonged. There is abundant evidence to show that the period of incubation may be less than twenty-four hours. On the other hand, it has been claimed that four or five weeks may elapse before the disease manifests itself. Most cases of scarlatina have an incubation period of from four to seven days. Even this wide limit, differing markedly from that of the other eruptive fevers, is subject to very many exceptions, and the literature teems with examples of scarlet fever developing a few hours after exposure, or only after many days, even weeks. Murchison believed the incubation period to be more often less than forty-eight hours in duration. The shortest authentic stage of incubation was in the case of Richardson, who after auscultating a scarlet-fever patient immediately became nauseated and chilly. He was conveyed home in the carriage of a friend, and dated an attack of scarlatina from that hour. Incubative periods of not more than twenty-four hours have been reported by many writers.[8] In 20 cases Dukes found the duration to vary from one to nine days, in 10 cases it was less than five days. Murchison reported, in the Transactions of the Clinical Society,[9] the incubative periods of 75 cases, none of which exceeded ten days. He considered a person safe from contagion who is not attacked within a week after exposure. Thomas[10] thinks that from four to seven days is the most frequent interval; Kaposi considers it to be about eight days; Gee thinks that seven days are rarely exceeded; Lewis Smith, that it is ordinarily less than six days. Longer intervals, however, are not infrequently noted. In one case, Hagenbach[11] determined it to be eleven days; in another, fourteen days. Intervals of twelve days or more have been recorded by Veit, Paasch, Böning, Lewis Smith, and others. From the rather untrustworthy results of inoculation, seven days would seem to have been the incubative period. Barthez and Rilliet, Gee, and others thought they had observed cases in which the incubative period covered several weeks, and, indeed, in delicate children, especially those with rachitis or with one of the neuroses, it may be much prolonged (Mayr). Holt[75] has collected 113 cases scattered through medical literature, occurring under circumstances which made it possible to determine the exact length of the incubation. The periods of incubation in these cases were as follows:

	Cases.		Cases.
Twenty-four hours or less...	6	Eight days	2
Two days	15	Nine days..................	5
Three days..................	28	Eleven days................	1
Four days...................	25	Fourteen days..............	1
Five days	6	Twenty-one days...........	1
Six days	15		
Seven days..................	8	Total	113

There is a growing belief that the incubation of scarlet fever lasts less than six days, and, without attempting to be more accurate, we accept that as the common duration. It is very often less than this, and but very seldom more. In this, as in most other features, scarlet fever shows great variability, and, if the term be allowable, a capriciousness contrasting strongly with the behavior of other specific fevers.

Symptoms: Period of Invasion.—For convenience of description it will be proper to describe scarlatina as following an *ordinary* or *mild*, and a *graver, course*. The course is very often irregular, from the absence of characteristic symptoms, or from the undue prominence of one or several of them, or from the presence of complications. In fact, scarlet fever may vary from an insignificant, even an unappreciable, disturbance of health, to a malady pursuing its fatal course with lightning-like rapidity; and although the type of the prevailing epidemic may be mild, severe, or malignant, individual cases can only in a measure conform to the standard, from which they will invariably differ to a greater or less extent.

Milder Forms.—At the end of incubation the active symptoms of scarlet fever usually develop suddenly; rarely they appear more gradually. In most cases fever is the first symptom observed. In larger children and adults an initiatory chill is often noted. Convulsions may occur at the outset; usually, however, they usher in graver forms of the affection. The fever develops during the night, or during the day the child loses its playfulness and in a few hours is found to have a high temperature, in most cases not exceeding 103° F. (39.5° C.), but occasionally reaching 104° to 105° F. (40° to 40.5° C.). At the same time the pulse will be full and frequent, beating from 120 to 140 times in the minute very commonly. The rapidly rising temperature and great acceleration of pulse are characteristic, and under favoring conditions should excite suspicions of scarlatina. The face becomes flushed, the eyes bright and injected. There is much thirst, but almost complete anorexia. Nausea and vomiting are so frequent that J. Lewis Smith attaches some diagnostic importance to the symptom. Of 214 patients it was present in 162. Jenner thought that severe vomiting is apt to precede severe throat symptoms. Diarrhœa sometimes occurs, especially in graver cases. The tongue may be only slightly coated; frequently it is covered with a white, creamy fur, but remains red at the edges. Already the little patient complains of sore throat (indeed this may be the first symptom to attract attention), and upon inspection the mucous membrane of the pharynx will be found to be swollen and dry, and of a bright or dusky-red hue, and often spotted with small areas of duskier redness. At this stage no curdy nor diphtheritic deposit will be observed. The nasal mucous membrane sometimes participates in the hyperæmia, and a nasal catarrh is induced. There will now be difficulty in deglutition, and already there may be some enlargement of the submaxillary and cervical lymph nodes. There are often headache and also delirium, sometimes of an active kind. As the fever increases in severity the patient becomes dull, listless, and drowsy, and various symptoms of cerebral disorder are common in graver cases. In very many cases, however, all the symptoms will be mild. There may be little fever, no noticeable disturbance of the various functions, not even sore throat. Beyond slight peevishness and irritability the child may not seem to be unwell. In not a few cases there may be no prodromal period at all, the eruption first attracting notice. During the prodromal stage the urine is rather scanty, acid, and high-colored. According to Gee, the urine is diminished in quantity; urea is not necessarily increased; chloride of sodium is diminished, sometimes decidedly, the diminution generally ceasing suddenly on the fourth, fifth, or sixth day; phosphoric acid, at first normal, is notably diminished on the fourth or fifth day, remaining for four days from one-third to one-half the normal quantity, and then returning to the healthy standard; uric acid is greatly diminished on the second and third days, becoming excessive on the fifth day, and then normal. Even at the earliest observation albuminuria may be noted. Böning, who denies a prodromal stage, and always encounters the eruption on the first day simultaneously with the chill, has found blood corpuscles, renal epithelium, and albumin in the urine from the very start. The respiratory movements quicken in proportion to the rapidity of the pulse. Nearly all cases will begin to show the eruption within twenty-four hours, many within twelve hours, a few during the second day. When the eruption appears later, an abnormal or unusually severe form of the disease often follows.

Stage of Eruption.—The eruption first appears upon the sides of the face, upon the neck and submaxillary region, and on the front of the chest, in the clavicular region, as small, pale-red points, closely aggregated, although at first discrete, and very slightly elevated. It rapidly extends over the chest (where it becomes most intense), and over the upper and lower extremities, and attains its full distribution by the end of the second day, acquiring a bright red or scarlet color. It occasionally happens that the eruption begins on other parts than those mentioned, or may never become general. Rarely it spreads more slowly, even fading in some localities before the lower extremities are invaded. It is especially apt to affect the flexures of the joints. In mild cases the spots remain discrete over most of the body, and may resemble a fine "prickly heat," densely arranged and of minute size. At times the eruption consists of dark-red points, surrounding hair follicles, separated from each other by less intensely red areas (Henoch). In cases of greater intensity it is coalescent almost universally, and presents a continuous brilliant scarlet surface, like the shell of a boiled crab or lobster. The intensity of coloration varies somewhat, even in the same patient, depending much upon the degree of heat; becoming paler when the surface is cooled, more scarlet when this is protected by heavy covering, etc. It is, however, not perfectly smooth, but shows the tiny papules upon the reddened base, and communicates to the hand passed over it a sensation of roughness and of dry and pungent heat. Upon the legs and arms the eruption very often becomes more scattered, assuming the form of separate tiny points; rarely it is distributed over distinct areas of the trunk and extremities, with intervals of faintly erythematous redness (scarlatina variegata). This form, however, is apt to appear in severe complicated cases. At the same time it must be remembered that, unlike measles, scarlet fever affects the face less than other parts. Never very intensely developed over the forehead, temples, or chin, the eruption entirely spares an area around the mouth, including the upper and lower lips and some distance beyond the angles of the mouth, and often extending upward to include the nose. This area contrasts with the surrounding parts by its remarkable pallor. It has been asserted that the cheeks are also spared by the eruption. This is not true. The cheeks do not show the pointed redness of the early eruption elsewhere, but at once assume a scarlet or crimson redness that is deeper than the color induced by fever. The lips are often dry and cracked, and may bleed. The face becomes considerably swollen, especially in the loose tissue about the orbits. The ears are also swollen and of a bright red color. The eruption does not spare the scalp. Upon the backs of the hands and feet the eruption is discrete, and is arranged in groups the size of a lentil, while upon the palmar surfaces of the hands and fingers, and upon the soles of the feet, a bright, diffused redness, with swelling, is seen. At times the eruption will be partial, developing upon the trunk alone, or on the extremities, or in isolated patches about the body. These cases may not be abnormal in other respects. The skin over the joints is especially prone to be affected. The lesions may be more or less disseminated spots, varying from the size of a pin head to that of the finger nail, or a half dollar, or even larger. It has been asserted that the eruption constantly consists of a papulated rash upon a reddened base, even when universally diffused. This is not invariably so, and one may encounter a smooth, uniform redness inappreciable to the touch. Where the eruption is very intense, small hemorrhagic spots or petechiæ may appear. When thus occurring, their occasional presence is not of serious importance. In warm weather especially, and in children too warmly covered with bedclothes, the surface, particularly of the neck, chest, and belly, is sometimes plentifully sprinkled with an eruption of sudamina. In some epidemics these are more often observed than in others. It is not impossible that the "miliary fevers" that formerly occasionally prevailed in Europe were in reality forms of scarlatina. Mayr has said that the eruption of scarlet fever often spares the skin of paralyzed limbs; but Kaposi asserts that it may be unusually intense upon these parts. In dark skinned races the eruption undergoes some modifications, which are greatest in those of full negro blood. In mulattoes and negroes it becomes often exceedingly difficult to distinguish the eruption. Of course the scarlet color is absent, a tinge of red will often struggle through the darkly pigmented skin, especially of the cheeks and abdomen. The true character of the eruption may often be revealed by a finely papular condition, the tiny papules of the size of a pin-point being made apparent by their acuminated summits, which give, against the dark background, a resemblance to a sprinkling of the surface with a fine dust. The hand passed over them can perceive the little asperities. These are closely aggregated. In many cases it is impossible to recognize the eruption, and the diagnosis must rest upon the concomitant symptoms, which will not be peculiarly modified.

While the eruption—which attains its height by the end of forty-eight hours in mild cases, later in severe ones—is developing, the other symptoms become pronounced. The faucial mucous membrane is uniformly redder, or occasionally shows numerous red macules; the uvula, tonsils, and buccal mucous membrane are reddened and swollen, and pain in deglutition increases. As the eruption reaches its height, the tongue parts with its coating in patches, exposing areas of intense redness. By the third day it acquires a uniformly brilliant red color, with enlarged papillæ scattered numerously over its general surface, and presents the characteristic "strawberry" or "raspberry" appearance. Exceptionally this exfoliation of the lingual epithelium does not occur, and the creamy deposit persists. In many mild cases there is slight nasal catarrh, with a thin discharge from the nostrils. A muco-purulent discharge from the nostrils is associated with the throat complications of the graver forms.

During this period the fever continues to increase until the completion of the eruption, or the prodromal temperature remains unchanged. In the type of cases we are considering 105° F. (40.5° C.) is not often exceeded. Should the fever continue to increase after the third day, grave solicitude as to the result will be justifiable. The other symptoms continue with undiminished vigor—digestive disorder, nausea, vomiting, complete anorexia, rarely diarrhœa, persist. The skin burns or itches more or less intensely. Nervous symptoms, restlessness, stupor, headache, delirium, usually diminish, but may continue unabated; or active delirium may occur. Convulsions at this time are very ominous. The sore throat becomes distressing, and the cervical and submaxillary glands enlarge and become painful. Bronchial and pulmonary inflammations occur only as complications. After the fourth or fifth day nearly all of these symptoms cease to increase, and it becomes evident, *cæteris paribus*, that the course of the disease is to be favorable. The eruption, after persisting in full development for a day or two, becomes duller and slowly fades, first in the parts earliest affected, latest from the back of the hands. The color, which at first completely faded, now leaves a yellowish stain when the finger compresses the skin. It is not, however, until after four, five, or six days, that the skin loses its scarlet color. This may last longer. Jenner[12] has known it to persist for from fourteen to sixteen days. The fever slowly declines, until it ceases about the sixth, seventh, or eighth day, or later, and not before the eruption has entirely disappeared. Sometimes, from unknown reasons, it persists for days after all local symptoms have ceased to be active. On the other hand, fever, in some very mild cases, will hardly be noticed, or will endure but a few hours. The throat manifestations, or the supervention of complications, may protract the fever for many days. The sore throat, unlike the other symptoms, often fails to show signs of amelioration after the height of the eruption. The swelling and redness may increase, and white or yellowish curdy deposits form upon the tonsils and uvula, or the posterior wall of the pharynx may be bathed in a thick muco-purulent discharge from the posterior nares. True diphtheritic membrane is not apt to form in these cases, but the neighboring lymph nodes may become highly inflamed and suppurate. It is probable that renal catarrh and nephritis occur more frequently during this period than is commonly supposed. The character of the urine is subject to considerable variation. At the beginning of the disease it has the appearance of the ordinary febrile urine or of a severe active hyperæmia. It is not usual for an acute nephritis to develop in the early stages of scarlet fever, but is most common in the second or third week. It may develop after the mildest forms of infection, and the greatest care should be (even when convalescence is well advanced) to guard against this serious complication. Frerichs, Reinhardt, Eisenschitz, Böning, Begbie, Newbigging, Holder, and others, consider the renal symptoms to be essential in scarlatina. This is, however, not true. Thomas[13] practised microscopic examinations of the urine in twenty-five of eighty patients, and in twenty of these daily. In the prodromal and eruptive stages he found slight albuminuria only rarely and transitorily. Decided alterations in the renal tract were most uncommon. Mild catarrh was more often seen. Only the more severe forms he considered to depend upon a specific scarlatinal influence. Fleischmann,[14] in 472 cases of scarlatina, reported dropsy during the first week in 9 cases. Not enough, certainly, to bear out the sweeping assertions just quoted, but sufficient to direct attention constantly to the condition of the kidneys in scarlatina.

Many cases of mild scarlatina fail to exhibit all the symptoms enumerated. The prodromal stage may be absent, sore throat may be insignificant or absent throughout. The tongue may never assume the "strawberry" appearance. The fever may be of feeble intensity. Finally, the rash may be faint and not widely distributed. It may be limited to a few reddish or pinkish punctate spots upon the neck or chest; or it may affect only the flanks or the flexures of the joints; or it may be so transitory as to escape observation or to be noted only during a few hours; or, finally, it may fail altogether to appear. On the other hand, sore throat may be the only active evidence of the disease. Cases that have been exposed to the contagion sometimes develop sore throat only. These may subsequently become dropsical from nephritis, or they may desquamate more or less abundantly, or even communicate scarlet fever to others. An interesting feature is a tendency, often shown by those exposed to contagion, to suffer from a mild attack of pharyngitis after every exposure. Many physicians, nurses, etc., experience this. Finally, the eruption may fail to appear, knowledge that scarlatina was present being acquired through the occurrence of desquamation or dropsy. Cases of this kind have been designated "*scarlatina sine exanthemate.*" They are not so very rare. At other times the eruption is so indeterminate in appearance that, in the absence of accompanying symptoms, it is impossible to speak positively of its character.

Stage of Desquamation.—After the fading of the eruption the patient passes into the stage of desquamation. This is an immediate result of the eruption. Desquamation begins usually upon the neck, and continues for from eight to fourteen days, but not infrequently for four, six, or even eight weeks or more. Usually not earlier than the sixth day of the disease it is noticed upon the neck and face, and quickly extends over the whole surface, and may even occur upon parts not visited by the eruption. Upon the face and neck the scales are mostly fine, but coarser than those following measles. From other parts the epidermis peels in great shreds. On the hands and feet the lamellæ are always large, and sometimes from these members the cuticle is removed in masses resembling a glove or slipper. Desquamation endures longest where the epidermis is thickest, often for weeks; that newly formed exfoliating repeatedly. The hair and nails are sometimes shed after scarlet fever. Desquamation is at times observed in those who have had no eruption, or at least one of very circumscribed extent. With the completion of desquamation the disease may be said to have run its course. Great care, however, must be exercised for some weeks to protect the patient from the effects of complications and from the sequelæ to which the disease has made him liable. With the fading of the eruption, the cessation of fever, and the beginning of desquamation, general improvement takes place. The tongue gradually resumes its normal appearance or for a time becomes again coated; the sore throat diminishes; the various functions are properly performed; appetite and strength return. Desquamation may, however, be sometimes delayed. The local use of oils and ointments during the eruption tends to make the desquamation less free. The occurrence of dropsy, dependent upon the development of an acute nephritis, sometimes defers the beginning of desquamation, and this may not become abundant until after the dropsy has subsided. Contagion has spread from desquamation beginning in this manner, after isolation has been abandoned as no longer necessary. In rare cases desquamation can hardly be said to occur at all. Even in mild cases, in winter, the patient should not be permitted to leave his bed until the end of the third week, or to leave his chamber until the completion of desquamation. In midsummer it is usually not advisable to insist upon confinement to bed for so long a period. Cases which run the apparently mild course just described are by no means free from danger, as they are often accompanied or followed by local pathological processes which, while they may not be essential symptoms of scarlet fever, are especially prone to affect those suffering from it. Such lesions will be considered among the complications and sequelæ of scarlatina.

Graver Forms.—Every case of scarlatina is dangerous. In those following the type just described the peril arises from processes that are not essential to the disease. Such forms pass, by insensible gradations, into those where life is imperilled by the greater or less intensity of characteristic phenomena. The graver forms of scarlatina may not differ in their initiatory symptoms from those already described. In most cases the severity of the disease is in great measure dependent upon lesions in the throat, while, as a rule, the eruption shows a more general distribution and a more intense coloration. The prodromal symptoms do not differ in kind from those of milder types, but are more severe. Vomiting is more apt to occur, and nervous symptoms to become prominent. Headache, jactitation, and delirium become more marked, or the patient grows petulant, drowsy, and stupid. Convulsions also may occur. Fever attains great intensity at the very outset, reaching 40 to 42 C. (104 to 106° F.), the latter temperature always denoting extreme danger. There is already sore throat, with difficult deglutition and with swelling and deep redness of the faucial mucous membrane, which by the third day, in the less severe cases, shows curdy deposits scattered over the tonsils. These deposits do not involve the mucous membrane, and may generally be detached by a mop or a brush. They are quite like the exudation of ordinary catarrhal pharyngitis. After the third or fourth day, under conditions of constantly increasing fever and general distress, in some cases, diphtheritic exudation begins to show itself over the tonsils and soft palate and posterior wall of the pharynx. It is an interesting point of difference between primary and scarlatinal diphtheria that the latter never begins to appear before the third or fourth day, after which date it is sufficiently common. Fleischmann reported diphtheria 168 times in 472 observations. The diphtheritic deposit is first developed on the lateral portion of the tonsils, except in those rapidly fatal cases in which the whole pharynx seems to be simultaneously involved. The patches are of a whitish or grayish-white color, and involve the mucous membrane sometimes to a considerable depth and superficial extent. At times the diphtheritic membrane rapidly spreads in a continuous sheet over the fauces, extending forward into the buccal cavity and into the posterior nares. In the latter case, a fatal termination is almost inevitable. Heubner[14] asserts that those cases in which the entire mucous membrane, from the root of the tongue to the œsophageal and tracheal orifices, is covered with the membrane, prove fatal within twenty-four or forty-eight hours, without exception. Here the membrane is sharply margined against the dusky-red mucous membrane, and within a few hours the slough shows signs of separation and develops a gangrenous odor. In these cases the membrane hardly ever travels down into the trachea. Bretonneau has made a positive assertion that this does not occur. It does so occasionally, however. Lewis Smith reports cases, with necroscopic examination, in which diphtheritic membranes extended along the trachea into the bronchial tubes. In the most severe cases, however, the deposit does invade the posterior nares, and the ordinary slight catarrhal discharge is supplanted by an offensive sanio-serous or sanio-purulent discharge from the nostrils, which causes excoriation of the upper lip. At the same time the nares become obstructed, and the little patient is driven to breathe almost entirely through the mouth. In many cases of extreme throat involvement the strength rapidly fails, pallor replaces the prematurely receding eruption, except at certain spots where this may persist as circumscribed patches of dusky redness; the temperature remains stationary or falls, the pulse becomes more and more feeble and rapid, and death ensues within a few hours, as if from blood-poisoning. Death either follows a slow spread of gangrene to the soft palate and tongue behind the sinus pyriformis, and to the walls of the throat, or occurs through diphtheritic inflammation of the lymph nodes and connective tissue of the neck, or through œdema of the glottis. At other times the clinical appearances during the first week may not be alarming, danger becoming imminent about the beginning of the second week. The fever may remain elevated, the eruption brilliant and intense, until a short while before death. In the rapidly fatal cases the throat and neck may not appear very much swollen. At other times the neck and submaxillary region are greatly swollen, principally from the inflammation of the glands and periglandular tissue. These parts become hard and brawny, and from the pressure upon the great veins acquire a livid appearance, which may also be communicated to the face and head. The tonsils and soft palate may be swollen until the throat will appear quite closed. The mucous membrane will be deeply congested, and covered here and there with diphtheritic exudation and with ulcers caused by the separation of sloughs. The posterior wall of the pharynx may be bathed in muco-pus. Retropharyngeal abscess is sometimes formed, and may precede the fatal termination. Dyspnœa may result from swelling of the fauces caused by inflammatory exudation into the parts, from œdema glottidis, or from extension of diphtheria to the larynx and trachea, or it may be a result of the imperfect oxidation of the blood. The term "diphtheritic" is here used in a clinical sense, to designate a condition of coagulation necrosis in the tissues involved, and has no reference to a pathogenetic relationship with true diphtheria. This necrosis occurs simply as a result of the intensity of the accompanying inflammatory changes. There is no evidence that true diphtheria may not coexist with scarlatina, but that the commonly observed membranous pharyngitis of scarlatina represents this combination is most improbable. Many of these membranes are undoubtedly due to the action of the streptococcus and staphylococcus infections. Their differentiation from true diphtheria is now made easy by the bacteriological examination in reference to the presence or absence of the Klebs-Loeffler bacillus. J. Lewis Smith has seen four instances in which the diphtheria became dissociated from the scarlatina, and attacked other persons as idiopathic diphtheria. Such observations are exceedingly uncommon. The scarlatinal diphtheritic membrane is indeed essentially identical with that of idiopathic diphtheria in structure. The differences are etiological. The diphtheritic poison and the scarlatinal poison, differing in their specific natures, possess in common the power to excite such violent inflammatory changes in the tissues that a coagulation necrosis results. The diphtheritic membrane of scarlatina, then, is purely scarlatinal in its origin. This view has received solid indorsement. It has been adopted by Henoch. Heubner considers scarlatinal diphtheria to differ from primary diphtheria both clinically and histologically. It begins with a simple catarrhal affection, and, following his observations, changes from catarrhal to diphtheritic inflammation on the fourth day. Koven also thinks that the throat affections of more severe grade are characterized by necrosis from direct intensity of the scarlatinal process, and are not of a truly diphtheritic nature. He observes that while two acute diseases rarely coexist, of 426 cases of scarlatina 125 had necrosis faucium, although at the period of observation there was not a single case of primary diphtheria in Christiania. He further declares that diphtheritic paralysis never occurs after scarlatina, and that while true diphtheria shows the membrane at once, the scarlatinal slough usually appears after several days of increasing angina, and does not extend to the larynx. Henoch has never seen a single case of accommodation paralysis of the eye or of the soft palate, nor of the neck, nor of the extremities, after scarlatinal diphtheria. The inflammation may, often does, extend along the Eustachian tube to the middle ear, and excites changes that give scarlet fever one of its principal terrors, resulting often in more or less complete permanent deafness. These changes will be considered with the complications and sequelæ of scarlatina. In a number of these cases cervical adenitis and periadenitis occur, and prolong the fever beyond the eruptive stage indefinitely, frequently resulting in suppuration. Occasionally the pus burrows deeply among the tissues of the neck, and extensive gangrene may follow. Williams has reported a case of extensive sloughing in the left anterior triangle of the neck, with exposure of vessels, followed by recovery. Other similar cases have been recorded. In most cases in which death does not speedily occur after suppuration and evacuation of pus recovery will take place, but the patient may ultimately succumb under blood-poisoning and protracted fever. Occasionally, also, parenchymatous tonsillitis may cause rapid and enormous enlargement of the tonsil, with the formation of pus, a condition of extreme gravity, especially if associated with retropharyngeal abscess and œdema of the glottis. In favorable cases the sloughs in the fauces will cease to extend, the œdema and dusky redness will slowly subside, and the diphtheritic ulcers begin to granulate.

In many cases the faucial symptoms here described do not appear, only because life is early destroyed by the intensity of the action of the specific poison upon the blood and tissues. In such malignant cases the patients often die with the rapidity of those who succumb to narcotic poisoning; or a series of convulsions inaugurate the disease and terminate life within an hour or two. This has been called the *atactic* form of scarlet fever. At other times brief initiatory symptoms have been followed by intense fever (106°–109° F.), with uncontrollable vomiting, diarrhœa, delirium, rapidly deepening coma, and death, before the appearance of the eruption. Or, again, the disease may begin in the ordinary manner, not suggestive of a severe course, and alarming symptoms may not develop until after several days; or it may be intense from the beginning, with severe and repeated convulsions, vomiting, profound nervous depression, and the appearance of the eruption at the usual time, with steadily increasing gravity of all the symptoms, until, after a few days, death results from convulsions or coma. Finally, the malignant symptoms will appear suddenly in the midst of what has seemed a mild attack of scarlatina. An unusually protracted period of invasion is sometimes the forerunner of malignant scarlet fever, and should always be regarded with apprehension. Cases may at times exhibit at the beginning alarming symptoms. A decided apathy, in which no notice of what is passing is taken, with great apparent depression and even delirium, excites the apprehension of the attendants, yet the pulse and temperature will not show marked variation from the normal. After the second or third day such cases will very often pursue a mild course. A high temperature and very quick pulse may even be added to these symptoms and justly excite alarm, and yet the case may assume a favorable character after the development of the eruption. In such cases as these the probability of the issue in life or death seems to vary from hour to hour. All the symptoms show intensity. The fever, accompanied by more or less severe initiatory symptoms, rapidly increases, the eruption is copious and deeply colored, the pulse beats 130, 140, 160 times, or oftener, to the minute, the respiration is proportionally accelerated, the throat duly shows more or less extensively the peculiar alterations. This course may be held throughout the first week, and even longer, without mitigation, the result remaining doubtful all the while.

In malignant scarlet fever the usual course is one of intensified general symptoms. Those of the invasion period are indicative of grave perturbation of the economy. By the time the eruption appears it is already evident that the patient is dangerously ill. He is apathetic, or perhaps extremely restless, remaining in one position not an instant. The skin is hot, dry, and pungent, the temperature very high, the features are swollen, the conjunctivæ injected, the fauces reddened and dry, the thirst is intense, but water and all ingesta are often vomited as soon as swallowed; the urine is scanty, or even suppressed, from acute renal inflammation. Diarrhœa may be present. The nervous phenomena become intensified. The eruption now appears, and may at first develop regularly, but after a while will become duskier and will not completely fade on pressure. The color tardily returns to the part whence it has been pressed. Coma or convulsions may now carry off the patient in full eruption. Often, however, the eruption will recede from certain parts in whole or partially, or it may become paler universally; or in place of the regular eruption hemorrhagic exudation will appear. Ecchymoses, from the size of a pinhead to that of the palm, or larger, will replace the usual eruption, which will in great measure disappear. Then livid spots, not fading on pressure, are found, generally upon the flanks and back, but may appear anywhere. According to Mayr, the hemorrhagic eruption may appear over a large part of the surface in children, but in adults is mostly confined to the neck, upper part of the chest, the back, and about the joints of the upper and lower extremities. This hemorrhagic variety is the most formidable form of scarlet fever, and is probably always fatal. Hemorrhages from mucous surfaces are exceedingly uncommon. Mayr has described a scarlatinal dissolution of the blood, in the gravest form of which death occurs in from twelve hours to five days. "Extreme muscular depression, with slight headache and a remarkably rapid pulse, are present from the very commencement. . . . The patient lies on his back with his eyes half open, but in an unconscious state. . . . Quivering movements of the muscles of the face and of the fingers are also commonly observed in these cases, and in children general convulsions often occur. The pupils are moderately dilated; the lips and tongue are dry, the latter being usually of a bright-red color. As the disease goes on, mucous râles are heard in the large bronchial tubes; the abdomen becomes distended, but there is seldom any enlargement of the spleen; the urine becomes scanty and of a dark-red color; the pulse continually increases in frequency, reaching as many as 200 beats a minute; the features become shrunken and the extremities cold." Death speedily follows. This form resembles the so-called typhoid scarlatina, in which drowsiness, stupor, delirium, and subsultus precede the fatal issue. The life-destroying symptoms are often connected with impairment of the heart's action, attributable to crippling of the vagus, when death occurs from heart paralysis, without widespread molecular disintegration. This failure is shown by increasing weakness, frequency and inequality of the pulse, with quickened and shallow breathing, and coldness of the hands and feet. Allbutt has classified the modes of death in scarlet fever as follows: (1) hyperpyrexia (this Jenner denies positively); (2) specific blood-poisoning; (3) special malignity of the case; (4) asthenia. In the rather uncommon event of recovery from any of the most severe forms of scarlet fever, the progress is slow, the essential symptoms, complications, and sequelæ proving all very obstinate. In those cases in which extensive diphtheritic exudation precedes a rapidly fatal course, the eruption undergoes many modifications, the integument remaining pale except for some few splotches about the joints, at other times showing only a few dark-red patches irregularly distributed, and again entirely disappearing before death. At other times the eruption persists in full efflorescence.

Changes in the Blood.—The number of the red corpuscles in general is but slightly altered, more, however, in scarlet fever than in measles. The same may be said concerning the character of the red cells and the amount of hæmoglobin; in scarlet fever poikilocytes and normoblasts are occasionally found. The state of the leucocytes is much more characteristic. In measles there is either a normal number or a diminution of leucocytes; in scarlet fever there is hyperleucocytosis. In the former, as the temperature falls the leucocytes gradually increase; in the latter the temperature and leucocyte curve run parallel. In both diseases, but especially in measles, is the number of polynuclear neutrophilic cells diminished, while lymphocytes, both large and small, are relatively increased. The eosinophilic cells are diminished in number in measles, reaching their normal state long after recovery; in scarlet fever they are constantly increased.

COMPLICATIONS. — *Nephritis.* — Derangements of the kidneys are the most important complications of scarlet fever. Indeed, a number of recent writers assert that these organs are always affected in this disorder. Among these may be mentioned Frerichs, Reinhardt, Begbie, Newbigging, Holder, Böning, and Stevenson Thompson. Steiner states that evidences of kidney disorder are always present in those who die of scarlet fever. Thomas' clinical observations do not bear out this statement, and Friedländer, who examined the bodies of two hundred and twenty-nine persons dead of scarlatina, found kidney disorder in less than one-half. Though renal inflammation is not shown as yet to be a constant accompaniment of scarlet fever, it occurs much more often than is commonly supposed. Renal catarrh, which Eisenschitz declares to be as much a feature of scarlet fever as bronchial catarrh is of measles, is indeed an extremely common complication. It usually escapes detection from the general neglect duly to examine the urine. Thomas, in denying that this catarrh is at all constant, shows that it also occurs in measles, croupous pneumonia, etc., and is often only an expression of the febrile condition. Yet the catarrh is relatively so common in scarlatina that he cannot avoid concluding that the specific influence of the disease is often concerned in its production. In many cases, from the very beginning, cylinder-like masses of renal epithelium may be detected. In milder cases the urine will contain mucous casts with increased quantity of mucus, but no albumin. In more severe cases the urinary sediment will contain hyaline masses with epithelium and epithelial *débris*, and red and white blood corpuscles. Slight albuminuria will also be present. This catarrh is usually insignificant, and but rarely serves as the starting-point for the graver and characteristic forms of nephritis scarlatinosa, though doubtless many milder forms of nephritis and dropsy originate in it. Thomas concluded, however, that the cases of scarlatinal nephritis not developing from preceding catarrh, but arising suddenly, usually end fatally. Scarlatinal nephritis varies greatly in the relative frequency of its occurrence, involving from five to seventy per cent. of cases in different epidemics. In the Children's Hospital, Hillier noted its occurrence in about half of the cases. Dickinson [16] considered this rather below than above the average. Fleischmann [17] noted 95 cases of Bright's disease in 472 observations. During 1861 every third child with scarlatina had dropsy, while in 1862 it affected only one case in ten. Thomas asserts that renal alterations develop in about one-half of all cases of scarlet fever. It has been shown that there are those who assert that the renal alterations are constant. On the other hand, Jaccoud [18] declares that for fifteen years he has never had a case of nephritis among his scarlet fever patients, a result that he attributes to his treatment. Albuminuria may appear at any time during the attack of scarlatina, though its most common occurrence is during the second and third weeks. Dropsy should not be taken as marking the beginning of the nephritis, the signs of which may be present in the urine sometimes for days before this occurs. In Fleischmann's cases dropsy occurred 9 times during the first week, 30 times during the second week, 23 times during the third week, 20 times during the fourth week, and 5 times after the fourth week. Of 60 cases at the Children's Hospital, 42 began between the end of the first week and the end of the fourth week; 5 became dropsical during the first week.

Nephritis during the first week of scarlatina often escapes detection from the blending of its symptoms with those of the essential disease, and from the attendants' neglect to examine the urine. Dropsy will, of course, attract attention, but this does not often occur so early, and may be confounded with the œdema from the exanthem. Rarely, the fatal issue of what was, apparently, malignant scarlet fever, may really have resulted from uræmic poisoning due to a fulminating nephritis. The symptoms may be identical. Fever, vomiting, headache, delirium, amblyopia, coma, convulsions, may have been present. The convulsions are often very irregular. They may be general, partial, or unilateral, tonic or clonic. The patient may have them in rapid succession, or may pass into a *status epilepticus* from which death alone will release him. The urine will be completely or partially suppressed. If secreted it will be of high specific gravity (1.020 to 1.040), dark and smoky in appearance, loaded with albumin, and forming an abundant sediment of hyaline, granular, epithelial, and blood tube casts, with renal epithelium and white and red blood corpuscles in greater or less quantity. If the kidneys become implicated toward the end of the first week, the symptoms may delay the course of what may otherwise appear to be an ordinary case of scarlet fever. Microscopical research will often betray the onset of the changes in advance of chemical analysis; casts of the renal tubules will be observed, with epithelial deposits and detritus, before albuminuria is established. This will shortly appear, and in severe cases the nephritic symptoms will obscure those of the scarlatina. There will be no constant relation between the amount of albumin, the tube casts, and the general detritus, one variety of sedimentary matter being at one time copious, at another scanty. At this time vomiting may appear with returning headache, the appetite will again fail, and pain in the loins may become annoying; the patient may again become dejected and feeble, and his fever may cease to diminish—may even exceed its original intensity. At other times no apparent influence will be exerted upon the scarlatina, which will follow its usually mild course until dropsy and albuminuria reveal the state of the kidneys. When the renal disorder develops after defervescence, during the second, third, or fourth week, or later, the same series of symptoms may be observed, their severity being in direct ratio with the earliness of their occurrence. Cases developing after the fourth week may be expected to pursue a favorable course. Although it has been asserted that the renal disorder may arise several months after a scarlatinal attack, a patient will almost certainly escape it if he pass the sixth week in safety. The symptoms in cases arising during these weeks are not always gradually developed, and some of the most disastrous results of the disease may be encountered, during the second, third, or fourth week, in children apparently convalescing from scarlatina, and often in full desquamation, who, after indisposition for a few hours, with nausea, headache, confusion of ideas or stupor, with return of fever, rapidly pass into coma or convulsions, ending after a short interval in death, before dropsy has developed, but after partial or complete suppression of urine. Scarlatinal nephritis has usually a mild and favorable course. Dropsy is usually the first symptom observed, first appearing in the face and sometimes remaining confined to this locality; at other times becoming general speedily, and giving an appearance of plumpness, but with a wax like translucency of skin. The face, upper and lower extremities, body wall, and prepuce may thus become dropsical. The serous cavities are also implicated, and more or less effusion into the pericardial, pleural, peritoneal, scrotal, and intracranial cavities occurs. Œdema of the lungs and of the glottis may imperil life. Desquamation is often completely arrested upon the supervention of dropsy. The temperature is more commonly but little above the normal (38.3 to 39 C.—101 to 103° F.). The pulse, sometimes feeble and accelerated, will often become remarkably slow and intermittent, and so remain throughout the attack. The child will grow dull and listless, and extremely feeble. Pain in the belly and in the back may at times prove very distressing, or, again, it may be absent. The tongue, having lost the strawberry aspect of the eruptive stage, will become pale, flabby, and coated. The appetite will fail, and the bowels become sluggish. The urine will rapidly diminish in quantity and may deposit urates abundantly, or may present a smoky and oily appearance, due to the abundant presence of epithelial cells, white and red blood corpuscles, and tube casts. The total amount may now be reduced to a few ounces. The blood corpuscles often form a thick red layer at the bottom of the test tube. This free admixture of blood may amount to pronounced hæmaturia, is generally post-scarlatinal, and, according to Schütz, occurs most frequently during the third or fourth week. Of itself it adds but little to the gravity of the case. The patient often feels fairly well, and may eat and sleep with comfort. While the pallor and œdema may be very decided, the temperature and pulse may vary but little from the normal, or may show the variations of ordinary nephritis. With the gradual improvement of the general symptoms the hæmaturia disappears. Heubner has reported a case of nephritis after scarlatina in which hæmoglobinuria was present. The urine was brownish-black; no blood corpuscles were found. Death resulted from asthenia on the fifth day after both albumin and hæmoglobin had disappeared from the urine.

The amount of albumin in the urine in scarlatinal nephritis is usually very great. The urinary sediment is abundant, and is largely composed of tube casts, the hyaline character predominating; finely and coarsely granular, epithelial, and blood casts are, however, numerous. Later, coarse fatty granules stud the casts plentifully. These casts are often almost diffluent, and differ strikingly from the firm and sharply outlined ones of more chronic nephritis. Crystalline deposits are scanty, and are mostly of uric acid and urates; on the other hand, the amorphous urates are often very abundant. The degree of albuminuria present is of less importance than the total quantity of urine secreted, rapid and pronounced diminution of this indicating the accumulation of nitrogenous waste in the blood, and consequently the danger of uræmia. According to Glax, a lessening of the proportion of urine secreted to the fluid ingested (2:3) not infrequently foreshadows the approach of uræmic symptoms, even though the urine contain no albumin. Whether the temperature remain normal throughout the attack, or whether, after an initial chill, it become elevated, and all the symptoms of acute nephritis develop, complete recovery may reasonably be expected if the patient pass safely through the earlier phases of the disorder. But although nephritis may be mild—the dropsy lasting only a few days, and, perhaps, being limited to slight puffiness about the eyes—the disorder does not usually entirely subside in less than a month. It may endure as long as three, four, or even five months; and there is good reason to believe that chronic nephritis in young people may, in rare instances, have had its beginning in antecedent scarlatinal inflammation of the kidneys. Such a result is, however, exceedingly uncommon.

The dropsy indicates the degree of renal derangement, except in the most acute cases, and sometimes attains enormous proportions. As the urine increases in quantity the albuminuria proportionately diminishes, and the dropsy disappears. The skin, which until now has been dry and inactive, becomes softer, more elastic, and resumes its proper functions. The appetite improves, the spirits, strength, and mental activity return, and good health becomes gradually restored. Just as the microscope reveals the earliest evidence of renal derangement, so does it continue to expose the results of pathological action after chemical tests fail to do so. Tube casts continue to appear in the urinary sediment, sometimes for weeks after the cessation of albuminuria, the blood casts, epithelial, coarsely granular, and fatty casts gradually giving place to finely granular, hyaline, and mucous ones, which in turn finally disappear. When the disorder terminates fatally, the symptoms will be those of acute nephritis; suppression of urine may be followed by cerebral disturbance, headache of violent character, during which blindness may occur, with or without dilatation of the pupil, vomiting, and convulsions, partial or general, coma, and sometimes paralysis; or the fatal termination may be slowly reached through constantly increasing asthenia; or, what is more frequent, complications may arise which cannot always be definitely ascribed to the nephritis or to the scarlatina itself. Such are inflammations of the pleuræ, of the pericardium and endocardium, the peritoneum, the cerebral meninges, etc. Pneumonia, acute articular rheumatism, or enteritis, may also hasten the fatal issue.

Cases are occasionally observed in which dropsy follows scarlatina, but without albuminuria. Indeed, a tendency toward non-albuminuric dropsy after scarlatina has been associated with certain epidemics. Scarlatinal dropsy without albuminuria has been observed by Guersant, Rilliet and Barthez, Noirot, Bouchus, Löschner, Duckworth, and others. Quincke[19] tries to explain such cases of non-albuminuric dropsy as not depending upon nephritis, but as a consequence of the scarlatinal irritation exerting some peculiar influence upon the connective tissue. Cases occur probably in the experience of most practitioners. One should be cautious, however, in deciding against a nephritic origin of these dropsies, except where they can be definitely attributed to anæmia and debility. Henoch[20] has asserted that nephritis may occur without albuminuria up to the time of death. He reports a case in which anasarca was present for three weeks after scarlatina, without tube casts or albuminuria, until convulsions occurred, death resulting from œdema of the lungs. The necropsy revealed the presence of acute nephritis. He also reports the case of a child, dead on the thirteenth day, of malignant scarlet fever, in whom repeated tests during life had not shown albuminuria, and yet whose kidneys showed indubitable evidence of hemorrhagic nephritis. Steiner has seen nephritis without dropsy, but never dropsy without nephritis, after scarlatina. It is altogether probable, however, that in many cases the dropsy following scarlatina without albuminuria is secondary to concomitant anæmia. This is the view adopted by Henoch. Whatever be their explanation, such cases usually run no remarkable course. The general health is not much reduced. The urine is in normal amount, the various functions are fairly performed. With the disappearance of dropsy convalescence is established.

Scarlatinal nephritis is not associated with any especial phase or type of scarlatina. It is as frequent after mild as after severe attacks; indeed, it is possible that the care exercised over those who have grave attacks of the fever, in proper nursing and surroundings, may furnish a safeguard against renal complications. At all events, there is a widespread belief that the milder cases are more apt to be followed by nephritis and dropsy. Violent nephritis may certainly follow a scarlatina so mild as to have escaped observation. Individual predisposition and epidemic type are probably the most important etiological factors, though at present enough is not known to justify dogmatic statement. The nephritis and dropsy may occur without antecedent symptoms of scarlatina. Instances of this are not uncommon. Several members of a family or of a school or asylum in which scarlatina has been known to prevail may exhibit dropsy and albuminuria characteristic of scarlatina, without having manifested any other symptom of the disease. Such cases pursue an ordinary course generally, but at times develop a severity altogether unexpected.

Inflammation of the Lymph Nodes and Connective Tissue of the Neck.—Although Barthez and Rilliet, and others, have observed cases of scarlatina in which there was no angina, in one form or another it is nearly always present. More or less hyperplasia of the neighboring lymph nodes also constitutes part of the ordinary phenomena of scarlatina. The infection is supposed to originate in the throat, the hyperplasia being due to reflex irritation from the scarlet-fever contagium, or to the secondary streptococcus or staphylococcus or mixed infections. It has already been shown that the inflammation sometimes leads to suppuration and even gangrene of the glandular and periglandular structures. This especially occurs in scrofulous and rhachitic children, but is probably a result of septic absorption. The active symptoms become prolonged beyond those of simple scarlatina into the second, third, or fourth week, and even later, and merit some especial notice. They may not develop until as late as the third or fourth week, thus constituting true sequelæ rather than complications. Usually the fever continues after the subsidence of the eruption, the pain and stiffness of the neck increase, and deglutition continues painful and difficult, or even almost impossible. The mouth may be held open and saliva constantly dribble from it. The neck becomes hard, brawny, and swollen; the integument tense, smooth, and shining. The outline of the neck sometimes stands in line with that of the head and underjaw, and it becomes impossible to distinguish the enlarged nodes in the mass of inflammatory exudation. The patient is unable to find repose, or to swallow food or fluids, unless in small quantities and with great pain. Rest is broken and unrefreshing. Suppuration reveals itself by dark-red, livid spots which soon fluctuate; or it may be deep-seated and difficult to detect, or may point and discharge internally. The parotid gland and periglandular tissue often become involved. At times more or less widespread necrosis may lay bare important muscles, vessels, and nerves, and involve large areas of tissue. These diphtheritic and gangrenous inflammations may give rise to phlebitis or arteritis with thrombosis, and embolism with metastatic inflammation. Compression of the larynx, of the trachea, or of the jugular veins may also result. At times pus may burrow into the deeper cervical structures. Hemorrhage may also occur from exposed vessels. Baader[21] reported two cases of death from hemorrhage thus occurring. The extent of these phlegmonous inflammations of the neck varies greatly. In most cases, after the evacuation of pus, recovery follows, though slowly. In more severe cases death may result from exhaustion or from blood-poisoning. In healing, the scars may be insignificant, or, where granulation involves a large surface and is protracted, the resulting cicatrix may occasion deformity by its contraction. Retropharyngeal abscess, which has already been described, is not common. Schmitz, in the Child's Hospital in St. Petersburg, did not observe it once in 450 cases of scarlatina. Cases, however, have been reported. Bokai reported it as occurring seven times in 664 cases; of these 2 were fatal. Lewandowsky[22] reported 2 cases, both resulting in recovery.

Disorders of the Auditory Apparatus.—These are very important complications of scarlatina. Probably most cases of deafness acquired in early life are results of scarlatina. Of 85 cases of affection of the middle ear following this disorder, 18 had lost the sense of hearing in one or both ears, and 3 were deaf-mutes.[23] Milder degrees of middle-ear inflammation arise by extension from the throat, and are simply catarrhal; but the severer forms are preceded by croupous-diphtheritic inflammation of the fauces. The milder form of otitis media will cause the patient some earache, of which, if he is old enough, he will bitterly complain. Infants will indicate their sufferings by cries, by raising their hands to the ears, by rolling the head toward the affected side. If the Eustachian canal remain pervious, all inflammatory exudation may escape, and no symptoms, other than those mentioned, and slight and transitory deafness, may occur. This latter symptom may result from the pressure of an enlarged parotid gland upon the external auditory canal. But in the severer forms the pain may be excruciating, the deafness more or less complete, and the fever high. The Eustachian canal becomes occluded from inflammatory swelling, and exudation accumulates in the cavity of the tympanum. Headache may be violent. The drum membrane will be bulged outward from internal pressure, and will be reddened and swollen. The pent-up fluid, unless released by puncture of the drum membrane, finds an exit for itself by perforation. Extreme pain is often produced by pressure upon the tragus and over the mastoid process. Rarely, delirium may be followed by signs of meningitis from extension of the inflammation from the middle ear to the dura mater, along the course of the middle meningeal artery. In mild cases the inflammation will subside, with or without perforation of the drum, and hearing may be perfectly restored. In severer cases, timely tapping of this membrane may yet preserve the sense of hearing; but, unfortunately, it but too often happens that the ossicles of the ear and the tympanic membrane are destroyed; the bony walls, even of the middle ear, become carious, and irreparable damage is done. The severer inflammations involve a croupous diphtheritic process that often entails wholesale destruction. According to Green, disease of the labyrinth, involving absolute deafness, may occur within a day or two. In such cases the watch held to the skull, the ear, or between the teeth, may not be heard. Green[24] thinks that when loud "clashing," "ringing of small bells," or "musical notes" are heard during scarlet fever or cerebro-spinal meningitis, these are apt to be immediate premonitions of labyrinthine disease; whereas the subjective sounds always accompanying acute purulent inflammation of the tympanum are described as "hissing," "singing," "buzzing," or "throbbing." He also suspects that the fluid secreted in immense quantity—a clear, limpid serum, differing from the wine-yellow serum of tympanic inflammation, may be labyrinthine peri- and endolymph. Pus may form in the mastoid cells. These changes may occur either as complications or as sequelæ. Caries sometimes appears quite early, and the chronic otorrhœa thus set up may last for years, occasioning widespread disorder of both soft parts and bone.[25] In necrosis following middle-ear disease, the facial nerve may become involved with subsequent paralysis. Fatal hemorrhage from the ear may occur after scarlatina, from exposure of vessels from the diphtheritic processes.[26]

Chronic posterior nasal catarrh, and necrosis of the bones of the nasal cavity, constituting various degrees of ozæna, sometimes follow the extension of the pharyngeal inflammation to the nasopharynx. The eye may likewise be implicated in scarlet fever. Conjunctivitis may develop as a complication, or diphtheritic inflammation may extend along the lachrymal canal and involve the conjunctivæ. It may produce keratomalacia and even destruction of the eyeball. Retinitis after scarlatinal nephritis has been observed by Schrötter. Its course is favorable. Temporary blindness may be due to uræmia. Acute amaurosis after scarlatinal nephritis has been noted.[27] Transitory blindness, lasting for from twenty to sixty hours, has been observed by Ebert,[28] Henoch,[29] Tolmachew.[30] In a case of Förster's it lasted eighteen days.

INFLAMMATION OF JOINTS.—Not very infrequently inflammation of the synovial membrane of the joints appears as a complication or as a sequel of scarlet fever. The usual date of its occurrence is during the second week or later. It is often only indicated by pain without swelling, and may be limited to a single joint. In other cases a number of joints are involved, usually the ankles and wrists, knees and elbows. The hip joints may be affected, and also the smaller joints of the extremities. The inflammation may betray all the features of acute rheumatism—the fugitive character of the inflammation, the metastases, the sweating, the fever, even the tendency to implicate the other serous surfaces, the pleura, the endo- and pericardium, and the meninges. Mahomed's[31] studies showed that, as the urine increases in quantity from the seventh to the fourteenth day, it loses its deposit of lithates, and often its albumin (if this has been present). It is highly acid, and uric acid is abundantly thrown down by the nitric-acid floating test. It was at this period that he found the rheumatism most apt to occur. This rheumatism seems identical with ordinary acute rheumatism, but follows a less protracted course. Numerous writers have seen purulent arthritis as a sequel of scarlatina. It commonly occurs during the second or third week, and in most instances is monoarticular. Pyæmic arthritis usually results in suppuration, erosion, and destruction of the cartilage of the joint. According to Spender,[34] the wrist-joint is most often attacked, next in frequency the knee and hip. Recovery may take place, but usually death follows the discharge of pus and the formation of fistulous openings, from exhaustion, or from the further progress of the pyæmia. The approach of these complications, which are fortunately rare, may be recognized through the thermometer.

Affections of the Heart and Pericardium.—Cheadle[32] quotes fifteen cases from West, in which endo- or pericarditis, or both, supervened upon scarlatina. These did not occur during the acute stage, but during desquamation. He, however, considered them rather the result of uræmia and nephritis than of rheumatism. Henoch[33] relates two cases in which acute arthritis appeared during the first week of scarlatina, followed by severe chorea and loud mitral murmur. As to the cardiac symptoms, Cheadle concludes that they occur in scarlatina as results both of scarlatina and of nephritis. He also thought that "scarlatina would appear to have a special influence in causing dilatation and hypertrophy without accompanying valvular disease." Endocarditis, which not uncommonly arises, may be very insidious, and may even pass undetected if not looked for. Probably not a few old valvular affections have originated in attacks of scarlet fever. Acute pleuritis or pericarditis may accompany joint inflammation, or may occur independently. In severe cases they may result in purulent exudation and ultimately terminate fatally. Sometimes the serous inflammations are pyæmic. Endocarditis ulcerosa may begin in this manner.

In the most severe and malignant cases of scarlatina the heart muscle undergoes, first, cloudy swelling, and later, fatty degeneration, especially on the right side. This is the occasion of death from heart failure in many malignant cases.

Affections of the Respiratory and Alimentary Tracts.—Inflammation of the respiratory tract is decidedly uncommon in milder scarlatina. Bronchial catarrh is apt to complicate serious cases. Pneumonia is seen sometimes as a secondary complication following nephritis, diphtheria, etc. Disorders of the intestines are also uncommon. Diarrhœa, when present, is usually associated with severer forms. Diphtheritic enteritis was the most frequent sequel in the cases observed by Fleischmann. Peritonitis may occur as a rare complication. Henoch has seen bedsores complicate scarlatina.

SEQUELÆ.—The affections that constitute true sequelæ usually are disorders that persist after scarlet fever has completed its course, having begun as complications. Thus are encountered chronic buccal, pharyngeal, nasal, and aural inflammations, nephritis (which, as a rule, ultimately entirely disappears), or inflammation of the various serous membranes. In some cases, marked by severe eclamptic seizures, there results contraction of different groups of muscles, giving rise to permanent deformity. Chorea may develop in connection with the arthritis and endocarditis. Progressive involvement of the limbs with paralysis and wasting may rarely be met with, showing the clinical features of an ascending spinal paralysis. Cerebral thrombosis and hemiplegia rarely occur. Mania has been known to follow scarlatina.[35] Gangrene, apart from that resulting from diphtheria of the throat, is infrequent. Noma has been observed by a number of writers (Barthez and Rilliet, Heyfelder, Böning, and others), but it is notably less common than after measles. Necrosis of the nasal cartilage was observed by Henoch during convalescence.

Concurrence with Other Specific Affections.—Scarlet fever may be complicated by, or may complicate, other acute exanthemata, not to the extent, however, that many writers believe. Mayr and Hebra, indeed, taught that scarlatina never coexists with measles or smallpox. This question is involved in much obscurity. Scarlatina may be simulated by a variety of affections that may in fact coexist with the exanthemata, by various erythematous eruptions, by the roseola that often precedes and accompanies the eruption of smallpox, by certain anomalous forms of measles, and by various medicinal rashes—those caused by belladonna, copaiba, chloral, and especially cinchona and its preparations. These considerations and faulty methods of observation and recording lead to the rejection of much of the evidence adduced in favor of these coexistences. After all faulty observations are thrown out, however, there still remains strong proof that scarlet fever may coexist with other exanthems. It will be everywhere admitted that one exanthem may follow close upon the heel of another. Prior[36] noted a case in which scarlatina developed on November 18th, varicella on December 2d, and measles on December 13th. When the two exanthems develop simultaneously, there will often remain much doubt, in the absence of evidence of the double exposure of the unprotected individual and of his subsequent double protection. Where one precedes the other by a few days, the difficulties are not so great. Scarlet fever has been observed as complicating, or complicated by, other exanthemata by Steiner,[37] Monti,[38] Thomas,[39] Fleischmann,[40] Fabore,[41] Stillen,[42] Zechmeister,[43] Backer,[44] Dornig,[45] Lewis Smith,[46] Murchison,[47] and many others. The combinations and the order of occurrence have been noted as follows, viz.:

Scarlatina and measles.
Measles and scarlatina.
Scarlatina and smallpox.
Smallpox and scarlatina.
Scarlatina and vaccinia.
Scarlatina and varicella.
Varicella and scarlatina.
Scarlatina and typhoid fever.

Concurrence of scarlatina and Rötheln has not been reported. A probable source of fallacy is the scarlatiniform rash that is often observed in smallpox, and occasionally in typhoid fever; indeed, Simon asserts that Fleischmann has even made this very error. The possibility of these rashes should always be held in mind when questions of concurrence are under consideration. When scarlet fever develops after smallpox the eruption involves the parts of the skin left free by the lesions of smallpox, more especially about the chest and abdomen. When the two exanthems appear simultaneously, their course is shortened; "the second mitigates the first and becomes shortened itself," excepting, according to Fleischmann, when severe smallpox occurs in connection with scarlatina, when death usually results. The same author asserts that if scarlatina appear at the period of maturation of smallpox, the latter, in mild cases, is shortened and mitigated. When scarlatina complicates measles, the latter is shortened, but the scarlatina thus occurring may be mild or severe. Barthez and Rilliet noted that in scarlatina-measles, when the former malady predominates, bronchitis is more marked; but when measles is most severe, faucial angina is worse. All of these statements lack such evidence as would entitle them to unqualified acceptation. Very often neither disease is well developed, and the true condition may be very difficult of recognition. In America these concurrences are more uncommon than they seem to be abroad.

Whooping-cough has been known to complicate scarlatina, and a number of non-specific affections may occur simultaneously with it. These coincidences are purely accidental and present no peculiar interest. Biart[48] has reported psoriasis as following scarlatina. Barthez and Rilliet assert that tuberculous children very rarely have scarlatina. Some chronic affections partially or entirely disappear during an attack of scarlatina. Among these may be especially mentioned certain cutaneous affections, eczema, psoriasis, etc., but they usually reappear upon the establishment of convalescence.

Surgical Scarlatina.—Sir James Paget, in 1864, and again in 1875,[49] declared that patients who have undergone surgical operations are peculiarly susceptible to the action of the scarlet fever poison. This question has attracted a great deal of attention. In France, Trélat was the first to accept this view, though scarlatinoid rashes had been observed by Civiale, Germain Sée, Tremblay, and others. Similar rashes were reported by Hutchinson, Hilton, Bryant, Lee, Moore, Stirling, and others. They had generally been considered as of septicæmic origin. In 1879 Paley and Goodhart[50] and House[51] reported observations of endemics of scarlatina in the Evelina Hospital for Sick Children and in Guy's Hospital. The first-named authors based their report upon twenty-five cases of scarlatina occurring in surgical patients. Of these nineteen were known to have been exposed to scarlatina, and all the rest, save one, were known to have had possible sources of infection. House's paper was based upon four cases of surgical scarlatina. The epidemic tendencies ceased upon the establishment of isolation, and one cannot doubt their scarlatinal origin. These writers were careful not to assert that *all* such red rashes should be attributed to scarlatina, or that there is *not* "such a thing as a rose rash in a typical case of septicæmia"; but they believe that when occurring in groups they may nearly always rightly be attributed to scarlatina. Riedinger and Howard Marsh also agreed that there exists in wounded persons a predisposition to scarlatina. While Holmes coincided with these views, he, however, declared that many cases of "surgical scarlet fever" are really due to pyæmia and other causes. Most recent writers incline to the opinion that these eruptions are due to true scarlatina. When any epidemic tendency is shown, every one will agree with such conclusions. This cannot be granted of rashes occurring in isolated cases. Of 25 cases reported in Paley and Goodhart's paper, scarlet fever attacked 17 after operations; 7 were without any wound whatever, and 1 had only an old sinus. In many of the cases reported by other writers there was no open wound. These reporters, unfortunately, most rarely note whether their patients had ever previously had scarlatina. Most children, when first exposed to the contagion of this disease, become infected. Is it remarkable that they are unable to withstand it when it attacks them, weakened by injury or surgical operation? Apart from epidemic influence, it is probable that scarlatiniform eruptions in the wounded may justly, in a large proportion of cases, occur quite independently of scarlatina. Rashes of septicæmic origin are well known to occur. Various fugitive eruptions often result from emotional and nervous irritations, or from the ingestion of certain articles of food or medicines. It must be admitted that scarlatiniform septicæmic rashes are uncommon. But there is excellent evidence that they occur.[52] Attempts have been made to establish a differential diagnosis for the surgical scarlatiniform rash. Cheadle,[53] for example, claimed that it has specific characters in not often being universal, and in being confined to the body and parts covered by the clothing; that it rarely lasts twenty four hours, and that it never desquamates. He also asserted that there is no tonsillar swelling, nor glandular enlargement, nor the peculiar "strawberry tongue." Such points of differentiation do not appear to be well founded. Scarlatiniform eruptions also occasionally follow the ingestion of certain drugs. They may be evoked by belladonna, copaiba, opium, chloral, mercury, and other drugs, but, above all, by cinchona bark and its derivatives. These eruptions are much more common than is generally supposed. Quinine has been frequently given to those who have been injured or submitted to surgical operations, and beyond question eruptions evoked by it are often attributed to other causes. A number of eruptive forms are observed, but the one of especial moment is the scarlatiniform rash. At the onset it often cannot be distinguished from scarlatina. Beginning with high fever and often with sore throat, the eruption appears upon the face, chest, and neck, and within twenty-four hours the entire surface may present a bright scarlet aspect. At the end of this period the resemblance may be made perfect by the "strawberry tongue." Up to this point the diagnosis may be impossible. Rarely, it remains so throughout the attack, especially when the ingestion of the cinchona preparation is continued. Usually, however, after thirty-six or forty-eight hours the type of normal scarlatina is departed from. The fever rapidly decreases, the angina disappears, and the rash either fades or acquires features unlike those of true scarlatina. It becomes duller, more papular, and often tends to form miliary vesicles. Eventually it may resemble ordinary "prickly heat." Sometimes, however, the scarlatinal features are preserved throughout. In either case a copious desquamation is sure to follow. This is usually lamellar. Even albuminuria has been known to add to the embarrassment of the diagnostician. These medicinal and septicæmic rashes occur in isolated instances, and may at times baffle the keenest diagnostic powers. We may conclude that unprotected persons who have suffered injury or who have undergone surgical operations are rather more liable to scarlatina than the unprotected healthy. Scarlet fever is more apt than the other exanthemata to attack such persons, because its symptoms vary within such wide limits that it often escapes the attention of those who readily detect other infectious disorders and provide against them. When an epidemic tendency of the symptoms we have been considering is shown to prevail, it may be confidently concluded that true scarlatina is present. Septicæmia is occasionally accompanied by a scarlatiniform rash which does not depend upon the scarlatinal poison. These rashes are often attributed to scarlatina.

Scarlatina Puerperalis.—While pregnant women seem to enjoy a remarkable immunity from the specific eruptive fevers, it is well known that during the *puerperium* they are especially subject to them after exposure, and that the disease is then apt to pursue a grave and often fatal course. Not only scarlatina, but measles and smallpox may affect the lying-in woman with such malignity that the symptoms may not acquire the features of the maladies to which they belong, but become indistinguishable from those of malignant septicæmia. Scarlatina is especially liable to attack the lying-in woman. It may assume the virulence referred to, or it may pursue a course in which it is difficult to determine whether its symptoms are septic or really scarlatinal, or, finally, it may appear with typical and unmistakable features. Not a few writers have thought that the scarlatinal virus may produce in the puerperal woman septicæmia, pure and simple. This view is maintained by Playfair, Braxton Hicks, Leishman, and others. They assert that in these women, after exposure to the specific contagium, symptoms of acute blood-poisoning may be developed, and not those of scarlatina. On the other hand, just as in septic conditions, independent of puerperal causes, an erythematous rash and other scarlatinal symptoms may be observed in which true scarlatina has no part, so must one guard against assigning to scarlatina every scarlatiniform rash occurring in obstetrical cases. It may be septic in origin, or it may be a medicinal eruption. When a septic, or medicinal, or other form of erythema can be excluded, and when exposure to scarlatinal influence is followed by any degree of the symptoms we are considering, are we in atypical cases to look upon the results of the infection as distinctly scarlatinal? More recent writers regard the scarlatinal nature of the disorder as preserved, and as capable of further dissemination. It has not been determined to what extent women who have already had scarlatina preserve an immunity from further attacks during their lying-in period. It would appear that the intensified predisposition of the childbed carries with it an increased liability to second or third attacks. Busey[54] has related a case in which the patient had already had scarlet fever. Other such cases are upon record.[55]

In all probability the scarlet-fever contagium evokes scarlet fever, and not septic disorder, in the puerperal woman, whose systemic condition affords peculiar susceptibility to its influence, and predisposes her to a virulence of its activity that often leads to disastrous results. The less remote the date of delivery the graver the course of the malady is apt to be. If the symptoms do not appear before the seventh day, their development is no longer to be feared. Olshausen[56] collected from the literature 111 cases, of which the scarlatina attacked, during pregnancy, 7; in 8 it immediately followed delivery; in 62 it occurred on the first and second days; in 27 on the third day; in 22 after the third day. After the fifth day none was attacked. While the puerperal woman shows intense susceptibility to scarlatina, the pregnant woman enjoys a marked immunity from it. Olshausen thinks, however, that the period of incubation may last for months during pregnancy, but only a few days during childbed. This opinion he rests upon no solid basis. Primiparæ are more often attacked than multiparæ. The mortality in puerperal scarlatina is high. In the series just alluded to it was 48 per cent (3 cases during pregnancy and 64 in childbed).

In the recorded cases studied by McClintock[57] the mortality was over 66 per cent. In 34 cases at the Lying-in Hospital the death rate was 30 per cent. Of 10 deaths at this hospital, 8 occurred when scarlatina had developed within thirty-six hours after delivery. Of 18 patients attacked on the first or second day, 8 died. Of those attacked on or after the third day (16 in number), all but 2 recovered. McClintock also quotes Dr. Halahan's cases, as follows, viz.: 3 patients, ill of scarlatina at the moment of delivery, died; of 5 attacked during the first twenty-four hours, but 1 recovered; of 10 attacked during the second day, but 1 recovered; of 4 attacked during the third day, but 1 recovered. The remaining 3, attacked on or after the fifth day, recovered. Braxton Hicks'[58] contributions to this subject have been most important. He believes that in one-half of the cases the usual symptoms of scarlatina are manifested, and that the disease almost always commences after the third day after delivery. The death rate will be greater the earlier after labor the symptoms develop. Though lying-in women are peculiarly liable to scarlatina, they are frequently exposed to its influence without detriment. Women have not seldom been confined in the room, even in the bed, occupied at the same time by scarlet-fever patients, without experiencing the slightest interruption of their normal convalescence; a result that is not astonishing in protected persons if the scarlatinal virus transmits only scarlatina, but which would not be expected were the virus equally competent to communicate septicæmia in these cases. While a large proportion of cases pursue a grave and anomalous course, there are many others in which a perfectly typical scarlatina is observed, without seriously endangering life. Secondary inflammations are not unknown. Metritis, cellulitis, peritonitis, or pyæmia may be developed, but whether these are direct results of scarlatina or of the puerperal condition is undetermined.

The exact nature of puerperal scarlet fever and surgical scarlet fever will remain in doubt until a specific organism of scarlet fever can be isolated. At present this is impossible. In the mean time it is interesting to note that with the development of aseptic and antiseptic methods in surgery and obstetrics, less and less is heard and seen of "puerperal" and "surgical" scarlet fever.

Relapses and Recurrences.—There are recorded numerous instances of relapse of scarlet fever within a short period after the original attack, and second or even third attacks after a more or less prolonged interval are well known to occur. By a relapse is meant a second attack of scarlatina that is evidently due to the persistent activity of the influences that excited the first attack.

Within a short period (three days after deflorescence in a case of Woldberg's[59]) after the original attack all the symptoms are repeated; the initial disturbances, the fever, the eruption, the angina, and other phenomena, with ensuing desquamation, are developed. It is held that the second attack is but the completion of the first, that it occurs after an incomplete primary attack, and that it tends to be severe in proportion to the mildness of the first, and often to affect in eruption only those parts which were originally spared,[60] imparting thus to the second eruption the appearance of scarlatina variegata. The relapse may be accompanied by complications of throat, kidney, and other disorders, that were not present in the earlier disorder, and *vice versa*. These relapses are usually very rare, but seem to be more frequent in certain epidemics.

Thomas applies the term pseudo relapse, or *reversio eruptionis*, to those cases in which the exanthem returns before the disorder has entirely completed its course. Trujawsky found the interval between the two attacks to be from seven to ten days, with an average of eight and five-eighths days. The intermissions are completely afebrile. These relapses have been explained by, (1) a recrudescence of the original contagion, and (2) the action of a newly acquired contagion from a source different from the original one. The prognosis is often graver than in the primary attacks.

Recurrences or attacks of scarlet fever occurring after a more or less protracted interval are more common, and are due to fresh infection. They may occur at almost any period. Trujawsky[61] noted, in 300 cases of scarlatina, 18 patients who had had a former attack. Of these 4 were under ten years of age, 10 were over ten years, and 3 were adults. The interval between the attacks varied from one and a half to seven years. Thomas had personal knowledge of a case in which a second attack occurred. Willan never saw one. Many years may elapse between the two attacks, as when a mother who had the disease during childhood again develops it by contagion from her child. Heyfelder himself had a second attack twenty-seven years after the first one. Trujawsky thought that immunity is greater against contagion originating at the home or in the neighborhood of the patient than when it is brought from a distance. A third attack in the same individual may be observed (as in Richardson's case), and there are reports of repeated attacks of scarlet fever. Bernouilli,[62] for example, mentions the case of a woman, fifty years of age, who experienced in rapid succession six attacks of an exanthem indistinguishable from scarlatina. Other similar cases are on record, but their consideration suggests that they may rather have been forms of medicinal eruption.

Acute exfoliative dermatitis may also be mistaken for scarlet fever, and may attack repeatedly the same person. Rashes resembling scarlatina may occur in various other affections, such as typhoid fever, smallpox, etc. Hallopeau and Tuffier[63] saw a scarlatiniform eruption in acute rheumatism, in which there were two relapses with intense erythema, followed by copious desquamation. The possibility of all such cases being mistaken for scarlatina should be remembered. It is a rather singular fact that many persons suffer from angina whenever they are brought into close personal relationship with those who have scarlet fever. This is commonly mild, but may occasion serious discomfort. Those who suffer thus from exposure to the scarlatinal influence do not communicate scarlatina to unprotected persons. Mild desquamation is said to have been noted in some such cases. This, however, would indicate a true scarlatinal infection.

Pathological Anatomy.—In most fatal cases every trace of eruption disappears after death. After a very intense exanthem, more or less redness may remain. After malignant cases blood extravasations may present the only post-mortem discoloration. The organs primarily affected are the *skin* and the *throat*; the principal complications arise in connection with the *ear* and *cervical lymph nodes*; and the chief sequela is *nephritis*. The *heart* may be affected as a result of the general septic condition, but its lesions are more frequently dependent upon the changes wrought in the kidneys.

Skin.—Remy[64] and Neumann have investigated the histology of the skin in scarlatina. Remy found the capillaries of the papillary layer dilated and hyperæmic, and filled with leucocytes which were enlarged and of different sizes, but not so large as in leukæmia. The vascular wall was not altered. The epidermis was thickened by increase of its cylinder cell layer. The horny layer, sebaceous glands, and hairs were unchanged. The sweat glands were empty and shrunken. Neumann found the cells of the rete swollen. In many specimens the prickle cells were elongated, and here and there formed interspaces in which exudation cells were embedded, and into which small blood extravasations often occurred. Exudation cells extended abundantly as far as the horny layer, and at the orifices of the follicles they were very numerous. In measles this epidermal layer presents no marked changes; hence it is not difficult to understand why the epidermal cells are so much more liable to carry the contagium in scarlet fever than in measles. The corium was swollen, the fibres were thickened, partly separated by proliferation, partly by enormously dilated vessels that were at times bulbous. It is this exudation into the epidermal layers that causes the loosening of the horny layer from its bed, and the characteristic desquamation. Löschner and Fenwick have also noted this infiltration of the rete. The latter writer found the basement membrane of the sweat glands also thickened and the lining membrane gone in places, but in other places it was increased so as to occlude the sweat glands. The deeper layers were normal throughout. The scarlet-fever exanthem, then, consists of hyperæmia with exudation. Remy found the changes he describes regularly and uniformly distributed.

Throat.—The throat symptoms, as constant as are those of the skin, are due to lesions that are always recognizable after death. The milder alterations offer nothing characteristic; they are identical with those of pharyngeal catarrhal inflammation. In more intense degree follicular inflammation, with suppuration and ulceration, is superadded, and œdema becomes more prominent. The inflammatory changes extend beyond the pharynx into the buccal and nasal cavities, while parenchymatous tonsillitis and inflammation of the cellular tissues of the throat and neck develop, with, sometimes, extensive gangrene.

According to Härlin (Thomas), scarlatinous angina is specific, and is marked by "a deep, bluish-red injection of the mucous membrane of the tonsils and neighborhood, of the uvula, of the posterior portion of the tongue in the neighborhood of the highly swollen papillæ, of the posterior portion of the region of the cricoid cartilage, and of that portion of the pharynx which includes these different parts, and measures about two inches in breadth." This coloring is said to be sharply outlined in the direction of its transverse diameter.

Among the earlier writers on scarlet fever, and as late as the years 1883 and 1884 when the Klebs-Loeffler bacillus was discovered and demonstrated as the specific cause of diphtheria, much space was devoted to the nature of the diphtheritic membrane so often formed in scarlatinous angina. The weight of opinion was that the scarlatinal virus, acting upon the virus of the throat, caused a coagulation necrosis that resulted in the production of the membrane, although it was held that occasionally the scarlatinal process might be complicated by a true diphtheria. The result of modern bacteriological researches has shown that the diphtheritic membrane is in all probability the result of the activity of streptococci and staphylococci or of a mixed infection. There may be, of course, a Klebs-Loeffler infection as well. The influence exerted by the scarlatinal virus in the production of the pharyngeal inflammation cannot be determined in the present state of our knowledge of the specific cause of the disease.

Kidneys.—Bacteriological examinations of the tissues in scarlet fever frequently show general streptococcus infections, probably having their origin in the lesions in the throat. In a number of these cases there may be found in the kidneys extensive lesions which bear no relation to the presence or absence of streptococci; on the other hand, streptococci may be found in the kidney without any lesion of the kidney.[77] We may assume, therefore, that at times the pathological changes are a result of soluble chemical poisons produced by the virus of scarlet fever or by the activity of the associated secondary infections by streptococci and staphylococci, and at times the lesions are due to direct infection of the kidney by organisms conveyed to it by means of the blood.

Councilman, who has made recent and extensive studies in the pathology of scarlet fever, divides the kidney lesions into two classes: (1) Representing simple degeneration of the epithelium; and (2) representing marked changes in the tissues of the kidney. The lesions of the second class he divides according to their anatomical distribution into (*a*) *interstitial*, in which there is marked proliferation of the interstitial tissue of the kidney; and (*b*) *capsular glomerular*, in which the lesions are chiefly confined to the glomerulus and its capsule.[77]

The first, the purely degenerative form, appears at the beginning of the exanthem, or a few days later, and disappears in a few days or weeks. It rarely excites œdema, and hardly ever kills. It is analogous to the alterations productive of the febrile albuminuria of many infectious diseases. Cloudy swelling and proliferation of the tubular epithelium, and, later, fatty degeneration, are shown. Within the tubular lumen are hyaline and granular cylinders, round cells, and desquamated epithelium.

The second type, the *interstitial*, was first described by Wagner as the lymphoid kidney.[77] The kidney is swollen, the capsule is easily stripped from the cortex, and the surface is moist, whitish, and opaque. Usually there is no hemorrhage, although in some cases punctiform areas may be found in the cortex and intermediate zone. The epithelium may show the changes characteristic of the first or purely degenerative class. The most marked feature of this class of cases is the thickening of the interstitial tissue and the abundant infiltration with round cells, most of which are plasma cells, with some lymphoid cells and polynuclear leucocytes. This form of nephritis may be markedly developed and yet not give rise to clinical symptoms any more pronounced than are seen in the first or purely degenerative class. It is not confined to scarlet fever, but may occur in the course of diphtheria, measles, and other infectious diseases of children, but is not commonly produced in adults in the same class of diseases.

The third form of nephritis, the capsular glomerular, is a more frequent accompaniment of scarlet fever than of any other infectious disease, but is not so common as the acute interstitial form. The kidney is swollen and hyperæmic, the markings of the cortex are obscured or effaced, while the hemorrhagic areas give to the kidneys a mottled appearance. Histologically the chief lesion of this form consists of a proliferation of the capsular epithelium combined with hyperplasia of the connective tissue. The proliferation of the capsular epithelium increases the pressure upon the glomerulus so much as to interfere with the blood supply and hence with the secretion of urine. It is this form of nephritis which is especially liable to give rise to dropsy, to greatly diminished amounts of urine, or to uræmia. The clinical appearance of the urine is that of an acute diffuse nephritis, the amount of blood, albumin, and casts depending largely upon the severity of the infection. Recovery may take place even from the severe forms of capsular glomerular nephritis, but chronic nephritis is a sequela in a certain number of cases. Friedländer holds this to be the only characteristic scarlatinal nephritis.

These three forms of nephritis—the simple degenerative, the interstitial, and the capsular glomerular—may usually be recognized histologically, but transition changes occur. It is not always practicable to make sharp definitions between early and late changes. The first set of changes are chiefly limited to the cortex. They are: 1. Increase of nuclei (probably epithelial) covering the glomeruli. 2. Hyaline degeneration of the elastic intima of minute arteries, especially of the afferent arterioles of the Malpighian tufts. The intima of these vessels is swollen here and there into spindle-shaped hyaline masses, causing narrowness of the lumen. There is similar hyaline degeneration of the capillaries of the glomeruli, rendering them often impermeable. These degenerated parts become fibrous in appearance, and Bowman's capsule becomes thickened. 3. A third change is multiplication of the nuclei of the muscularis of the minute arteries, with increased thickness of their walls. This is greatest at the point of entrance into the glomeruli, but is also distinct in other arteries of the cortex and in the base of the pyramids. There are also swelling of the epithelia of the convoluted tubules and proliferation of their nuclei, especially of the tubules close to the afferent arterioles of the glomeruli. In some cases the epithelium of the large tubules of the pyramids is detached. Klein's[66] observations, (1) that the hyaline changes readily affect the arteries near their point of branching, and (2) that the hyaline substance is of the nature of elastic tissue, agree with the conclusions of Neilson concerning the arteries in various cerebral disorders and in many infectious diseases. He does not think that the anuria and uræmic poisoning in scarlatina, when the kidney does not show conspicuous change, are due to compression of the vessels of the glomerulus by the nuclear germination, as claimed by Klebs,[67] but rather to the changed state of the arterioles, and suggests that the increased formation of arterial muscular fibres, under the stimulus supplied by the disease, may cause a contractility that obliterates the calibre of the arterioles and shuts out the glomerulus from the circulation, and thus, so far as it operates, suppresses the secretion of urine. The parenchymatous changes found in the early stages are slight and difficult to detect, the cloudy swelling and granular degeneration being limited to small portions of convoluted tubules. The second order of changes begins about the ninth or tenth day. They are interstitial as well as parenchymatous. Round cells are found around the larger vascular trunks, spreading into the bases of the pyramids and into the cortex. This process begins about the end of the first week, and gradually increases until portions of the cortex, rarely portions of the bases of the pyramids, are converted into pale, firm, round-cell tissue, in which the tubules become compressed and obliterated. The parenchymatous element of the nephritis consists in crowding of urinary tubules with lymphoid cells and various kinds of tube casts, and fatty degeneration of the epithelium of the tubules. This grows more marked with the advance of interstitial changes. The round-cell infiltration of the cortex begins at the roots of the interlobular vessels, spreading rapidly toward the capsule of the kidney, and laterally among the convoluted tubes around the glomeruli, at first between the medullary rays, but later encroaching upon them. Portions of the cortex may be converted into firm, pale, bloodless cellular masses in which Malpighian tufts and urinary tubules become more or less destroyed. In one case renal embolism was encountered; both interstitial and parenchymatous inflammation was very intense. The kidney was markedly enlarged. Klein also noted deposition of lime in the epithelium and lumina of the tubules, first of the cortex and then of the pyramids, at an early stage of scarlatina, when only slight changes are otherwise shown. He concludes that cases of scarlatina which are fatal after the ninth or tenth day usually show more or less well-marked interstitial nephritis.

Lymph Nodes.—Peculiar changes have been noted in the lymph nodes by Klein. In addition to the ordinary inflammatory infiltrations which he describes as occurring in the lymphatic follicles connected with the organs of the throat and in the lymph nodes of the neck, the ordinary lymphoid cells are greatly diminished in number, and are replaced by large granular cells containing numbers of germinating nuclei.

Liver.—This viscus becomes slightly enlarged from cloudy swelling. In one case Klein noticed, after two days' illness, acute interstitial hepatitis. The middle and internal coats of some arteries show the same alterations as in the kidneys. Wagner observed lymphoid new formations and numerous collections of cells and nuclei, especially in the interacinous connective tissue.

Spleen.—In the spleen the changes are uniform and constant. They are: 1. Enlargement of the Malpighian corpuscles. 2. Hyaline degeneration of the intima of the arteries. 3. Proliferation of the nuclei of the muscular coat of the ultimate arterioles, with increased thickness of their walls. 4. Hyaline swelling and degeneration of the adenoid tissue around the degenerated arteries. 5. In the central parts of the Malpighian corpuscles the ordinary nuclei of the lymph cells disappear, and in their stead are found large hydropic cells containing pigment (Klein). Other writers assert that there is no uniformity in the splenic changes, beyond a slight enlargement. Biermer has observed enormous enlargement of the Malpighian bodies.

Intestines.—Disorders of the alimentary canal are not frequent in scarlatina, and when they occur it is usually in grave cases. They then not infrequently constitute the principal complicating lesion. In the cases of Fleischmann, diphtheritic enteritis was the most common sequel. The peculiar "shaved-beard appearance" of Peyer's patches has been at times observed, and at times these patches and the solitary glands are prominent, reddened, and inflamed, with associated tumefaction of the mesenteric glands (Harley). Barthez and Rilliet show, however, that in cases in which the typhoid-like lesions have been discovered, the symptoms shown during life did not resemble those of typhoid fever; and conversely, cases of typhoid scarlatina cannot be expected to reveal these lesions after death. Enteritis is more often catarrhal in nature. It has been asserted that in scarlatina the exanthem invades the mucous membrane to the same degree as the skin. Post-mortem evidence of this, however, is by no means constant. The glands throughout the alimentary tract are sometimes swollen, and sometimes form small ulcers and extravasations.

Brain.—It is rare that even the most intense cerebral symptoms occurring in the course of scarlet fever are due to meningitis. Hyperæmia of the brain and meninges, with great venous engorgement, is often seen, but signs of pronounced change are extremely uncommon.

Ear.—An acute otitis media is the most common affection of the ear met with in scarlet fever. The inflammation is especially likely to result in the destruction of tissue, the formation of adhesions, and the establishment of a long-continued suppurative process with accompanying necrosis.

Periostitis and osteitis occur in connection with affections of the joints, of the nose, of the pharyngeal and aural cavities, and of other parts, but afford nothing characteristic. Neither do the general serous surfaces show peculiar lesions. The condition of the blood and blood-vessels after certain rapidly fatal cases is important. Sometimes the blood is very fluid and black. At other times clots are abundant and firm; again, it may have become diffused throughout the tissues. Remy has seen all the vessels of the papillary layer of the skin filled with coagulated blood. Thrombosis of the sinuses has been noted after scarlatinal diphtheria (Thomas).

Heart.—Fatty degeneration of the heart following cloudy swelling, with dilatation, occurring particularly in the walls of the right ventricle, is a frequent result of scarlatina, as it is of other infectious disorders.

Diagnosis.—Scarlet fever must be distinguished from measles, rubella (Rötheln), roseola variolosa, scarlatiniform rashes of septic or medicinal origin, certain idiopathic erythemata, and diphtheria. From measles it differs in its shorter incubative stage, and in the character of its prodromes. In the former affection there are symptoms of coryza and bronchitis, with photophobia, sneezing, coughing, and the appearance of Koplik spots on the mucous membranes of the cheeks and lips (see *Measles*), while in scarlatina the prodromal symptoms especially involve the throat and in children are frequently associated with vomiting. In scarlatina the eruption begins to appear during the first or second day; in measles during the third or fourth day. During the course of scarlatina there is an absence of catarrhal symptoms for the most part. There are the characteristic sore throat and enlarged papillæ on the sides and tip of the tongue, the peculiar "strawberry tongue" (after the first two or three days), the well-defined eruption, the more protracted fever, the pronounced desquamation, and the tendency toward renal complications. The eruptions differ both in their development and in their distribution in the two affections. In scarlatina the face is characteristically invaded by the eruption, which entirely spares the area about the mouth, and is nowhere copiously developed in this region; while in measles the eruption is, probably, most intense upon the face. The macules in measles are large, irregular, and mostly papular. In scarlatina the eruption is punctate and more regularly distributed, not elevated; it is scarlet in color, and generally coalescent, while in measles it is more discrete, elevated, arranged very extensively in forms of crescents and segments of circles, with greater or smaller areas of healthy skin between the lesions, and is of a darker raspberry color. In measles the stage of eruption lasts for from three to four days, and begins to decline as soon as the eruption upon the lower extremities becomes complete. It occupies about thirty-six hours in attaining its acme. In scarlatina this stage lasts for from two to six days or more. It attains its acme in about eighteen hours. In measles there is a rapid return to a normal temperature in uncomplicated cases, while in scarlatina both eruption and fever decline more slowly. The conjunctival, nasal, and bronchial catarrh of measles is absent in scarlatina. In measles the tongue remains coated throughout. Sore throat is constant in scarlatina, quite uncommon in measles, and when present is almost invariably only catarrhal. The fever in scarlatina is at once more intense and more protracted. The desquamation of scarlatina is pronounced and lamellar; that of measles insignificant and branny. The presence of leucocytosis, not otherwise to be accounted for, is evidence in favor of scarlet fever and against measles. Scarlatina is frequently complicated by diphtheritic pharyngitis and renal inflammation, measles by inflammations of the respiratory apparatus.

The eruption of rubella (Rötheln) more closely resembles that of scarlatina. It is paler, more discrete, and its lesions are larger and more distinctly papular. It is more transitory, and fades almost without desquamation, which, when present, is branny. Rötheln, moreover, has a longer incubation, almost no prodromal stage, sometimes marked catarrh, and but slight elevation of temperature. It is feebly contagious, of much shorter duration, and is hardly ever followed by nephritis and dropsy. The diagnosis is difficult only when the eruption of rubella becomes confluent. Here, however, the confluence involves certain areas. It is sharply circumscribed by normal integument, and shows in contrast the outlying characteristic lesions. It is of a pale rose-red, and not of a scarlet color, and is accompanied by the peculiar symptoms of rubella, and rarely lasts more than thirty-six hours. Both measles and rubella may at times closely resemble the milder forms of scarlatina, and from the eruption alone the diagnosis may be difficult; but a consideration of all the symptoms will usually lead to correct conclusions. The presence of leucocytosis, in the absence of other conditions to account for it, is strong evidence in favor of scarlet fever.

Roseola variolosa should excite embarrassment only when it occurs before the peculiar eruption of smallpox has appeared. It is less general, is more like a simple diffuse erythema than is scarlatina, and is so speedily followed by the characteristic vesicular eruption that doubt will soon be dissipated. Its coexistence with the essential eruption may excite suspicions of a concurrence of scarlatina and smallpox. Such an error may readily occur.

Obstetrical and surgical scarlatina have already received attention. When erythema begins near a wound and becomes scarlatiniform in spreading, a septic origin must usually be allowed, though instances of scarlatina thus beginning have been reported; otherwise, septic erythema is more circumscribed and irregular. Scarlatina in the wounded and in lying-in women may be perfectly typical.

Medicinal eruptions have unquestionably been at the bottom of many errors of diagnosis. It has been shown that many drugs may excite eruptions and general symptoms very like those of scarlatina, but for the most part they are simple active hyperæmias, such as are produced by the action of belladonna upon the cutaneous arterioles. Such eruptions differ from that of scarlatina in the absence of prodromes, and, usually, of fever. They are also mostly partial and without the history, course, or results of scarlatina; but at times, and especially when they follow the ingestion of preparations of cinchona, the whole complex of scarlatinal symptoms may be accurately simulated. The conditions for diagnosis have already been pointed out. In second or repeated attacks of so-called scarlatina, due consideration of the possible influence of drugs as an etiological factor will doubtless convert some very puzzling cases into very simple ones.

Acute exfoliative dermatitis and desquamative scarlatiniform erythema[68] may well be mistaken for scarlatina upon their first appearance. The rash is more protracted than in the essential fever, and is less abrupt in its onset. The local symptoms are very marked, while the constitutional phenomena are usually insignificant. The desquamation may begin while the eruption is in full florescence. These affections are not contagious and have no specific sequelæ.

An erysipelatous eruption may be like that of scarlatina. It, however, differs markedly in its distribution, its evolution, and its course, being never universal, always progressive, and of indefinite duration. The subjective symptoms are quite different in the two affections; the erysipelatous eruption is painful both spontaneously and on pressure. Much œdema accompanies the latter eruption.

Diphtheria may complicate scarlatina, and the intensity of the local inflammation may induce a coagulation necrosis exactly corresponding to the membranous formations of diphtheria. Idiopathic diphtheria may especially resemble scarlet fever when it is accompanied by the erythematous exanthem that is sometimes developed, either early in the disorder or later, in cases of blood poisoning. At first it may not be possible to arrive at a correct diagnosis. According to Robinson,[69] in the early diphtheritic erythema there is no marked elevation of temperature. The rash may begin in any region, and rarely extends to the whole surface. The tongue is not affected, and there may be no special general disturbance. Desquamation does not occur. Bacteriological examination of the nasal and buccal secretions will almost always determine the presence or absence of true diphtheria. The late diphtheritic erythema is septic.

When the eruption of scarlatina is imperfectly developed, or when it does not appear at all, and when sore throat and fever are the only symptoms to attract attention, the diagnosis must rest upon the history of the patient and his surroundings, and upon the course of his illness. In not a few cases a retrospective diagnosis of scarlatina must be made, after the occurrence of desquamation or the supervention of nephritis and dropsy under conditions that indicate their scarlatinal origin.

PROGNOSIS.—The mortality from scarlet fever varies widely in different epidemics. From the affection that in Sydenham's time "hardly deserved the name of disease" to a pestilence of intense malignity, all degrees of fatality have been, and continue to be, observed. Epidemics have been recorded in which no deaths have occurred. Recently Whitla[70] has recorded but a single death in 133 cases of scarlatina treated in hospital. Such results are, unhappily, exceptional. The mortality has been known to reach 30 and 40 per cent. An excessively high rate of mortality is, in great part, attributable to epidemic tendencies toward grave complications, diphtheria, nephritis, etc. In private practice the death rate will not often exceed 10 per cent. In hospitals the percentage of deaths is usually much higher, the result being due to the fact that milder cases are kept at home for the most part, and not to differences in social condition, except in so far as neglect and exposure previous to admission may have aggravated an attack or have excited a complication. The death rate will be high or low in accordance with the type of the prevailing epidemic, and the average mortality of the disease should always be considered with reference to this. Neither season nor atmospheric condition appears to exert any influence upon the epidemic type. Likewise, telluric conditions do not modify it. Benign and malignant epidemics follow each other without evident cause. The mortality at the beginning and during the height of an epidemic is greater than during its decline. Barring the effects of extreme poverty and exposure, scarlet fever affects the rich and poor impartially. The sexes are almost equally attacked, but age exerts a striking influence upon the result. Children under one year of age, though less apt to be attacked, are especially liable to fatal forms of the disease. According to Fleischmann, the mortality at St. Joseph's Hospital was: under one year of age, 75 per cent. (8 cases, 6 deaths); from one to four years of age, 43 per cent.; from five to twelve years of age, 19.6 per cent.; the total mortality being 10 per cent. The majority of deaths occur under the sixth year of age; with increasing years the prognosis becomes more favorable. Fleischmann's records show a higher mortality than those of some other writers. For example, Kraus gives 4 deaths in 13 cases less than one year of age; 29 deaths in 113 cases from the close of the first to the close of the fifth year of life; 10 deaths in 106 cases from the end of the fifth to the close of the twelfth year of age; and 2 deaths in 40 cases from the twelfth to the twentieth year of age. Voit reported 1 death in 5 cases less than one year of age; 24 deaths in 166 cases from the first to the close of the sixth year of age; 10 deaths in 109 cases from the sixth to the twelfth year of age. Roset reported 16 deaths in 43 cases less than one year of age; 31 deaths in 156 cases from the first to the close of the fifth year of age; and 3 deaths in 88 cases over five years of age.[71] An exception must be noted to the favorableness of the prognosis in persons of maturer years, in the case of puerperal women, in whom scarlatina has already been shown to be especially malignant. No case can appear to be so mild as to justify a prognosis unqualifiedly favorable. From the beginning until the termination in recovery there is no period when a sudden change may not place the life of the patient in jeopardy, whether by an aggravation of the essential symptoms of the disease, or by the supervention of complications. The prognosis, however, is generally favorable if the disease pursues a regular course; if the eruption follows a brief prodromal stage and is regularly developed; if the fever, more or less intense from the first, does not exceed at the height of the eruption 40° C. (104° F.), and, steadily falling, reaches the normal on the sixth, seventh, or eighth day; if the angina do not assume a diphtheritic character, and is not complicated by parenchymatous tonsillitis, retropharyngeal abscess, or cellulitis of the throat or neck; if the kidneys remain unaffected or show only slight evidences of disorder. On the other hand, the prognosis is more grave when the eruption appears after a prolonged prodromal stage, or when the attack is ushered in by convulsions or other profound nervous disturbance; or when the temperature reaches a high degree, 40.6° to 41° C. (105° to 106° F.), at once; or when intractable vomiting is present; or when diarrhœa is a prominent feature; or when the pulse beats more than one hundred and twenty times to the minute, and is feeble, unequal, and irregular; or when the throat is ulcerated and develops diphtheritic inflammation; or when suppurative, parenchymatous, or gangrenous inflammation of the tonsils, or retropharyngeal abscess supervenes; or when the neck becomes swollen, brawny, and livid from glandular, periglandular, and diffuse cellular inflammation. Apprehension should always be excited if the eruption come out imperfectly or irregularly while the fever is intense; or if, once fully developed, it suddenly fade; or if the eruption assume a livid color or a distinctly hemorrhagic character. A coppery hue of the eruption is unfavorable, as is also a livid coloration of parts not invaded by the eruption. Small, scattered petechiæ in the midst of an otherwise normal eruption are unimportant. Miliary vesicles, developing in the ordinary course of the fever are insignificant; occurring later, during an attack of unusual severity, they are often the forerunners of death. Convulsions first occurring after the height of the fever are more ominous than if occurring earlier. Should the eruption, and especially the fever, continue unabated after the usual period, dangerous complications are to be apprehended. Coma is of grave augury, as indicating uræmia, œdema of the brain, or even meningitis. Nephritis is more serious the earlier it is developed. It occasionally happens that scarlet fever at first shows the symptoms of a mild attack, but, before the completion of the eruption, assumes a malignant character. If symptoms of malignancy occur after the completion of the eruption, they are usually attributable to complications. On the other hand, all the signs of malignant scarlatina may be present at the outset. High fever, rapid pulse, convulsions or coma, protracted vomiting, intense eruption, may all yield after the second or third day, the disease thenceforward pursuing a mild course; again, symptoms of malignancy may disappear upon the supervention of a delayed eruption. Mayer[72] observed a temperature of 43° C. (109.4° F.) on the evening of the second day. The temperature subsequently varied slightly until the fourth day, when, upon the appearance of the eruption, it subsided. The occurrence of scarlatinal diphtheria always increases the danger of death. Heubner regards its sudden extension to the soft palate and to the portals of the œsophagus and trachea as certainly to be followed by death within from twenty-four to forty-eight hours, the fatal issue occurring either through gradual progress of gangrene, by inflammation of the lymphatic glands and connective tissue of the throat and neck, or by œdema glottidis. When circumscribed spots are invaded and the lateral portion of one tonsil shows the first patch, from which the membrane gradually spreads, recovery may occur. Diarrhœa persisting during the attack greatly increases the danger. Nephritis is always a serious complication, though terminating favorably in most cases. The danger is usually proportionate to the earliness of its occurrence. Death may occur as in ordinary nephritic inflammation. Scarlatinal nephritis most rarely becomes chronic. Inflammation of the organs of hearing, while rarely imperilling life, often results in partial or complete deafness. This, according to Burkhardt-Merian,[73] depends upon croupous-diphtheritic inflammation primary in the throat. The prognosis is more unfavorable if the process be allowed to go untreated. Rheumatic and rheumatoid inflammations are not commonly dangerous complications. Endo- and pericarditis, pleurisy, peritonitis, meningitis, pneumonia, dysentery, parenchymatous degeneration of the heart, etc., are all complications of extreme danger. Purulent inflammations of pyæmic origin usually constitute sequelæ of scarlatina, and are of the gravest importance.

TREATMENT.—Mild cases of scarlatina require little more than good nursing, the regulation of the diet, and proper precautions against the spread of the disease to the other members of the household. Severe cases, on the contrary, tax the resources of the physician to his utmost.

General Principles of Prophylaxis, Hygiene, and Disinfection.—As soon as the disease is recognized the patient should be removed to a clean, well-ventilated room, preferably at the top of the house, and accessible by way of back stairs, and all persons not concerned in the care of the patient should be rigidly excluded.

The following practical rules and directions, taken in part from those issued by the New York Board of Health, for the prevention of the spread of the disease in a family in which one case exists, cover in a general way the matter of prophylaxis and disinfection. They should be followed as closely as possible, but at times may be modified to suit the requirements of the case. A copy should be given to the nurse and parents at the beginning of the quarantine, and they should be instructed to study the principles on which the directions are based in order that they may know how to meet conditions which are constantly arising in the course of the disease and which cannot be specially mentioned in directions intended for general use.

1. If possible one attendant should take the entire charge of the sick person, and no one else besides the physician and nurses should be allowed to enter the sick-room. The attendant should have no communication with the rest of the family. While in the sick-room she should wear a covering to protect her hair, and a gown, which should be removed when she leaves the room. When leaving the portion of the house which is quarantined she should change her shoes, and dress and disinfect her hands and face, and should make use of the back stairs, so far as possible in going in and out of the house. The members of the family should not receive or make visits during the illness. Other children in the family should not be allowed to go to school, if they remain in the infected house, and if sent away they should be kept from other children until the stage of incubation has passed. The physician should exercise great care not to carry the contagious elements to other patients. Disregard of such precaution by many physicians is a fault only too common, and one which deserves the most severe condemnation. A cap covering the head and back of the head, a gown reaching from the neck to the floor, and rubber overshoes should always be put on before entering the patient's room. When these are removed, they should be dipped in carbolic acid or corrosive sublimate solution, and hung up to dry in an ante-room, where they will be ready for use on the following day. Rubber gloves are also a useful addition to the articles just mentioned.

2. The discharges from the nose and mouth must be received on handkerchiefs or cloths, which should at once be immersed in a carbolic solution (made by dissolving six ounces of pure carbolic acid in one gallon of hot water, which may be diluted with an equal quantity of water). All handkerchiefs, cloths, towels, napkins, bed linen, personal clothing, night clothes, etc., that have come in contact in any way with the sick person, after use should immediately be immersed without removal from the room in the above solution. These should be soaked for two or three hours and then boiled in water or soapsuds for one hour. They should be laundried separately from the household articles.

3. Great care should be taken, in making applications to the throat and nose, that the discharges from them in the act of coughing are not thrown into the face or on the clothing of the person making the applications, as in this way the disease is likely to be caught.

4. The hands of the attendant should always be thoroughly disinfected by washing in carbolic solution, and then in soapsuds, after making applications to the throat and nose, and before eating. Rubber gloves may be worn with advantage while handling the patient.

5. Surfaces of any kind soiled by discharges should be immediately flooded with the carbolic solution.

6. Plates, cups, glasses, knives, forks, spoons, etc., used by the sick person for eating and drinking must be kept for his especial use, and under no circumstances be removed from the sick-room nor mixed with similar utensils used by others, but must be washed in the room in the carbolic solution and then in hot soapsuds. After use the soapsuds should be thrown into the water closet, and the vessel which contained it should be washed in the carbolic solution.

7. The room occupied by the sick person should be thoroughly aired several times daily, and swept frequently, after scattering wet newspapers, sawdust, or tea leaves on the floor to prevent the dust from rising. Af-

ter sweeping, the dust upon the woodwork and furniture should be removed with damp cloths. The sweepings should be burned and the clothes soaked in the carbolic solution. In cold weather the sick person should be protected from the draughts of air by a sheet or blanket thrown over his head while the room is being aired. In summer the windows should be kept open sufficiently to secure free movement of air and agreeable temperature; in winter an open wood or coal fire should be kept constantly burning. The temperature of the room should not exceed 21° C. (70° F.) nor fall below 18° C. (65° F.). The patient should be kept in bed even during the mildest attacks, with only enough bed covering to secure comfort.

8. When the contagious nature of the disease is recognized within a short time after the beginning of the illness it is advised that all articles of furniture not necessary for immediate use in the care of the sick person, especially upholstered furniture, carpets, and curtains, should be removed from the sick-room. If the disease is well advanced this should not be done without first taking precaution to disinfect them properly.

9. When the patient is beginning to recover and the skin is peeling off, the body should be washed once daily in warm soapsuds, and afterward rubbed in oil or carbolated vaseline. This should be continued until all roughness of the skin has disappeared.

10. When the patient has recovered and the Board of Health inspector has authorized his discharge, the entire body should be bathed and the hair washed with hot soapsuds, the nose, mouth, and ears should be disinfected as far as practicable with antiseptic sprays, and a corrosive sponge bath of 1 to 2,000 to 1 to 5,000, according to the age of the patient, should be given. The patient should then be dressed in clean clothes (which have not been in the room during the sickness) and removed from the room.

The Health Department should be immediately notified, and disinfectors will be sent to disinfect the room, bedding, clothing, etc., and under no conditions should i be again entered or occupied until it has been thoroughly disinfected Nothing used in the room during the sickness should be removed until this has been done.

11. The attendant or any one who has assisted in caring for the sick person should also take a bath, wash the hair, and put on clean clothes, before mingling with the family or other people, after the recovery of the patient. The clothes worn in the sick-room should be left there, to be disinfected with the room and its contents by the Health Department.

12. As contagion sometimes occurs after very prolonged intervals it is generally better to observe the rule that isolation should be practised until the completion of desquamation. Ashby[illegible] lays down the following rules in reference to the discharge of a scarlet-fever patient from quarantine. (1) If desquamation is complete scarlet-fever cases may be discharged at the end of the sixth week, although in order to secure absolute immunity it is wiser to delay until the eighth. (2) Cases complicated with nephritis, empyema, otitis, or glandular abscess, should be detained until the cure is completed. (3) While it is important that the desquamation should be as complete as possible, the detention of the patients beyond the eighth week in order that the last vestige of epidermis should be removed from the feet, etc., is unnecessary. Such detention is, however, often insisted upon by health authorities.

13. The uses of belladonna and other "specifics" as a means of prophylaxis are based upon untenable hypotheses. Scarlet fever often fails to spread even when a number of persons have been exposed and the danger of drawing incorrect conclusions from the use of drugs as prophylactics is very great.

The following are the best known disinfectants:

Heat.—Continued high temperatures destroy all forms of life Boiling for at least one-half hour will destroy all disease germs.

Carbolic Acid.—A standard solution is composed of six ounces of carbolic acid dissolved in one gallon of hot water. This makes approximately a five-per-cent. solution of carbolic acid. The commercial colored impure carbolic acid will not answer for this purpose. Great care must be taken that pure acid does not come in contact with the skin. When practicable, the carbolic solution should be used as hot as possible. The cost of carbolic acid is much greater than that of the other solutions, but generally is much to be preferred. When the cost is an important element, the bichloride solution may be substituted for all purposes for which carbolic is recommended, excepting for the disinfection of the discharges, eating utensils, or articles made of metal, and of clothing and bedding, etc., which is very much soiled. Its poisonous character, except for external use, must be kept constantly in mind.

Corrosive Sublimate (bichloride of mercury).—A standard solution is composed of sixty grains of pulverized corrosive sublimate and sixty grains of the chloride of ammonia, dissolved in one gallon of water. This solution must be kept in glass, earthen, or wooden vessels (not in metal vessels).

The above solutions are very poisonous when taken by mouth, but are harmless when used externally.

Milk of Lime.—A standard solution is made by mixing one quart of dry freshly slaked lime with five quarts of water. Lime is slaked by pouring a small quantity of water on a lump of quicklime. The lime becomes hot, crumbles, and as the slaking is completed a white dry powder results. The powder is used to make the solution. Air-slaked lime has no value as a disinfectant.

Formaldehyde.—The use of formaldehyde gas for disinfection of rooms, clothing, and furniture, after the discharge of the patient, has now become general, and has proved superior to the older methods. The simplest, most convenient, and inexpensive apparatus for this purpose is the Schering lamp in which paraform pastils are burned, two pastils being used for each thirty-five cubic feet of air space. More powerful generators for the disinfection of very large areas are now commonly used by the Boards of Health, to whom the question of disinfection is generally referred.

The proprietary disinfectants, often widely advertised, and whose composition is kept secret, are relatively expensive and often unreliable and inefficient. It is important to remember that substances which destroy bad odors are not necessarily disinfectants.

Diet.—The diet should consist in easily assimilable food; the nearer this approaches a pure milk diet the better. Cold drinks may be allowed; cold-water lemonade, raspberry vinegar properly diluted, soda-water agreeably flavored, are grateful to the patient and preferable to warm and mucilaginous drinks. Though milk should form the principal article of food, light broths and soups, beef tea, chicken jelly, and, especially during convalescence, the various appetizing and wholesome preparations of food now so abundantly supplied may be given.

Internal medication may be held in reserve, a careful observation of all symptoms being meanwhile maintained and the conditions of the kidneys systematically ascertained by daily observation.

Hydrotherapy.—By far the safest and surest agent for reducing temperature in scarlatina is cold water which should always be tried before resorting to the use of antipyretic drugs, which are often dangerous, and the use of which should be discouraged. This may be applied in various ways. The simplest method is by frequent spongings with cold or tepid water under cover of the bedclothes. At the same time cold wet cloths may be applied to the head, and the patient may be permitted to suck small pieces of ice. In most cases it is better that the water be warm. The spongings may be repeated frequently during the day and night. In cases in which, with an elevated temperature, the eruption develops incompletely, or is much delayed in appearance, the body may be immersed in water somewhat cooler than its normal temperature. A cool bath (27° C. = 80° F.) has been extolled as of singular virtue in such cases, and at times it is of the highest value. The tepid, even the warm bath, is probably of equal benefit in most cases. Recent writers have denied that efforts to "bring out" an imperfect or delayed scarlatina, eruption are of any avail. There can be no doubt, however, that treatment with this object in view is often successful. The hot bath, even with the addition of mustard, by exciting cutaneous hyperæmia, will often relieve the congestion of internal parts. Warm and hot drinks made from various vegetable substances were formerly much employed to "bring out" the eruption. They were given copiously, and often in combination with such diaphoretics as spiritus mindereri, spirits of nitrous ether, etc. This plan of treatment is not much practised to-day. The cold bath, which should be of a temperature not lower than from 24° to 27° C. (75° to 80° F.), should be reserved for cases whose temperature exceeds 40° C. (104° F.). The body should be immersed but for an instant, the benefit of the plunge consisting largely in the dilatation of the vessels of the skin through reaction. The cold pack is also of value in these cases. When the temperature steadily rises to an alarming degree, or when hyperpyrexia is developed almost at the outset; when, with or without well-developed exanthem, stupor or coma, or other grave nervous disorder, arises, and when the pulse becomes very rapid, feeble, and irregular, the maintenance of life depends upon the reduction of temperature. Here it is impossible to give hard-and-fast rules for conduct. Water below the normal temperature of the body still remains our most efficient means of reducing the excessive heat. The lower the temperature of the bath, the more rapidly is this result attained, but the shock of the sudden contact with the cold water may exert a depressing effect that may not speedily pass off. The body cannot remain in very cold water longer than a minute or so without exciting chattering of the teeth, lividity about the mouth, and a pinched appearance of the features and of the surface. The warm bath (32°–35° C. = 90°–95° F.) has been highly extolled as favorably influencing the course of scarlet fever when used at the very beginning. Thompson employed it thus constantly, and never lost a case treated in this manner. In a bath of from 27°–30° C. (80° to 85° F.) the patient may remain for five or ten minutes. These baths should be repeated as often as the temperature of the body becomes as high as 39.5°–40° C. (103°–104° F.). To avoid alarming the little patient, the bathtub may be covered with a sheet or blanket. Placing him upon this, he may slowly be lowered into the water. Upon removal from the bath the patient should be wrapped in a dry blanket. As the body soon dries under the protection afforded, rubbing with towels may be avoided. The skin should now be anointed with oil or other agreeable fatty substance. Refreshing quiet and sleep often follow this bath. In using the wet pack, a blanket may be spread upon a hard couch or bed covered with oil cloth; upon this a sheet wrung out in cold water is laid. The naked patient is stretched upon this sheet, which along with the blanket is wrapped about him snugly. The brief sensation of chilliness is soon replaced by one of warmth, and after a few moments the body breaks out into copious perspiration. This may be encouraged by hot drinks, and hot bottles to the surface. The patient should not remain too long in the pack, otherwise hyperpyrexia may rather be increased than diminished. In the intervals between the baths, in extreme cases in adults, an ice cap may be worn, and cloths wrung out in iced water may be applied to the epigastrium. The application of ice to the head in the case of infants and young children is, however, a dangerous practice owing to its depressing influence, and should rarely, if ever, be resorted to. Nothing can exceed the efficacy of the above-described method of treating scarlet fever with high temperature; but to secure its full influence, it must be pursued systematically and intelligently. The thermometer must constantly direct the actions of the physician. The prejudices of friends and attendants against the immersion of the fevered body in ice-cold water will not extend to the use of tepid and cool baths, from which, indeed, equally good results may be obtained. The baths may have to be repeated at intervals of two or three hours for days before the fever begins to yield; or they may unhappily altogether fail to control the irresistible intensity of the disease. On the other hand, they frequently exert a most gratifying influence upon the course of the malady, the temperautre becoming permanently reduced, the pulse quieter, fuller, and regular; jactitation, delirium, and coma being replaced by composure, consciousness, or natural sleep. Often an attack that appeared about to pursue a malignant course, under the influence of the bath becomes benign and terminates favorably. While exalted temperature that threatens to destroy life can, in the manner indicated, often be reduced, the course of the disease itself cannot be aborted. No remedy is known that can be said to exert a specific influence over it. Vaunted specifics have not withstood the test of experience.

Medicinal Treatment.—Probably the most popular routine treatment of ordinary scarlet fever is that of carbonate of ammonia. When in cases of very elevated temperature the heart action flags, the pulse becoming rapid, feeble, and unequal, when delirium or stupor appears, the preparations of ammonia are demanded. The carbonate, in doses of one to three grains to a child five years of age, may be given every third hour in aqueous solution with milk, which in a great measure destroys the pungent, disagreeable taste; or it may be given in solution of the acetate of ammonia, a most commendable combination. The aromatic spirits of ammonia may be employed for the same purpose. Hoffman's anodyne, whiskey, or brandy is especially indicated when the nervous system shows alarming signs of perturbation, delirium, jactitation, stupor, etc. When strong cardiac stimulants are demanded, the fluid extract of digitalis in one-minim doses, for a child of five years, or strychnine in doses of gr. $\frac{1}{200}$ to gr. $\frac{1}{100}$, should be given. Caffeine and camphor are also of use as adjuvants to the cardiac stimulants already mentioned. Purgation, which should usually be avoided, may at times become necessary. Small doses of calomel (gr. $\frac{1}{6}$ to gr. $\frac{1}{4}$) repeated every hour until the bowels are moved, generally act well. Castor oil is a harmless and safe, but nauseous agent. Rhubarb and scammony are also efficient cathartics; either may be given in doses of five grains to a child six years of age. When depression is profound, reliance should be placed on enemata in preference to active cathartics.

During the progress of the disease the expectant plan of treatment is most to be recommended. The daily bath or sponging should be continued. It is probable that renal complications are thus frequently avoided. The patient should be jealously guarded from draughts and dampness, and even the mildest cases should be kept in bed for at least ten days after the cessation of fever; nor should the patient be allowed to leave his room before the expiration of the third week. Out-of-door exercise cannot be resumed in disregard of season, or of barometric and thermometric variations. In midsummer, when windows and doors must remain open, the question of out-of-door exercise is rather one of danger to others than of personal risk; while in spring, autumn, and winter the risks of exposure are especially great. During these seasons the patient should not venture into the open air before the sixth or seventh week of perfectly normal scarlatina. During convalescence the daily baths should be continued until desquamation is completed, and daily innunctions with mild antiseptic ointments, such as carbolated vaseline or boracic ointment, will both expedite this process and minimize the dangers of contagion. No further medication besides an appropriate tonic will be required.

Nasopharynx.—If the angina does not exceed a simple hyperæmia, mild alkaline antiseptic sprays applied frequently to the nose and throat by means of an atomizer are all that are required. If the patient is young and resists vigorously this treatment, it should not be persisted in. If the nasal discharge is profuse and purulent, gentle syringing with such solutions as Dobell's, Seiler's, and alcohol is indicated. Should the throat develop the whitish curdy deposits of follicular inflammation and the erosions that so often accompany acute catarrhal pharyngitis, an antiseptic gargle will act beneficially and will correct fœtor of breath, and to some extent disinfect the secretions and exhalations. For this purpose one of the subjoined prescriptions may be employed:

℞ Acid. carbolic. cryst. . . . . ʒ ss.
Glycerin . . . . f. ʒ i.
Aq. destil. . . . . q.s. ad f. ℥ vi.
M. Sig.: Use as a gargle or spray.

Or

℞ Tinct. ferri chlorid. . . . . f. ʒ i.
Potass. chlorat. . . . . ʒ ss.
Glycerin. . . . . f. ʒ i.
Aq. destil . . . . q.s. ad f. ℥ viij.
M. Sig.: Use as a gargle or spray.

When the inflammation is more severe, and accompanied by more or less superficial ulceration, applications should be made with a probang or camel's-hair pencil. When the surface is foul and covered with offensive exudation, an excellent application is the following, first recommended by J. Lewis Smith:

℞ Acid. carbolic. . . . . gr. iij.–vi.
Liquor ferri subsulphat . . . . f. ʒ ij.
Glycerin . . . . f. ʒ vi
M. Sig.: Apply with a brush three or four times a day

Or the following:

℞ Tinct. iodinii. . . . . f. ʒ i.
Glycerin . . . . f. ℥ vij.

Diphtheritic inflammation, if associated with the presence of the Klebs-Loeffler bacillus, calls for the treatment with the antitoxin of diphtheria, in addition to the local treatment of the nose and throat by sprays and gargles. Cauterization with silver nitrate, acid nitrate of mercury, chromic acid, or other agents should not be practised.

Tracheotomy should never be performed. A case of scarlatinal diphtheria which presents the symptoms which demand this operation, in the idiopathic disorder, is beyond the resources of surgical art.

Lymph Nodes.—Inflammation of the lymph nodes of the neck and of the adjacent connective tissue may be treated first by inunction of oil or cerate. In severer forms an ice bag, and when suppuration threatens, creolin or flaxseed poultices should be applied. Points at which suppuration appears should be incised early and freely to prevent burrowing. Gangrenous inflammation may sometimes be arrested by strong caustics. Iron, quinine, stimulants, and nourishing and supporting food should be administered in these conditions with a free hand, but always with care not to derange the digestion of the patient.

Ear.—Scarlatinal aural inflammation calls for special treatment, and whenever possible it should be referred to the aurist. The nasal douche should be used and the diphtheritic pharyngeal and nasal cavities should be repeatedly syringed with antiseptic solutions, for it is by the extension of the inflammation along the Eustachian tube that the severer forms originate. When the aural inflammation is established, inunctions of mercurial ointment, or of the oleate of mercury, or of iodoform ointment, should be made about the ear several times daily. When the tympanic membrane becomes strongly injected and bulges outward, paracentesis for the release of the pent-up exudation should be performed. Timely tapping of this membrane will often preserve the imperilled sense of hearing. This operation is especially commended by Buck and Olshausen. It is simple and very easily performed. The sensitiveness of the membrane may be obtunded to a slight degree by the instillation of a four-per-cent. solution of muriate of cocaine. Pomeroy's directions for performing the operation are as follows: "A good-sized speculum is introduced into the meatus. Then an ordinary broad needle, about one line in diameter, with a shank of about two inches, such as oculists use for puncturing the cornea, should be held between the thumb and fingers, lightly pressed so as not to dull delicate tactile sensibility. The part being well under light, the most bulging portion of the membrane should be lightly and quickly punctured with a very slight amount of force. The posterior and superior portion of the membrane is most likely to bulge. The chorda tympani nerve usually lies too high up to be wounded. The ossicles are avoided by selecting a posterior portion of the membrane. After puncture the ear should be inflated by an ear-bag whose nozzle is inserted into a nostril, both nostrils being closed, so as to force the fluid from the tympanum. The puncture may need to be repeated at intervals of a day or two, provided that the pain and bulging return."[74] When pain and tenderness only are present, hot fomentations to the external ear, and to the parotid and mastoid regions, are very soothing. Laudanum and sweet oil, or a two- to four-per-cent. solution of sulphate of atropine instilled warm into the external meatus, often give relief. Frequently renewed solutions of cocaine are very efficacious. Bags of hot table salt, or of heated flowers of hops, are well-known domestic remedies. When perforation occurs spontaneously the hearing may be preserved, but partial deafness is often permanently established, and sometimes the sense of hearing is totally abolished. In such cases the ear should be frequently syringed with warm water, or with warm solutions of boracic acid followed by insufflations of boracic-acid powder. Granulations and polypi developing in the course of chronic otitis may be benefited and even cured by astringent powders and washes. Surgical interference will at times be necessary.

Nephritis.—When nephritis arises in the course of scarlet fever, or as a sequel, prompt measures for its relief must be adopted. Where it forms a feature of rapidly fatal malignant scarlatina, it may have no time to develop symptoms, or these may escape detection, or the virulence of the disease may throw the renal disorder into the background, or render attempts to treat it futile. In milder cases, and later, during the latter part of the first or during the second or third week, especial attention may be devoted to the treatment of nephritis. Slight albuminuria will occur, according to Mahomed, during convalescence, associated with constipation and a hard pulse, indicative of high arterial tension, without subjective symptoms, and remediable by a brisk purge. This author also asserts that a slight chilling of the surface is sufficient to cause transitory albuminuria. The patient should therefore be carefully protected, in the manner already indicated. Dietary management will go far toward preventing renal complications. A rigid milk diet, in all cases of scarlatina, is regarded by Jaccoud as absolutely preventive of nephritis. Though this may be an extravagant statement, it is certain that in scarlatina there is no better diet than one of milk. Should nephritis arise, it is the more important that the milk diet should be continued. From two to three or four pints may be given during the twenty-four hours, in small quantities, at brief intervals, the latter amount being sufficient for an adult without other food. If there are reasons why milk cannot be taken, light broths and soups and chicken jelly may be substituted, together with light farinaceous food. Buttermilk may at times be preferred, and bonny-clabber and slip or junket (milk sweetened and flavored and coagulated with liquid rennet) are often relished, and are excellent articles of food. Proper regard having been paid to the hygienic surroundings and nutrition of the patient, a brisk hydragogue cathartic should be administered, unless diarrhœa be already present. For this purpose there is nothing better than the compound jalap powder. For a child, from five to twenty grains of this should be ordered every night, as required, the object being to secure several watery actions of the bowels every twenty four hours. The proper dose for an adult is one drachm. The desired watery stools may also be readily secured by the saline cathartics if given in concentrated watery solution. The more drastic purgatives will rarely be required, except in uræmic intoxication and in extreme dropsy, when podophyllin, croton oil, elaterin, etc., may occasionally be employed with benefit. When dropsy is but slightly pronounced, purgation may not be required.

The action of the skin should next demand attention. Frequently during the day the body may be wrapped in flannels, wet or dry, as hot as can be borne; or the wet pack may be applied. When available, the steam bath or hot-air bath is to be strongly recommended. The hot plunge bath may also be employed most advantageously. Pilz has especially lauded this treatment. It should be used after the method of Liebermeister, by gradually increasing the temperature of the bath from 36° C. to 40° C. (96° to 104° F.), in a half-hour. Under its daily use dropsy speedily disappears. Diseases of the heart and lungs, while not positively contraindicating this plan of treatment, necessitate great caution in its application. Sudden chilling of the surface after the bath should be avoided. The imminence of the danger is usually proportionate to the degree of impairment of the function of the kidneys. In giving remedies to modify their action, none calculated to increase their hyperæmia should be employed. Exception can hardly be made in favor of juniper, which enjoys with some writers considerable reputation in scarlatinal nephritis, and digitalis has received very general approval as a most useful diuretic in acute nephritis. From one fluidrachm to a half fluidounce of the infusion (which is much the best preparation for the production of diuresis) may be given three or four times daily, the dose varying with the age of the patient. Its effects, however, are hardly as happy as when dropsy is associated with, or dependent upon, cardiac weakness. Diuretics that act specifically upon the secreting cells of the urinary tubules, the sedative or refrigerating diuretics, are to be preferred, as a rule, in the treatment of scarlatinal nephritis, and will often achieve most astonishing results. Of these the salts of potash are most efficacious—the citrate, the acetate, the bitartrate, and the bicarbonate. For slight nephritis and anasarca a lemonade made with bitartrate of potash will be taken with avidity, and will often almost magically increase the quantity of urine, reduce the dropsy, rapidly diminish the albuminuria, and cause a radical change for the better. Diuretin in five- to ten-grain doses may be combined with this with great advantage. This lemonade may be made by adding one drachm of cream of tartar to a pint of boiling water, into which a sliced lemon has been dropped. This quantity, properly sweetened, may be drunk during the day by a child five years of age. Water may be allowed freely, or any of the mild domestic infusions may be substituted for it, their virtue residing principally in the amount of fluid. The free use of water is especially to be recommended as unirritating, and tending to wash out of the tubules the exudate choking up their lumina. In more severe cases, where life is threatened through one or another form of uræmia, very energetic treatment will be required. Jaborandi may now prove useful. J. Lewis Smith, Hirschfeld, and others have commended its action highly. For a child two years of age, one-twentieth of a grain of pilocarpine may be given by the mouth every fourth or sixth hour, or the same amount may be injected hypodermically, and prove much more efficient. Both diuresis and diaphoresis will be promptly increased, and in favorble cases the uræmic symptoms will disappear. Hot saline injections, given by rectum and repeated several times a day are frequently of value in threatened uræmia. Uræmic coma and convulsions, developing suddenly or after progressive renal embarrassment, should be treated without reference to the scarlatina and upon general principles. A remedy of most undoubted value, at least for the control of convulsions, is chloral, which, if the patient be unable to swallow, may be injected in full doses under the skin or into the rectum.

After the more acute nephritis has subsided and convalescence promises to become established, iron becomes one of our main reliances, in virtue of its combined hæmatic and diuretic properties. The Mistura ferri et ammoniæ acetatis will generally be found to be the best of the old preparations. Recently many new and excellent preparations of iron in organic combination have been put upon the market. Quinine is also a remedy of great value in the treatment of convalescence from scarlatinal nephritis. During the height of the inflammation, local treatment is often of great importance. If fever is intense, the pulse full and strong, and if pain and tenderness in the back are pronounced, the abstraction of blood, by leeches or cups, from the loins will often prove beneficial. Large sinapisms and poultices may be applied over the kidneys. Besides assuaging the irritation they tend to promote diuresis and diaphoresis. For obvious reasons, turpentine should not be employed as a counter-irritant in these cases. Ascites may occasionally be so excessive that the pressure exerted upon the kidneys interferes with the action of therapeutic agents, and impedes the functional activity of these organs. Paracentesis abdominis, by relieving this compression, will often be followed by copious diuresis and the rapid disappearance of general anasarca. Cases of scarlatinal nephritis which pass into chronic Bright's disease, as rarely happens, will require the treatment appropriate for this condition. During convalescence the usual precautions will be necessary. The treatment of other complications and sequelæ of scarlet fever is not peculiar, and will require no special notice here.

Serotherapy.—In 1896 Josias, of the Trousseau Hospital, gave an account of the treatment of a case of scarlatina with Marmorek's antistreptococcus serum. The results apparently were inconclusive, and subsequent trials by other investigators have proved equally so. Quite recently the efforts to secure a specific antitoxic serum for scarlatina have received a new impetus, and have given rise to much discussion.

Baginsky, of Berlin, claims to be the first to call attention to the association of a streptococcus with scarlet fever, and he has announced that Dr. Aronson has demonstrated an anti-scarlet-fever serum, which, as he believes, will prove specific in this disease. Priority is disputed by Moser,[53] who asserts that, with Pirquet, he previously had shown this association, which was also independently found by Salge as a result of agglutinating reactions, the peculiarity of which was first demonstrated by van de Velde and Paltauf. The first antistreptococcus serum, he says, was produced by Marmorek, and Aronson's was perfected on similar lines, while his own is based on different principles. Aronson's test comprises a macroscopic, and not the microscopic agglutination reaction on the peculiarity of which Moser bases his claims of priority. Out of ninety-nine cases of fatal scarlatina, Moser has been able to cultivate [54, 55] streptococci from the blood in the heart in sixty-three cases. These results accord with those of previous investigations, and make it probable that streptococci play an important part in the disease. On the other hand, the use of ordinary antistreptococcus serum has not proved of use in treating the disease. Moser points out that this may be due to the fact that there are different varieties of streptococci. The organism isolated from scarlatina differs from other varieties found in other diseases, in being almost innocuous for rabbits, and in possessing different agglutinating properties. Moser therefore prepared a special immune serum from streptococci obtained from scarlet-fever cases. As there is no proof yet that the organism is the same in all cases, he produced a polyvalent serum by injecting horses with increasing doses of the mixture of living cultures obtained from different cases of scarlet fever. The organisms were grown on bouillon, and were not passed through animals. After months of such treatment the serum was drawn off and preserved in a sterile condition, without any addition of a preservative. The serum was tried in eighty-four cases. At first the dose was too low. Later, better results were obtained, doses of 180 c.c. being used. Possibly the serum was more potent in the later cases. The individual doses varied from 30 to 180 c.c.; the latter amount is now chiefly used. In seventeen cases classed as mild or moderately severe, there was no mortality. In sixty-two cases classed as severe and apparently hopeless there were sixteen deaths. The earlier the injection the more favorable is the result. The chief clinical result is the rapid improvement in the general condition. With early injection the rash may not fully develop, or may fade much sooner than usual. The disturbances of the central nervous system disappear in a short time, while the temperature and pulse often show a critical fall. The symptoms of heart weakness are favorably influenced. The throat clears up more quickly, and although superficial necrosis is not prevented, Moser has not observed deep destruction. As yet, nothing can be said about the effect of serum on the renal and middle ear complications. The whole course of the disease is shortened, and convalescence occurs much sooner. Injections of normal horse serum had no effect on the course of the disease. Serum rashes were often noted, but joint pains and abscess formation were rarer. A much larger number of observations must be made before a definite opinion can be held in regard to the efficacy of this form of serumtherapy in scarlatina. The results already attained certainly warrant further investigation along the same or similar lines.

Roger[87] attempted, in a single case, to treat scarlet fever by injecting into a vein 80 c.c. of serum taken from the blood of a patient recently convalescent from scarlet fever. The case was apparently comatose at the time of the experiment, and recovery took place, but no conclusion can be drawn from this single instance. Obviously it is not a method practicable for general use, and is only of scientific interest.

Preventive Inoculation.—Stickler[86] in 1897 attempted to produce a mild type of scarlet fever by inoculating children with subcutaneous injections of mucus obtained from the throats of recent cases of scarlet fever. The results of the experiment showed that the symptoms produced were practically as severe as those of the typical cases of scarlet fever, and that preventive inoculation on the principles of vaccination for the smallpox was impracticable. Incidentally his experiments showed that the secretions of the mouth and pharynx of scarlet fever are highly virulent, as all the symptoms of scarlet fever appeared, with hardly any incubation period, within from two to twenty-four hours.

I. E. Atkinson.

Revised by *Maynard Ladd.*

[1] Historisch-Geograph. Pathol., vol. i., New Sydenham Soc. Translation, p. 172. [2] Amer. Journ. of the Med. Sciences, October, 1855.
[3] Jahrbuch f. Kinderheilk., 1870.
[4] Hebra: Diseases of the Skin. New Syden. Soc. Translation, vol. i., p. 218.
[5] Lancet, 1883, i., 191. [6] *Ibid.*, 1885, i., 354.
[7] *Ibid.*, 1883, i., 685. [8] Rehn: Jahrb. f. Kinderheilk., 1869, 4.
[9] Vol. xi., 1878. [10] Ziemssen's Cyclop., vol. ii., p. 169.
[11] Jahrbuch für Kinderheilk., 1875, viii. [12] Lancet, 1870.
[13] Jahrbuch für Kinderheilk., i., 1870. [14] *Loc. cit.*
[15] Vierteljahr. f. Dermatol. u. Syph., viii., 522.
[16] Adjumnaria, p. 320. [17] Jahrbuch für Kinderheilk., 1870, 111.
[18] Gazette des Hôpitaux, 1885, lviii., 118.
[19] Berliner klin. Wochenschr., 27, 1882. [20] *Ibid.*, 50, 1873.
[21] Correspondenzbl. f. Schweizer Aerzte, No. 8, 1876.
[22] Berliner klin. Wochenschr., 8, 1882.
[23] Burkhardt-Merian: Volkmann's klin. Vorträge, 128, 1884.
[24] Boston Med. and Surg. Journal, x., 228.
[25] Gundrum: Med. News, 1882, xli., p. 231.
[26] Bender: *Loc. cit.* Hynes: Lancet, ii., 1870.
[27] Deutsche med. Woch., x., 37-40.
[28] Berliner klin. Wochenschr., 1868, No. 2. [29] *Ibid.*, 1868, No. 9.
[30] Jahrbuch für Kinderheilk., 1872, v., 324.
[31] The Practitioner, 1875, xvi., p. 21. [32] Lancet, 1885, ii., p. 795.
[33] Charité Annalen, 1876, iii., p. 588.
[34] British Medical Journal, No. 198, 1870.
[35] Roloske: Deutsche med. Woch., October 8th, 1881. Mitchell: Edinburgh Med. Journ., February, 1882.
[36] Deutsche med. Woch., 31, 1883.
[37] Jahrbuch für Kinderheilk., N. F., 1, p. 431.
[38] *Ibid.*, xxii., H. 2, p. 15. [39] *Ibid.*, N. F., 4, 1870.
[40] *Ibid.*, ix., 766. [41] L'Union médicale, April 30th, 1882.
[42] Wiener med. Wochenschr., 39, 1877. [43] *Ibid.*, 43, 1877.
[44] Deutsche med. Wochenschr., 31, 1883.
[45] Berliner klin. Wochenschr., 43, 1883.
[46] A Treatise on the Diseases of Infancy and Childhood, Philadelphia, H. C. Lea. [47] Medical Record, ii., 1859.
[48] Journ. of Cutan. and Venereal Diseases, vol. i., 1883.
[49] Clinical Lectures and Essays.
[50] Guy's Hospital Reports, 1879. [51] *Ibid.*
[52] Konetschke: Wien. med. Presse, 1882, xxiii., 1483; Ffolliott: Brit. Med. Journ., i., 1879. [53] British Med. Journ., 1879, ii., p. 75.
[54] Amer. Journ. of the Med. Sci., lxxxvii., 1884.
[55] Page: Lancet, 1885, i., 887.
[56] Archiv f. Gynäkologie, ix., Bd. 2, 1876.
[57] Dublin Journal Medical Sciences, February, 1866.
[58] Obstetrical Transactions, 1871, vol. xii., p. 58.
[59] Berliner klin. Wochenschr., 47, 1872. See also Smith: Med. Times and Gaz., 1870, ii., 1053.—Schwarz: Wien. med. Wochenschr., 12, 1871. Broadbent: Brit. Med. Journ., April 1st, 1876.—Barrs: Lancet, 1883, ii., p. 102.—Farrar: Lancet, 1875, i., p. 109.
[60] Trojanowsky: Dorpat. med. Zeitschr., i., 1871.
[61] Dorpat. Med. Zeitschr., iii., 1873.
[62] Correspondenzbl. f. Schweizer Aerzte, No. 5, 1876.
[63] L'Union médicale, 8, 1883. [64] Progrès médical, 1880, 47.
[65] Wiener med. Jahrb., 2 H., 1882.
[66] Transact. Patholog. Soc., London, 1877, xxviii., p. 435.
[67] Handbuch der path. Anat.
[68] Brocq: Journ. Cutan. and Venereal Diseases, August, 1885.
[69] Journ. Cutan. and Venereal Diseases, April, 1883.
[70] Dublin Journ. Med. Sci., March, 1885.
[71] J. Lewis Smith: Pepper's System, vol. i., p. 534.
[72] Ann. de Médecine d'Anvers, London Med. Rec., 1882, 52.
[73] Volkmann's Sammlung klin. Vorträge, No. 128, 1880.
[74] J. Lewis Smith: Pepper's System of Medicine, vol. i., p. 548.
[75] British Medical Journal, 1886, ii., p. 813.
[76] Class: Jour. Amer. Med. Assn., February 24th, 1900.
[77] Rotch: Pediatrics, 1901.
[78] Holt: Diseases of Infancy and Childhood, 1902.
[79] Nothnagel's Encyclopedia of Practical Medicine, American edition, 1902.
[80] Pearce: Boston City Hospital Reports, 1899.
[81] Kober: American Journal Medical Sciences, 1901.
[82] Baginsky: Berliner klin. Woch., 27, 29, 1900.
[83] Moser: Berliner klin. Woch., 48, 49, 1902.
[84] Moser: Wien. klin. Woch., 41, 1902.
[85] Moser: Jahrbuch für Kinderheilk., 1903, 57, der dritten Folge, 7 Band, 1 Heft.
[86] Stickler: Trans. Med. Soc., New Jersey, 1897.
[87] Roger: Presse méd., 1896, iv., 425.

SCHOENLEIN'S DISEASE.—See *Morbus Maculosus Werlhofii.*

SCHOOLEY'S MOUNTAIN SPRINGS. — Morris County, New Jersey.

Post-Office.—Schooley's Mountain. Hotel.

Access.—From New York viâ the Delaware, Lackawanna and Western Railroad, to Hackettstown, thence three miles by stage to springs; or viâ the Central Railroad of New Jersey to German Valley, thence two and one-half miles by stage; from Philadelphia viâ the Philadelphia and Reading Railroad to German Valley, etc.

Schooley's Mountain is a broad plateau in the northern part of New Jersey, 1,200 feet above tide water, overlooking the Musconetcong Valley on the north and German Valley on the south. The scenery in the vicinity is varied and picturesque, and the neighborhood abounds in beautiful walks, drives, landscapes, etc. Among the near-by points of interest are Lake Hopatcong, Budd's Lake, and the romantic Delaware Water Gap. The chalybeate spring, situated half a mile from the hotel (the Heath House), has enjoyed for many years a reputation as a ferruginous tonic. The analyses which have thus far been furnished are not entirely satisfactory. It is an established fact, however, that the iron is present in relatively small quantity. The waters are recommended in cases of general debility, and of torpor of the liver, and in renal and bladder disorders. At the Heath House is another spring, which has been analyzed by Prof. George H. Cook, State geologist. It appears from this analysis that the water is rich in mineral ingredients. Nevertheless, so far as we can learn, it is not used for medicinal purposes. The Heath House and cottages consist of several detached buildings, none of them over three stories in height, with accommodations for three hundred and fifty guests. They are situated in the midst of a beautiful lawn of twenty-five acres. It is stated that the "temperature here averages ten degrees lower during the day, and from fifteen to twenty degrees lower during the night, than at New York or at Philadelphia. *James K. Crook.*

SCHOOL HYGIENE.—The physical conditions attending the education of the child at school are quite as important as his mental training. School hygiene embraces all that pertains to the physical welfare of the child in the course of instruction, both subjectively and objectively, including his own physical condition, and the effects of his environment. That the subject is attracting increased attention is evident from the enactment of laws relating to the ventilation and sanitary condition of school-buildings, the restriction of contagious diseases among school-children, and the medical inspection of schools. About one fifth of the entire population is under instruction in the schools, either public or private, at a period of life when good health and its preservation are matters of the highest importance.

SCHOOL-BUILDINGS. SELECTION OF SITE.—The site should be chosen with reference to the convenience of a majority of the population for whom the building is intended, having in view a reasonable probability of future increase. It should be well back from the street, and not on a main street or thoroughfare. The neighborhood of noxious and offensive, as well as noisy trades, should be avoided. Nor should it be near the line of a steam railway. Proximity to liquor saloons should be avoided. Fortunately in some States, a definite distance is prescribed for such nuisances, so far as proximity to school-houses is concerned.

The location should not be overshadowed by a hill of greater height than the school-building, especially upon its western side. The size of the site, including the playgrounds, should be largely determined by the number of pupils to be accommodated, a space of thirty square feet being desirable for each pupil.

The site should be capable of thorough drainage, and should be graded to a higher level than that of the contiguous streets. The soil of the immediate neighborhood should also be dry, and there should also be opportunity to obtain a supply of pure drinking-water.

School-Building.—In the planning of school-houses, the school-room should be the unit first considered. According to Shaw, "the school-building should be a number of

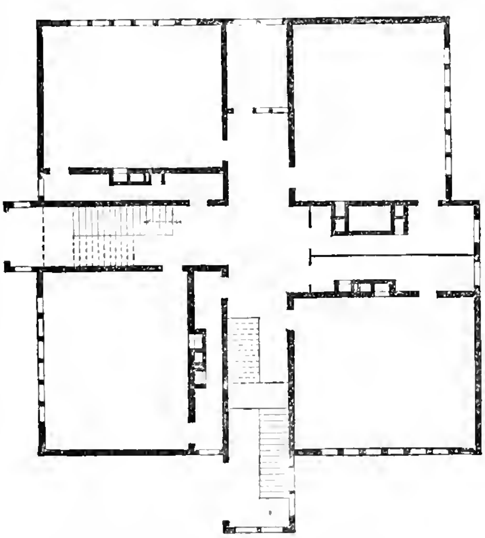

FIG. 4157.—A Good Single Floor Plan. Rooms well arranged for seating and lighting. (Shaw's "School Hygiene," The Macmillan Company.)

school-rooms properly disposed, and not a whole cut up into school-rooms, whose size and arrangement are dependent upon the size and shape of the building."

The general shape of the school-room should be oblong, with the aisles running lengthwise of the room. This allows proper lighting of the desks (Fig. 4158).

The question of the size of the school-room has received much attention, and has been made the subject of experiment until definite standards may now be recommended, depending upon the ventilation, heating, lighting, and the needs of the eye and ear of the pupil. A minimum of 15 square feet of floor space and 200 cubic feet of air space for each pupil should be insisted upon. For a room intended for forty eight pupils these conditions may be secured with a height of 13 feet, length 30 feet, and width 25 feet. A greater length than 30 to 32 feet is not admissible since the scholars in the rear row of seats would be subjected to unnecessary eye-strain when looking at blackboards or other objects at the opposite end of the room.

Lighting.—The amount of glazed surface admitting light to a school-room should be from one sixth to one-fourth as much as the floor space of the room, in order to provide sufficient light for all parts of the room in cloudy weather. This limit, however, may not be sufficient in case of obstruction by trees, houses, or adjacent hills. In crowded cities, and other places where well-lighted locations are not available, the use of ribbed glass, and Luxfer prisms is recommended for the purpose of increasing the illumination. In the Building Rules of the Board of Education (England) are the following excellent suggestions:

"The light should, as far as possible, and *especially in class-rooms*, be admitted from the left side of the scholars. All other windows in class-rooms should be regarded as supplementary, or for summer ventilation. Where left light is impossible, right light is next best. Windows facing the eyes of teachers or scholars are not approved. In rooms fourteen feet high any space beyond twenty-four feet from the window wall is insufficiently lighted. Windows should never be provided for the sake merely of external effect. All kinds of glazing which diminish the light and are troublesome to keep clean and in repair should be avoided."[1]

Rooms having a northern exposure should, other things being equal, have a more liberal provision for light than those with a southern exposure.

According to Shaw:[2] "If a school-room is insufficiently lighted and more light cannot be admitted from the left or near, the windows placed on the right should have their sills eight feet above the floor, and the amount of light admitted by such windows should in no instance be strong enough to overpower the light admitted from the left."

Spaces between Windows.—The windows should be placed with as little space as possible between them, to avoid the production of alternate bands of light and shade which are injurious to the eye.

Height of Windows.—The windows should extend as near to the ceiling as possible, since the higher they extend the better the illumination. Windows arched at the top decrease the illumination.

Height of Window Sills.—The English rules advise a height of at least four feet above the floor. Some authorities advise a height of five feet, but this would interfere too much with the amount of glazed surface. Large single panes of glass for upper and lower sash allow the least obstruction of light, and readily admit of cleaning.

Color of Walls.—No color should be used which absorbs light. Reds are to be avoided. Yellow is not restful to the eye. A pale greenish-gray, nearly white, appears to be the best suited for school-rooms.

Window Shades.—Window shades are useful in bright sunny days, and especially when the ground is covered with snow, to modify the effect of light. They should roll up from the bottom and should be somewhat darker than the walls. The direct rays of sunlight should not be allowed to fall upon any occupied desk.

Arrangement of Seats.—The best arrangement is that which allows the pupils to face one of the shorter sides of the school room, the windows being at the left of the scholars as they sit in their seats. It is also best to have the aisle at the side opposite the windows considerably wider than that upon the side next the windows. This allows some freedom of movement about the blackboards, as well as space for other school exercises (Fig. 4158).

If the seats are arranged so that the scholars face the long side of the room, those upon the outer rows are at some disadvantage in looking at objects on the wall behind the teacher, such as maps, etc.

Blackboards.—The best blackboards are made of slatestone, and should be either black or dark green. If blackboards are not used, slated paper, cloth, or walls

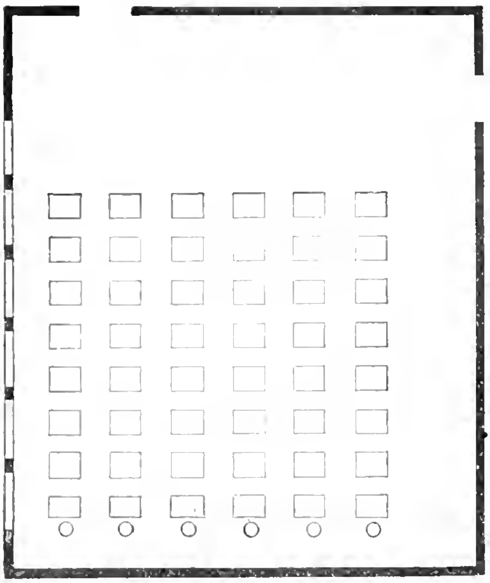

FIG. 4158. Model Arrangement of Seats; Windows at Left of Scholars. (From Shaw's "School Hygiene," The Macmillan Company.)

may be prepared. For young scholars the bottom of the board should not be more than twenty-six inches from the floor, varying from that height to thirty-six inches for the older grades. Their width from top to bottom should be about four feet.

Number of Stories.—When it is practicable, the number of stories should be limited to two above the ground. This rule is especially applicable to that class of schools in which the scholars frequently pass from one story to another during the day.

Basement.—A basement should always be provided. Its walls and floor should be so constructed as to prevent access of dampness, and the walls should rise above the ground sufficiently to permit the entrance of sunlight.

Hallways and Entrances should be sufficiently ample to allow the building to be rapidly emptied in cases of emergency.

Stairways.—All stairways should be well lighted, and should be at least five feet wide, and should be broken by landings about half-way from top to bottom. Diagonal steps, or spiral stairways should not be permitted. Steps with six-inch risers and eleven-inch treads are easiest for school children, but six and one-half inches may be allowed for stairs in high schools.

Floors.—Floors should be made of well seasoned hard wood, free from cracks. At the junction of the mopboard and the floor, a concave strip will allow better cleaning and sweeping (Fig. 4159). The floors between the occupied stories should be made as nearly sound proof as possible. Cornices, mouldings, and other projections which catch dust should be avoided.

Moist sawdust may be used in the cleaning of floors. Bad floors should be replaced, or treated by planing, and filling the cracks. Pure oil is not so good an application for floors as preparations containing a considerable proportion of wax or paraffin, since the oil darkens the floor and interferes with the light.

Cloak-rooms.—These should be provided, and furnished with shelves and hooks for clothing, hats, and overshoes. They should be so arranged as to admit of free ventilation.

Heating and Ventilation.—The importance of the proper heating and ventilation of school buildings depends largely upon the climate or region in which the school house is located. In the tropics where windows may be open throughout the year, an abundant and constant supply of fresh air can be had, and the question of heating is of little consequence. In temperate climates, however, the subject assumes greater importance.

The common modes of heating large school-houses are by hot air, steam and hot water. The two latter are generally preferable for large school-houses, since by them the rooms in different parts of a building can be warmed more equably than by hot air.

In rural districts a supply of fresh air may be introduced by means of jacketed stoves after the manner described in the nineteenth report of the State Board of Health of Massachusetts, p. 315.[3] The ventilation should be of such efficiency as to provide a supply of thirty feet of fresh air for each pupil per minute. The inlets and outlets should be of such size that the incoming warm air shall not have a velocity of more than four hundred feet per minute, and this inlet, for a room of standard size, should not have an area of less than four square feet. A wire screen of one-eighth inch wire, with meshes of one and one-half inches, is better than a cast-iron register. The inlet and outlet should be on the inner or warm side of the room, the inlet being placed about eight feet above the floor, and the outlet in the floor or very near it.

Temperature.—A temperature of 65° to 68° F. should be maintained during school hours. Dr. Lincoln recommends 66° as a proper standard. Most English authorities are in favor of lower temperatures than these.

Humidity.—Good ventilation requires a proper amount of moisture to supply the loss involved in heating the air to a sufficient degree to insure comfort. Various devices have been invented to supply this deficiency. The ordinary water-pots which are supplied with hot-air furnaces cannot be relied upon to produce a sufficient degree of humidity for health and comfort.

Carbonic Acid as an index of impurity in the air. The amount of carbonic acid in fresh outdoor air is about 3 parts in 10,000.* In order to secure the highest degree of comfort and health for the scholar who spends a portion of his time every day in the school-room, the amount of carbonic acid in the air should not be allowed to exceed 7 parts per 10,000. For the purpose of measuring the relative amount which may be present in an occupied school-room several devices have been invented, but none which have thus far been devised appear to be capable of giving as satisfactory results as a quantitative analysis of the air by a competent chemist. Dr. Haldane has recently brought to notice a new apparatus for which he claims that "the analysis after some practice can be relied on to within 0.5 volume on either side of the right result." The apparatus, however, requires very careful manipulation, since "a variation of 0.1° C. in the temperature of the water in which the air burettes are immersed would, unless compensated, cause an error of fully three volumes per 10,000 in the analysis.† A sim-

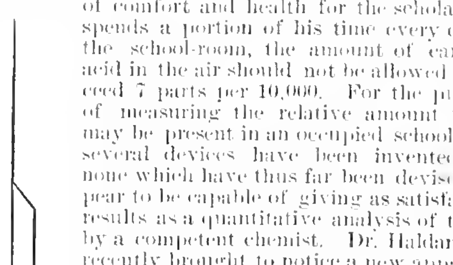

FIG. 4159. Section of Concave Strip at Corners Between Mop Board and Floor.

* Average of sixty-two analyses in summer and winter, in country air of Scotland. Dr. Haldane, in report of committee to inquire into the ventilation of factories and workshops, 1902, p. 93.

† *Loc. cit.*, pp. 117 and 120.

ple apparatus which can be used by the teacher in any school-room for the purpose of determining, at least approximately and with facility, the relative amount of carbonic acid present in the air of the room, under the ordinary conditions of school attendance, is very much needed.

Lavatories, Water-Closets, etc.—The best location for these appliances, sometimes by an exclusive misapplication of terms called "sanitaries," is in a separate building outside the school-house. In consequence of the severity of the winters in northern climates, and the increased cost of heating, this is not always practicable, and these conveniences are usually placed in the basement in large buildings, especially where they are connected with the public sewer system. No system, however, should be tolerated in which the ventilation of the water-closets is in any way connected with the general ventilation of the school. They should be well lighted. If latrines or troughs are used, they should be so constructed as to admit of thorough cleansing and flushing with water. Systems providing for the drying or cremation of excreta in the basement of school-buildings require the most careful janitorship, and are not to be generally recommended.

Urinals.—These can be successfully maintained only in school-buildings connected with a public water supply. Slate or asphalt is the best material for construction. There should be an abundant flush of water, and a gutter at the bottom with a sufficient inclination to carry off the water rapidly to the drain or soil pipe.

The plumbing, the care, and management of the closets, latrines, and urinals should be of such good character as not to require the use of disinfectants or deodorizers. The substances often recommended to be placed in such places for the purpose of "disinfecting" the air do not disinfect, but merely substitute one smell for another.

Outhouses in Country Districts.—In districts not supplied with good systems of water and sewers, the maintenance of convenient and cleanly outhouses is a difficult problem, since, without the strictest attention on the part of teachers and janitors, they are likely to become sources both of physical and moral uncleanliness. Such outhouses should be located at least forty feet from the school house, and there should be entirely separate buildings for each sex. These should also be separated by a tight board fence extending from the school-house, at least six and one-half feet in height. They should be provided with ample and well-cemented vaults, so constructed as to admit of emptying and cleansing without difficulty. They should be so made as to exclude all water from any source, except that contained in the excreta.

Provision should also be made for the storage of an ample supply of dry loam under cover. This can usually be obtained during the warm season. It should be applied daily during the time of school attendance, a sufficient quantity being applied each day to cover the fresh contents of the vaults.

Water Supply.—In cities it is customary to provide a supply of water from the public supply. As a general rule such water is pure and wholesome. On the contrary, instances have occurred in which the authorities have found it necessary to shut off the water of the public supply from the schools in consequence of serious pollution at the source. Lead pipe should not be used for the conveyance of water to the school-buildings nor for its distribution in them. It is desirable to have as many faucets on each floor as there are separate schools. There should also be opportunity for washing hands when coming from the closets and urinals, for which purpose soap and towels should be provided.

In country schools the supply is often obtained from wells, and special attention should be paid to their proper location in order to secure them from pollution. If there is any doubt as to the quality of the water, it should be submitted to a competent chemist for analysis. School house wells should be thoroughly pumped out at the close of the vacations in localities where the water is not used through the vacation. Water for the schools should not be kept in open pails, and the use of a separate drinking cup for each scholar should be encouraged.

School Baths.—The provision of places for bathing in connection with the public schools, as introduced recently in a few cities, undoubtedly exerts a decided influence, moral as well as physical, upon the children of those schools, an effect which extends to the homes of such children, among a large portion of whom the facilities for bathing are of the most limited character. Added to this, in schools which are provided with swimming tanks, the instruction given in this art has the advantage of being both healthful and of a life saving kind. The swimming tank adds materially to the cost of maintenance, on account of the fuel required to keep a large body of water at a proper temperature. Shower baths are now provided in connection with several of the public schools in New York, Boston, and other cities. In the town of Brookline, Mass., a public bathhouse erected in close proximity to the high school-house gives abundant opportunity to scholars in the public schools both for bathing and swimming all the year round.

School Furniture.—Since the scholar spends a large part of his school life seated upon some sort of seat, and, in all the higher grades, provided also with a desk, it is of the highest importance that these two articles of furniture should be as correctly made as possible. In an article by Dr. W. H. Burnham the following requirements are given:[4]

1. The height of the seat should be about two-sevenths that of the body.
2. The width should be about one-fifth of the length of the body, or three-fourths the length of the thigh.
3. The seat should slope downward a little toward the back, and be slightly concave, having bevelled edges in front.
4. A back rest is essential for hips and shoulders.
5. The correct "difference" or vertical distance from the seat to the edge of the desk is that which permits the child when sitting erect to place both forearms on the desk, without raising or lowering the shoulders.
6. Of equal importance is the "distance" * of the seat from the desk, which may be (*a*) "zero," (*b*) "positive," or (*c*) a "negative" distance, necessitating facility in adjustment.
7. A desk slope, preferably of fifteen degrees for writing, with capacity for adjustment to other purposes.
8. Strength, durability, and simplicity of construction.
9. Surfaces easy to clean, and unfavorable to the accumulation of dust.
10. A moderate price.

The principal objections to badly contrived school seats and desks are the liability to produce eye-strain and distortion of the spine. Almost any sort of seat may produce one or the other of these effects if pupils are kept continually sitting for long periods of time, without exercise, and especially if they are engaged in writing for lengthy periods. There is, however, a decided choice in school furniture, and the tendency is constantly in the direction of improvement (Figs. 4160 and 4161).

According to Janke the edge of the desk should be of such height above the seat as to be opposite the navel of the scholar who sits erect, so that, in placing the forearm upon the table to write, the elbow must be bent a little to one side and to the front of the scholar.[5]

Much improvement has been accomplished in the United States by means of adjustable desks, so constructed as to admit of change and adaptation to the wants of scholars at an age when growth is most rapid.

Shaw says: "Desks and seats should be adjusted vertically twice a year, at the opening of school in Septem

* Janke describes the "distance" as the horizontal interval between a vertical line touching the front edge of the seat, and another vertical line let fall from the edge of the desk. If these lines coincide, the "distance" is *zero*; if the desk overlaps the seat, the "distance" is *minus* or *negative*; if the edge of the seat falls to the rear of the edge of the desk, the "distance" is *plus* or *positive*.

ber, and again in February or March; and at whatever time during the year a pupil enters school or is transferred to another room, his seat should be adjusted to him "[2] Desks should be constructed to fit the children.

According to Hope and Browne: "Short lessons at bad desks are likely to be less injurious than long confinement at the most perfect."[3] The sitting posture is in itself bad, and should be counteracted by active exercise. Hence the use of blackboards for drawing and writing by beginners in place of copy-books is earnestly advised. In most American schools at the present day fixed seats and desks are in use, but in Germany several authorities give preference to movable seats and desks, on account of the facility thus offered for cleansing the floors[6] (Figs. 4162 and 4163).

FIG. 4160.—From Shaw's "School Hygiene."

As an instance of the serious effects produced by want of adaptation of school furniture to the ages and heights of children, Dr. C. F. Scudder reports that twenty per cent. of the girls in the grammar grades of the Boston schools were round shouldered, as a result of malpositions due to defective desks and seats.[7] In several rooms he found girls who differed seven years in their ages, and nearly twenty two and one half inches in height, seated at desks and in seats of exactly the same size. In one school eighteen per cent. of the scholars, when sitting back in their seats, could not touch the floor with their heels.

FIG. 4161.—From Shaw's "School Hygiene."

To counteract the ill effect of bad postures, even when properly adapted seats are supplied, periods of relief, together with exercises intended to correct bad habits of this sort should be given, to be repeated several times during each school day. During the first school year such periods should be more frequent than in the later years of school life. During the first year the child should not be confined at his desk more than one-third of the time.

Notwithstanding all that has been said and written in recent years about the importance of physical culture in schools, the tendency is still to train the mental faculties at the expense of the physical development of the scholar. There is consequently a decided necessity for devoting a greater share of each day's work to physical exercise. The recess should be maintained, and at least fifteen minutes in each session should be given "in which all scholars should, so long as the weather and climate permit, go out of doors, and engage in some form of physical activity" (Shaw). And this period of relaxation should be in addition to the regular systematic exercises which should form a part of the programme of each school day.

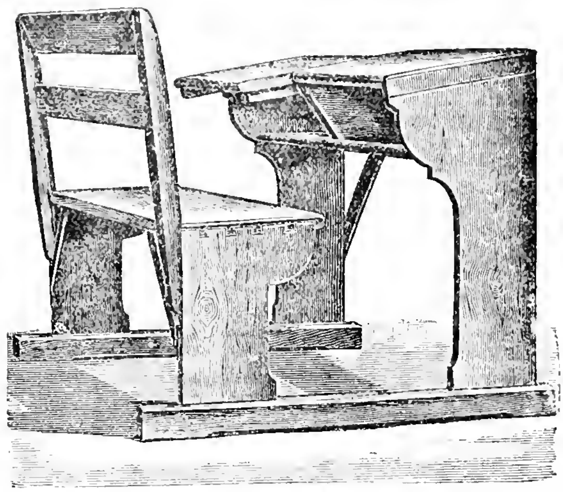

FIG. 4162.—Double Seat, used in German Schools. Movable and durable, but clumsy.

THE MEDICAL INSPECTION OF SCHOOLS.—In most European countries at the present day, the sanitary authorities exercise some sort of supervision over the public schools.[8] The well-known work of Dr. Janssens at Brussels has for years served as a model in this direction. In France, as early as 1842, it was ordered that every

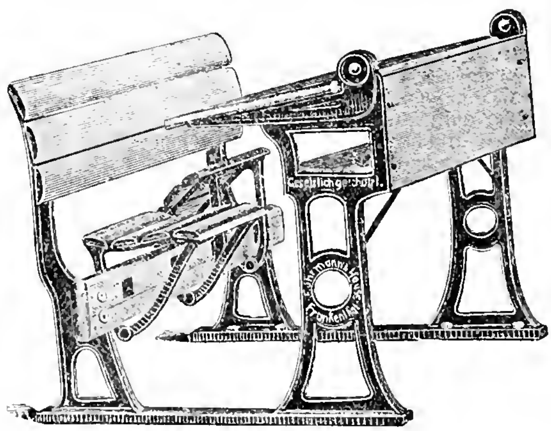

FIG. 4163.—German Double Seat. Movable.

public school should be visited by a physician, who should inspect the localities and the general health of school children. New regulations defining explicit duties of such medical inspectors in Paris were adopted, and went into effect January 1st, 1884.*

The first systematic medical inspection of schools in America was inaugurated in the Boston schools in 1894 on the advice of Dr. S. H. Durgin, chairman of the Boston Board of Health. Since that time New York, Philadelphia, Chicago, Hartford, Milwaukee, and other cities have adopted a similar course. The principal object at first aimed at was the search for unrecognized cases of infectious diseases, by which means it was believed that much could be done toward preventing their spread. Much good, however, can be accomplished in other directions toward improving all those conditions, both subjective and objective, which relate to the health of school children.

In Boston the city is divided into fifty districts, each of which is provided with an inspector who visits each of the schools in his district daily in the morning. Children who appear to be ill from any cause, and especially those suffering with incipient infectious diseases, are sent to their homes. The teachers soon become familiar with the work and render efficient aid to the inspectors.

The principal diseases detected by such inspectors, as shown by the experience of inspectors in different American cities, are the specific infectious diseases of childhood, whooping-cough, measles, mumps, chickenpox, diphtheria, scarlet fever, influenza, and tuberculosis, also laryngitis and tonsillitis, rhinitis, acute bronchitis, suppurative diseases of the ear, acute catarrhal conjunctivitis, imperfect sight, and contagious skin diseases, especially pediculosis, which often proves a serious pest among school children.

Eyesight.—Every possible means should be used to prevent impairment of the eyesight of school children, since the demands of school life impair the eyesight of a very large percentage of those who pass through the curriculum of several years.

The types employed in printing school books should produce letters of the most legible character, and the lines should be amply spaced or leaded. Cohn advises that the length of the lines should not be more than 10 cm. (4 inches).

White paper with a dull, unreflecting surface is best for the eyes of school children.

Blackboards should be kept clean and black, and should not be allowed to become gray in consequence of retention of particles of chalk. As a general rule, slates are not so good as paper. They become greasy, and the writing is generally more illegible than when it is written upon paper. Other sanitary reasons are also urged in forbidding their use.

Children should not be permitted to assume bad postures while writing, since they also injure the eyesight. The pupil should sit erect, and the book should not come nearer to the eyes than twelve inches.

Testing the Eyesight and Hearing.—Every teacher should know how to make the common tests for eyesight and hearing, which should be applied soon after the beginning of the school year, so that children who are found to be short-sighted or defective in hearing may be properly seated near the front of the room.

In schools where medical inspection is regularly made, this examination should be conducted by the medical inspector. Children are often punished or regarded as dull, when there is either a defect of the vision or of the hearing. Defects of the eyesight should be reported to the parents, so that a thorough examination may be made by an oculist and the proper glasses furnished.

Samuel W. Abbott.

BIBLIOGRAPHICAL REFERENCES.

[1] Hope and Browne: Manual of School Hygiene, 1901.
[2] Shaw, E. R.: School Hygiene, New York, 1901.

* Palmberg's "Public Health and Its Applications."

[3] Pinkham, J. G.: The Ventilation of School Rooms heated by Stoves, Nineteenth report of State Board of Health of Massachusetts.
[4] Burnham, W. H.: Outlines of School Hygiene, in Pedagogical Seminary, vol. ii., No. 1, 1892.
[5] Janke: Grundriss der Schulhygiene, 1901.
[6] Eulenberg: Schulhygiene.
[7] Scudder, C. F.: Seating of School Children and Lateral Curvature of Spine. School Document No. 9, Boston, 1892.
[8] United States Commissioner of Education. Medical Inspection of Schools, Report, 1897–98, vol. ii.
Bernstein: Viertetjahrsschrift f. gericht. Med. u. Gesundheitswesen, 3, 1892.
Bowditch, H. P.: The Growth of Children.
Billings, J. S.: Ventilation and Heating, New York, 1893.
Burgerstein: Notizen zur Hygiene des Unterrichts und des Lehrerberufes, Jena, 1901.
Burgerstein and Netolitzky: Handbuch der Schulhygiene, 1900.
Chapin, C. V.: Municipal Sanitation, Providence, R. I., 1901, p. 7.
Cohn, Hermann: Lehrbuch der Hygiene des Auges, 1892.
Eighth and Twenty-second Annual Reports of State Board of Health of Massachusetts, 1877 and 1890.
Hartwell, E. M.: Reports of Director of Physical Training, Boston, 1894 and 1895.
Lincoln, D. F.: Report of Committee on School Hygiene. Amer. Med. Association, Chicago, 1893; also article in Buck's Hygiene and Public Health, vol. ii., New York, 1879.
Marble, A. P.: Sanitary Condition of School-Houses. Bureau of Education, Washington, D. C.
Pettenkofer: Ueber Luft in den Schulen, 1892.
Ravenhill, Alice: The Teaching of Hygiene in the Schools and Colleges of the United States. Journ. San. Institute, April, 1902, p. 27.
Risby, S. D.: School Hygiene and Diseases of the Eye, Philadelphia, 1897.
Winsor, F.: School Hygiene. Fifth Report of Massachusetts State Board of Health, 1874.
Young, A. G.: Seventh Annual Report of State Board of Health of Maine, 1892.

SCHWALBACH is a spa situated in the province of Hesse-Nassau, Prussia. It lies in the valley of the Münzenbach, about twelve miles from Wiesbaden, and five miles from the health resort Schlangenbad. Its elevation is 972 feet above sea level, and as it is well protected against all but the southerly winds, its climate is mild and well suited for invalids. There are eight mineral springs at Schwalbach, known as the Wein-, Stahl-, Rosen-, Paulinen-, Ebe-, Neu-, Linden-, and Adelhaid-Brunnen. There is but little difference in the composition of the waters of these springs. The following is the analysis of two of the springs, as made by Fresenius. In 1,000 parts there are, of:

	Wein-Brunnen.	Linden-Brunnen.
Ferrous bicarbonate	0.057801	0.006902
Manganous bicarbonate	.009085	.004680
Sodium bicarbonate	.245345	.042317
Calcium bicarbonate	.572129	.429277
Magnesium bicarbonate	.605120	.395257
Ammonium bicarbonate	....	.002205
Lithium bicarbonate	....	.002633
Strontium bicarbonate	....	.001048
Sodium chloride	.008630	.017622
Sodium sulphate	.006193	.016156
Potassium sulphate	.006469	.006414
Sodium nitrate	....	.005541
Sodium phosphate	Trace.	.000138
Aluminum phosphate	....	.000197
Silicic acid	.046500	.032821
Organic matter, etc	.000046	.000063
Total solids	1.55871	0.963921

The gases are carbonic acid and a very small proportion of sulphureted hydrogen.

Schwalbach is a favorite health resort, and is visited by several thousand guests every year. The diseases for the relief of which a course of treatment at this spa is recommended are anæmia and chlorosis, epilepsy, chorea, progressive muscular atrophy, neuralgia, neurasthenia, hysteria, and other functional and organic nervous disorders, Bright's disease, diabetes mellitus, chronic vesical catarrh, and various affections of the female sexual organs.

The waters are employed externally and internally, according to the individual indications, and facilities are afforded for pine-needle, mud, vapor, and other baths. The season lasts from May to October. There are excellent accommodations for visitors.

SCIATICA. See *Neuralgia.*

SCIRRHUS. See *Carcinoma.*

SCLERA. See *Eye.*

SCLERA, DISEASES OF THE.—Although the sclera becomes secondarily involved in various morbid processes originating in other parts of the eyeball, primary disease of this structure is comparatively rare. Scleritis, or inflammation of the sclerotic, as a primary affection, is recognized only as originating in a narrow zone of the sclera, bounded in front by the cornea and behind by the insertion of the recti muscles. In this situation we meet with two varieties of scleritis—simple and complicated.

SIMPLE SCLERITIS (episcleritis) commences as a localized subconjunctival hyperæmia at a short distance from the corneal margin. As the episcleral tissue becomes infiltrated, a smooth swelling appears, which is but slightly elevated above the surrounding surface, and is usually of a dingy yellowish-red color, sometimes resembling a pustular formation, though ulceration or loss of substance never occurs. The conjunctival vessels over and around the swollen part are more or less engorged, but the conjunctiva in general remains normal. After a few days or weeks the nodule assumes a dull violet hue and becomes flatter, in which form it may remain stationary for a long time, or may gradually disappear, leaving a more or less permanent dull gray or ash-colored spot. Occasionally two or more such nodules are present at the same time, or as one disappears others may develop. The slow progress and tendency to recurrence of these nodules frequently render the disease tedious and protracted. One or both eyes may be affected, or as one recovers the other may undergo the same process.

The subjective symptoms are seldom severe; they consist in an unpleasant sensation of weight or pressure in the eye, undue sensitiveness to light or cold, and perhaps slight headache; rarely there may be considerable photophobia and sharp pain. This disease belongs almost exclusively to adult life, and is most common in elderly people. The gouty, the rheumatic, and the scrofulous diatheses are all credited with lending a predisposition to this form of scleritis.

Treatment.—Any special dyscrasia on the part of the patient must be taken into account and suitably dealt with; and while exercise in the open air is to be enjoined, the eye must be protected from strong light and from sudden changes of temperature. The local use of sulphate of atropine is allowable in the early stages, especially if there be marked symptoms of irritation. In the absence of these, instillations of solution of eserine—gr. ½ or 1 to the ounce—twice daily, are often very efficacious. Massage, with the employment of oxide of mercury ointment (amorphous yellow oxide of mercury 1 part, and fat or vaseline 25–50 parts), has been highly recommended. Dry or moist heat, applied to the eye in the usual way, several times daily, may be beneficial.

In regard to internal medication, the choice of remedies will depend on various circumstances. Mineral waters, iodide of potassium, salicylate of soda, protoiodide of mercury, hypodermic injections of pilocarpine, and many other remedies have been used with more or less success, according to the special indications present in the individual case.

COMPLICATED SCLERITIS (sclero-keratitis, scrofulous scleratitis). This is a much more serious affection, owing to the involvement of the cornea, iris, and ciliary region in the inflammatory process and also to the tendency which exists to disastrous changes in any or all of these parts. Sclero-keratitis, commencing in the sclerotic, begins with one or more dusky infiltrations of the sclerotic, as in simple scleritis, but close to the corneal margin, the cornea being involved from the first, or after the scleral affection has existed only a short time. The pericorneal tissues are more deeply and more generally involved than in simple scleritis, and in some cases the cornea becomes extensively opaque; sooner or later the iris may participate in the inflammation, as is shown by visible changes in its appearance and by the presence of posterior synechia, or the entire ciliary region may become intensely congested and sensitive (iridocyclitis). The special dangers to which the eye is subjected in any given case may be approximately estimated by the severity of the disease in the several parts affected—extensive changes in the cornea threatening permanent opacity of this structure; in the iris, more or less complete posterior synechia, and in the ciliary region, ciliary staphyloma. There may be one or more foci of inflammation; when there are several of these, the entire pericorneal zone may be involved, or the same thing may happen more slowly through repeated relapses, each time a different area of this zone being attacked. The low dusky swelling of the sclerotic, continuous with a patchy opacity of the adjacent cornea, is the characteristic objective sign of this disease, which, as a rule, is subacute in all its manifestations. Occasionally, however, the inflammatory process is more active, and there are intense photophobia, considerable lachrymation, and severe pain. The disease may at any time subside, leaving a dull grayish, thickened appearance of the sclerotic, and a corresponding irregular marginal opacity of the cornea. If several foci have been present, the cornea will have the appearance of being irregularly encroached upon by the sclerotic. With the subsidence of the inflammatory process the dull slaty-gray sclerotic may present a zone of thickened tissue around the cornea, which sometimes looks as if it were pushed forward, giving the anterior part of the eyeball an elongated appearance; or, more frequently, the sclerotic immediately around the cornea yields in certain places, and an irregular, nodular-looking projection (intercalar staphyloma) is formed behind the cornea. This prominence is sharply defined anteriorly, but becomes gradually flattened toward the level of the normal sclerotic posteriorly. After repeated attacks of inflammation the staphylomatous bulging may involve the entire circumcorneal zone of the sclerotic, giving rise to great enlargement and distortion of the anterior part of the eyeball; at the same time the iris may become expanded from the periphery, and the anterior chamber is often considerably enlarged. The development of staphyloma in this class of cases does not often depend on increased intraocular tension, but on a gradual expansion of the softened sclerotic. If the staphyloma is to be regarded as evidence of increased tension we must assume that the softened sclera has yielded more readily than the nerve entrance; otherwise it would be difficult to understand the well-known fact that extensive changes in the form and appearance of the eyeball are under these circumstances not inconsistent with fairly good vision.

The subjects of this disease are usually young adults, and it affects women far more frequently than men. "It is not known to be associated with any special dyscrasia, but generally occurs in persons with a feeble circulation and a liability to 'catch cold'; in some cases there is a definite family history of scrofula or phthisis" (Nettleship).

Treatment.—During the irritative stages soothing remedies are indicated. Protection from cold air and strong light is always advisable, warm fomentations are generally beneficial, and instillations of atropine are useful if there is much irritation, especially if the iris is at all involved.

In the more acute forms of this disease the writer has seen great improvement follow the use of antipyrin in doses of fifteen grains several times daily. Mercury may be used in moderation if the patient is not too anæmic. If a distinctly rheumatic or gouty tendency exists, the usual constitutional treatment for these conditions is indicated; in some cases colchicine is very useful, in others diaphoretics, such as pilocarpine hypodermically, give excellent results. Iridectomy may be performed if there are extensive adhesions of the iris and a tendency to the development of staphyloma. If vision is destroyed and the eyeball is greatly enlarged, an operation for the removal of the staphyloma may be indicated.

Staphyloma of the sclera (ectasia) occurs under the most varied conditions, but usually as the result of prolonged increase of intraocular tension.

As a *congenital* anomaly of rare occurrence there is sometimes a partial bulging of the sclerotic, associated with congenital coloboma of the choroid (scleral protuberance of von Ammon).

Extensive destruction of the cornea from suppurative keratitis is commonly followed by more or less complete corneal staphyloma, and this may extend to the sclera, giving rise to more or less general enlargement of the eyeball. Iridocyclitis and iridochoroiditis, followed by occlusion of the pupil, give rise to increased tension of the eyeball, and this in the course of time, if not relieved, causes scleral staphyloma, usually in the ciliary region. Protracted increased tension from neglected glaucoma (glaucoma consummatum), or from dislocation of the lens, is a common cause of scleral staphyloma. Under these circumstances the bulging is usually far back, behind or between the insertions of the recti muscles.

In an ectasia following inflammatory or glaucomatous processes the protruding part is lined by a corresponding portion of the stretched and attenuated uveal tract. Bulging of the sclerotic may occur at any part, during the course of suppurative panophthalmitis, prior to rupture of this tunic and the escape of the contained pus.

Intraocular growths likewise cause bulging of the sclerotic, either by softening of the tunic in the vicinity of an intraocular growth, by the increased tension which such growths induce, or by simple expansion from excessive development of the growth. For the diagnosis of these conditions, see article *Eye, Tumors of*.

Ectasia of the sclerotic at the posterior pole (sclerectasia posterior), as met with in axial myopia, is a condition of frequent occurrence. (See *Myopia*.) Its presence is easily determined, by means of the ophthalmoscope, by the existence of a crescent or irregular circle of choroidal atrophy, which nearly always commences at the temporal side of the optic papilla. *Frank Buller.*

SCLEREMA NEONATORUM.—This rare disease of early infancy, to which a number of other names have been given at various times, such as *algidité progressive*, *induratio telæ cellulosa*, *l'endurcissement athrepsique*, was first described by Underwood as a hidebound condition of the skin occurring in new-born infants. At birth, or shortly after, a peculiar induration of the skin appears, usually first upon the lower extremities, whence it spreads rapidly to other parts of the integument, involving the entire surface of the body in a few days. When the disease is fully developed the infant appears as if frozen; the surface of the body is cold; the skin is hard and wax-like at first, but later usually becomes somewhat livid; the limbs are fixed and rigid, and, owing to the stiffness of the cheeks and lips, suckling is impossible. The respirations are weak and shallow, and the circulation is feeble. Death commonly occurs within eight or ten days. The disease may be congenital, in which case the infant is either stillborn or dies within a day or two.

The affection is most probably due to malnutrition arising from improper or insufficient food, poor hygienic surroundings, or previous exhausting disease. It may follow cardiac disease, gastro-intestinal affections, disease of the lungs, or any other malady which greatly lowers the vitality of the infant. The congenital cases or those which occur a day or two after birth are of unknown origin.

According to Langer, the induration of the skin arises from solidification of the fat, brought about by the abnormally low bodily temperature, the fat of infants, owing to differences in composition, solidifying at a much higher temperature than that of adults. This explanation, however, is not entirely adequate. Parrot, who first distinguished the affection from œdema neonatorum, with which it was for a long time confounded, believes it to be a drying out of the tissues brought about by the draining off of the fluids of the body by previous debilitating disease. This author finds the skin thinner than normal, the fat diminished, and the vessels, especially of the papillary layer, greatly contracted. Ballantyne agrees in the main with Parrot's conclusions.

The only affections with which sclerema neonatorum is likely to be confounded are scleroderma and œdema neonatorum. From the former it may be distinguished by the early age at which it occurs, no case of scleroderma having yet been observed in the first few months of life. From œdema it differs in the waxy appearance of the skin, the absence of pitting on pressure, the rigidity of the limbs, and the more general distribution of the cutaneous changes, œdema being most marked in the dependent parts of the body.

The *prognosis* is extremely unfavorable, death occurring in almost all cases. In the exceptional cases in which the entire surface is not involved, recovery may take place.

Treatment consists in the employment of measures to increase the temperature of the body, which is always much below the normal, and the administration of easily digested food and stimulants. As the infant is unable to nurse, it is necessary to administer the nourishment with a flexible tube through the nose, or by enema.

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SCLERODERMA.—Scleroderma (*σκληρος*, hard; *δερμα*, skin)—also known as *sclerodermia*, *sclerema*, *sclerema adultorum*, *scleriasis*—is a rare, chronic disease, characterized by a peculiar hard, leather-like condition of the skin occurring in diffuse areas or in sharply circumscribed patches. The circumscribed form, sometimes called *morphœa* and regarded by some authors as a distinct affection, has been fully described elsewhere and will not be considered here. Diffuse scleroderma begins either acutely or insidiously with slight stiffness of the skin, which usually presents a certain amount of swelling and hardness. Vague pains in the joints and muscles may precede the alterations in the skin, but marked or characteristic prodromal symptoms are usually wanting. The induration and stiffness of the skin spread slowly or rapidly (more commonly the former) over considerable areas, and in rare cases the entire integument becomes involved.

When the disease is fully developed the skin is remarkably firm and inelastic, smooth or slightly scaly, no longer susceptible of being picked up between the fingers and more or less adherent to the underlying tissues. While the color of the skin is usually white or yellowish-white, a considerable amount of pigmentation is often present in the shape of streaks and macules of various shades of brown.

Subjective symptoms are, as a rule, slight. There are a feeling of tension and occasionally more or less itching. Tactile sensibility is as a rule unaltered, but in exceptional cases there may be slight hyperæsthesia or anæsthesia.

The functional activity of the glands of the skin in mild cases is usually unaltered, but in advanced or severe ones the excretion of sweat and sebum is diminished to a greater or less degree.

When the skin about the joints is affected movement is more or less interfered with, and in atrophic cases ankylosis with consequent complete immobility may result. When the face is attacked, the features are motionless, as if covered with a mask; the nose is pinched; the mouth contracted so that it is opened with difficulty; the eyes are only half-open or staring, owing to the immobility of the lids. If the skin of the thorax is involved extensively, the movements of respiration may be considerably impeded.

The parts most commonly affected are the face, the neck, the upper portion of the trunk, and the upper extremities, but no part of the integument is exempt, although the palms and soles are rarely affected.

In some cases the morbid process is not confined to the skin, but attacks the mucous membranes of the mouth, pharynx, larynx, and vagina.

In the great majority of cases constitutional symptoms are absent, but in those exceptional ones in which the affection begins acutely with marked œdema of the skin, spreading rapidly over a considerable surface, constitutional disturbance, such as chills and fever, may precede or accompany the alterations in the skin.

The course of the disease varies within considerable limits. When it has reached its acme, it may remain unchanged for months or years, and then the induration may slowly disappear, the skin resuming its normal suppleness and softness; or, after the disease has progressed toward recovery for a time, relapses may occur and new areas be invaded. On the other hand, the skin may become more tense, thinner, and parchment-like; the subcutaneous cellular tissues and fat may disappear, and the underlying muscles atrophy. When this atrophic process affects the extremities they are greatly reduced in size, distorted, and the joints ankylosed. When the hands are affected great distortion of the fingers with marked wasting occurs, a condition which has been described as *sclerodactylia*.

Owing to the extreme tension of the skin ulceration readily occurs, especially over bony prominences. The general health is, as a rule, but little if at all affected; but in very extensive cases with atrophy, especially if accompanied by ulceration, death may take place from exhaustion.

But little is known concerning the immediate causes of scleroderma. It occurs much more frequently in the female sex than in the male. In the cases collected by Lewin and Heller (four hundred and thirty-five in number), two hundred and ninety-two, or sixty-seven per cent., were women. Age seems to have but little influence upon the frequency with which the malady occurs, although it is most frequent between twenty and forty years of age. Exposure to cold and damp appears to exert a predisposing influence. In a certain proportion of cases the affection has followed some disease of the nervous system, and in a number of instances (sufficiently numerous to indicate more than an accidental association) traumatism of some kind has immediately preceded it. In many cases, however, if not in most, the patient has been in good general health at the time of the beginning of the morbid changes in the skin.

Although the pathology of scleroderma is quite obscure, there is much in favor of the view that it is primarily an affection of the nervous system, a trophoneurosis; this, however, yet remains to be demonstrated. According to Crocker the various symptoms are produced by obstruction to the arterial and venous blood supply, and by interference with the flow of lymph, these being responsible for the alteration in the nutrition of the skin which characterizes the malady. Unna finds the chief pathological alterations in an hypertrophy of the collagenous tissues affecting all parts of the cutis, and consequent atrophy of the blood vessels and the epidermis. The changes in the epidermis are slight, consisting of occasional deposits of pigment and mechanical alterations due to pressure. A considerable exudation of small round cells surrounds the narrowed blood vessels, the sweat and sebaceous glands, and the hair follicles. The lymph spaces are narrowed, and in the cases in which atrophy occurs, an obliterating endarteritis is present.

The symptoms of a typical, well-developed case of scleroderma are usually so characteristic that the *diagnosis* is readily made. The peculiar induration of the skin characteristic of the malady is found in no other disease except sclerema neonatorum; but this latter affection is met with only in the new-born and the induration of the skin is accompanied by marked coldness of the surface.

The *prognosis* is decidedly unfavorable. While it is true that a certain small proportion of cases end in recovery, the disease usually lasts for years even when recovery does take place. When atrophy occurs, a return of the skin to its normal condition is not to be expected. In cases in which a considerable part of the integument is involved, interfering greatly with movements of the limbs, death may eventually take place with symptoms of marasmus; or, owing to his debilitated condition, the patient may fall an easy prey to some intercurrent affection.

Treatment.—Patients with scleroderma should be given an abundance of easily digested, assimilable food, such as milk, eggs, and butter. The clothing should be warm and abundant, so that there may be no danger of chill. Such tonic remedies as iron, quinine, arsenic, cod-liver oil, may be given with the view of improving the patient's general health. Massage and frictions with bland oils and fats should be systematically and persistently employed for the purpose of improving the nutrition of the skin. Mild galvanic currents may be applied to the indurated skin to improve the circulation and nutrition. Drugs have little, if any, direct influence over the course of the disease. Thyroid extract has been given with asserted good effect, but its value is doubtful. Hans Hebra has reported marked benefit from hypodermatic injections of thiosinamin, one-half a Pravaz syringeful of a fifteen-per-cent. alcoholic solution being given every second day; and more recently Neisser has recommended the same treatment. Liebreich found considerable improvement follow the internal use of cantharidin in doses of 0.0002 gm.

Milton B. Hartzell.

SCOLIOSIS. See *Lateral Curvature of the Spine.*

SCOPOLA.—(*Scopola Belladonna*; incorrectly, "Japanese belladonna.") The dried rhizome of *Scopola carniolica* Jacq. (fam. *Solanaceæ*).

This drug is chiefly of interest at the present time because of the very extensive use of its extract, like that of belladonna root extract, to substitute belladonna leaf extract, which last is officially directed to be used in the manufacture of belladonna plaster (see *Belladonna*). Scopola is, however, likely to be introduced into the forthcoming edition of the Pharmacopœia. The very similar species *S. Japonica* Maxim., of Japan, is the real *Japanese belladonna*. The Japanese Pharmacopœia is said to authorize its use, as an alternative, whenever belladonna is prescribed. This species is not with us a commercial article.

S. carniolica is a native of Central and Southern Europe. The plant somewhat resembles the belladonna plant. The leaves, which are considerably used for adulterating belladonna leaf, are not so large as the latter and are narrowly obovate, instead of broadly ovate, and have a tapering base. The underground portion of the plant is very different from that of belladonna, consisting of a tortuous horizontal rhizome from which descend, vertically, numerous roots, quite closely resembling belladonna roots, though averaging only half the size or less, and of a rather bright yellowish- or brownish-red, instead of the dull gray color of belladonna root, and usually rather evenly marked with small, transversely oblong, light colored scars. The rhizome, of which the drug almost wholly consists, is usually from two to four inches in length, as thick as the fingers, sympodial in development, shortly and sharply flexuous, and marked on the upper surface with rather closely set large shallowly cup-shaped stem scars. The outer surface is gray brown, mostly darker than that of belladonna root. Its fracture is accompanied by the emission of the same puff of dust that accompanies that of belladonna root, and the internal color is much the same, though usually somewhat darker than that of the latter.

The important constituents of scopola are its alkaloids, of which the total amount averages about the same as in belladonna root, namely, a little more than a half of one per cent. The composition of this alkaloid is as yet uncertain. It has been believed that about one-tenth of it is hyoscine (which see), but some recent analyses appear to indicate that there is much less. The remainder is a mixture of hyoscyamine and atropine. It has been believed that it is composed mostly of the former, but our ideas of the relations between these two alkaloids, both here and in belladonna, must be regarded as in a transition state.

Since the publication of our article on belladonna and atropine, a very remarkable discovery concerning this subject has been made, the conclusions having been reached independently by a chemist at Marburg and by Cushny and Schlotterbeck at Ann Arbor, the latter working along physiological lines. It has been found that hyoscyamine presents two forms, one dextrogyre, the other lævogyre, the one inert physiologically, the other acting precisely like atropine, but with exactly twice the energy. These two, combined, make atropine, of intermediate strength and optically inactive. It now remains for the percentages of these alkaloids and of the respective forms of hyoscyamine to be determined anew.

From what has preceded, it is apparent that the action of scopola will be practically that of belladonna in kind, and that their relative strengths cannot be stated positively until questions regarding the constituents shall have been more definitely settled. The present indications are that they are almost equal in strength, and that scopola can be used, in the same doses, for all the purposes for which belladonna root is used.

Henry H. Rusby.

SCROFULA.—Precisely analyzed from the standpoint of modern pathological anatomy and bacteriology, scrofula or scrofulosis may be defined as tuberculous lymphadenitis (see *Lymph Nodes, Diseases of*). Clinically it should be considered as the chronic form of tuberculosis of lymph glands. As thus defined it is evident that the term has no excuse for existence *per se*, and deserves recognition only in a synonymous sense. In fact, because of the confusion attending its proper usage, and because the principal condition to which it is applied can be more specifically designated, it would be better definitely to abandon the word scrofula as has already been advocated. In consideration of its historical interest, and on account of the persistency with which it adheres to popular parlance, scrofula still claims a passing notice.

Strictly speaking, then, scrofula is a morbid state whose chief anomaly is a tuberculosis of lymph glands, more especially the nodes of the cervical region and of the mesentery, occurring commonly in childhood, though not confined to this period. Accompanying this adenitis is a constitutional disorder formerly regarded as a distinctive dyscrasia (the "*scrofulous*" or "*strumous*" *diathesis*), but which is now known to be the anæmic, cachectic, or debilitated state attending tuberculous infection or intoxication. A broader and more ancient conception included as scrofulous such affections as tuberculosis of bones and joints, of the skin (*scrofuloderma*, or more properly, *tuberculides*), and of the mucous membranes, and even the various forms of visceral tuberculosis. A more serious misuse of the term is that which would comprise all disorders accompanied with hyperplasia or hypertrophy of lymphatic glandular structures. Thus the adenitis of other chronic infections, like the atypical pyogenic, the syphilitic, that of glanders and that of actinomycosis have been regarded as scrofula. Leukæmia, and more particularly pseudoleukæmia (Hodgkin's disease), have been classed with it at times, and the error still persists of confounding status lymphaticus (see *Status Lymphaticus*) and scrofula. So far as Hodgkin's disease is concerned, there may be some justification for its having been regarded in the same light as scrofula, especially in view of the researches of the last five years, which tend to show that the diffuse lymphadenitis of so called pseudoleukæmia is occasionally, at least, the result of an infection with the bacillus of tuberculosis in which the morbid changes have pursued an anomalous course.

Besides the more pronounced manifestations such as pertain to the glandular system, other minor affections which we now regard as secondary complications, were included among the evidences of scrofula. Examples of these are the scrofulous keratitis, conjunctivitis and blepharitis, various forms of otitis media, nasal and pharyngeal catarrh, and eczema or other skin diseases. The constitutional types once the subject of much attention, by which scrofulous individuals were classed as the "sanguine," "phlegmatic," and "pretty," are no longer regarded otherwise than indicative of a tuberculous taint either hereditary or acquired.

In fine, used in its most exclusive sense as indicating a tuberculous lymphadenitis, scrofula claims distinction only in that it refers to a sluggish, chronic tuberculous infection in which the exciting agent, the bacillus of tuberculosis, frequently seems to exist in a state of attenuated virulence. Or, it may be, that some of these infections result from other atypical members of the ray fungus group of parasites allied to the tubercle bacillus in morphology and tinctorial reactions, but endowed with diminished pathogenic powers.

Otherwise scrofula is tuberculosis, as manifested not only by its morbid anatomy and histology, and its bacteriology (as concerns the presence of the specific bacillus both in the diseased tissues and in cultures), and also by the results of inoculation experiments. This conclusion was reached by the more astute pathological anatomists, particularly of the German and Austrian schools, even before the advent of the bacteriological era, and there is no disposition to question it to-day after the critical modern studies in which the more precise methods of histological and bacteriological analysis have been employed. Hence a discussion of scrofula is based upon a study of chronic tuberculosis of the lymphatic glands, variously complicated with such anomalies as cutaneous, osseous, and synovial tuberculosis; and the scrofulous or strumous diathesis becomes the dyscrasia attending local or general tuberculosis either in its latent or in its chronic state. For the elucidation of such phases of the question as pathology, etiology, diagnosis, prognosis, and treatment of scrofula, therefore, the student is referred to the treatises upon tuberculosis in its various aspects and more especially those which refer to chronic tuberculous lymphadenitis. An exhaustive résumé of the bibliography of scrofula, mostly of interest from the historical standpoint to-day, is presented by Cornet (Nothnagel's "Specielle Pathologie u. Therapie," Bd. xiv.).

A. P. Ohlmacher.

SCROFULODERMA.—This form of tuberculosis of the skin includes those cases in which the skin is involved by infection from diseased lymph channels and nodes. Playing as it does only a secondary part, the cutaneous tissue is involved only when the breaking down glands or nodules are evacuated. This gives rise to both openings and sinuses in the skin which lead to the necrosed material. The discharge is thin and contains cheesy matter and leucocytes. The tubercle bacilli have been demonstrated both in the discharge and in the walls of the sinuses.

Oscar H. Holder.

SCROPHULARIACEÆ (the Figwort family).—A large, widely distributed and diversified family, comprising more than one hundred and seventy five genera and about twenty-five hundred species. It yields the important drugs Leptandra and Digitalis, besides which quite a large number are or have been employed to a lesser extent. Several of these, as follows, are of sufficient importance to be entitled to brief mention. The active constituents of this family appear to be chiefly glucosidal.

Mullein is a title commonly applied in this country to the fresh or dried leaves of *Verbascum Thapsus* L., an exceedingly coarse, stout herb, with a simple and erect stem, native of Europe, and now growing everywhere as a weed in the Eastern United States. The large, obovate, thick leaves are densely woolly, and are sometimes applied as a mild counter irritant, usually in the entire condition, but sometimes made into a poultice. They are mucilaginous and very slightly bitter. They are sometimes made into a tea and used as a demulcent in irritating cough. They possess slight laxative properties. In Europe the name mullein is more commonly applied to the flowers of this and related species. They possess constituents similar to those of the leaves and are similarly employed, though they contain a little volatile oil and coloring matter. Olive oil in which they have been macerated has quite a high domestic repute in many localities as an emollient.

Hedge Hyssop is the common name of a little perennial herb, *Gratiola officinalis* L., of Europe, which contains one or more glucosides, the very bitter crystalline one, *gratiolin*, being apparently the active agent. Its medicinal properties entitle it to a thorough investigation, since it is so active as to constitute a rather powerful emetico-cathartic poison, with marked diuretic properties. Its use, in doses of 0.2–1 gm. (gr. iij.–xv.), has been wholly unscientific, applying especially to gout and rheumatism.

Figwort is the dried herb of one or more species of *Scrophularia*, the genus from which the family takes its name. Like the last, the drug has not received any scientific investigation. Its bitter crystalline contituent, probably a glucoside, has been called *scrophularin*. There is also a very small amount of a volatile oil. Figwort appears to have some slight anthelmintic powers, but has been chiefly used, like mullein, in the form of a poultice. Its use is far more common in Europe than in this country. *Henry H. Rusby.*

SCURVY; SCORBUTUS.—(Including Barlow's Disease.)—DEFINITION.—Scurvy is a systemic disease dependent upon an improper or ill balanced dietary, characterized in its general expression by anæmia (secondary), hemorrhages into the skin and subjacent tissues, spongy or ulcerating gums, progressive debility and emaciation, resulting in death unless checked in its course by the necessary dietetic and medicinal treatment. The word scurvy is probably of Scandinavian origin, the Swedish *skorbjugg*, Danish *skojarbug*, being equivalent to the German *Scharbock*, meaning soft or relaxed stomach.

GENERAL CONSIDERATIONS.—Throughout all ages scurvy has been one of the classical diseases of mankind, and although it has been successfully eliminated as one of the social and sanitary problems of civilized life, yet it would be a great mistake to infer that, by reason of our better knowledge of its causation and character, it has ceased to be a possibility in our modern surroundings. Cases continue to be reported in our most recent journals. The ancient writers abound in references to it, giving in fanciful terms their theories as to its nature and cause. In his work on "Airs, Waters, and Places," Hippocrates describes the disease in an unmistakable manner, and Pliny and Strabo give us satisfactory accounts of scurvy as it appeared among the troops in the campaigns of Cæsar Germanicus and Ælius Gallus. Indeed, it has been from time immemorial the scourge of armies, ravaging the ranks of the crusaders, the soldiers of the Middle Ages in their long sieges, the cohorts of Napoleon in Egypt, and even the troopers of the last decade of the nineteenth century, in all parts of the world where warfare is carried on under climatic or dietetic conditions new and strange to the soldier. In our own country it has invalided half a garrison, at Council Bluffs (1820) resulting in a mortality of over thirty per cent., and later during the Mexican war our troops suffered from its appearance while in that country. During the civil war the statistics of this disease show a total of 46,910 cases in the Union army, of which 771 proved directly fatal, a small relative ratio, but it undoubtedly expended its force indirectly as a contributary factor in the termination of other cases with which it was concurrent. The same experience is recorded in the Crimean War, where 23,365 cases occurred in the French army, and 17,557 in the British army, while the numbers in the Turkish army were almost countless, as that force was practically decimated by its ravages. The Franco Prussian war again recorded its appearance, though with a much lessened ratio of invalidism, and the Russo Turkish War repeated the story. In the German army as late as 1897, there were seventy-four cases of scurvy and in the Russian and Austrian armies, the same year, a ratio of over one per thousand strength. But in the popular conception, as well as in the professional mind, scurvy is looked upon as a disease of the sea, and of those "who go down to the sea in ships and have their business in great waters." Beginning with the first known geographical explorations of the fifteenth century, involving long voyages in unknown oceans, the records of those famous discoverers always included with their marvellous tales of "new-found lands" the story of sufferings and death among their intrepid seamen from the disease then known as scurvy. Pierre Quirino, Vasco de Gama, and Jacques Cartier all record the ravages of this disease among the crews of their vessels. As late as the eighteenth century Anson lost more than four-fifths of his men while sailing round the world. Coming down to modern times, the experience of the Marine-Hospital Service of the United States, whose function is, in part, to care for sick and disabled seamen of the merchant marine, is the most accurate index to its prevalence among American sailors, as well as a few of other flags who are treated in our marine hospitals. From the statistics compiled for a period of twenty-eight years (1872 to 1899 inclusive) the following table has been constructed to show its occurrence and frequency:

CASES OF SCURVY TREATED IN UNITED STATES MARINE HOSPITALS FROM 1872 TO 1898 INCLUSIVE.

Year.	Number of cases scurvy.	All diseases treated.	Year.	Number of cases scurvy.	All diseases treated.
1872	18	13,156	1888	17	48,203
1873	47	13,529	1889	32	49,518
1874	59	14,356	1890	28	50,671
1875	25	15,009	1891	32	52,092
1876-77	89	31,983	1892	30	53,610
1877-79	24	39,155	1893	34	53,317
1880	39	24,860	1894	27	52,803
1881	42	32,613	1895	14	52,643
1882	55	36,184	1896	24	53,804
1883	43	40,195	1897	20	54,477
1884	27	44,761	1898	6	52,709
1885	34	41,714	1899	3	55,489
1886	18	43,822			
1887	37	45,314		824	1,066,887

This is less than one per thousand cases treated for the period stated. Dividing the twenty-eight years into three periods, the following result is obtained: 1872–1880, 301 cases; 1881–1889, 305 cases; 1890–1899, 218 cases.

These figures require but little explanation beyond stating that about half of the cases of scurvy treated by the service is reported from the stations on the Pacific coast, principally San Francisco. These cases are taken from vessels coming "round the Horn" from England or elsewhere, a long voyage of several months, in which the conditions of diet, confinement, lack of exercise, etc., aid the development of the disease. While on duty at San Francisco the writer had opportunities to study and treat about seventy-five cases of scurvy in the course of three years, and it is from this experience that he has derived his practical knowledge of the disease.

ETIOLOGY.—Scurvy—speaking in general terms—is a disease dependent on diet and occupation. It exists either in epidemic or in endemic form whenever persons subsist for a prolonged period on a dietary which does not contain fresh vegetables, or vegetables in a properly preserved state. This condition, when aggravated by an unsanitary environment, is thereby accentuated. It is still a subject of controversy what may be the precise elements in this vegetarian problem, to the lack of which are logically due the scorbutic symptoms. Everything, however, tends to the conclusion that the disease is dependent upon the insufficient ingestion or the deprivation of the potassium salts of fruits and vegetables. These salts, in which potatoes, for example, are so rich, must have a very potent influence in maintaining the alkalinity of the blood and preventing acid intoxication. When to this lack of vegetables, with their organic and inorganic elements, is added the enforced adhesion to a meat diet, especially if salted, or preserved by other similar processes, we have the ideal conditions under which scurvy begins and maintains its invasion. Resulting from this is a probable hyperacidity of the blood through the loss of the carbonates derived from the vegetable salts and the following loss of coagulability, with progressive anæmia. In this state of theoretical acid intoxication there is an increase in the ammonia-neutralized acid excreted as compared with the free acid. The blood is found to be dark and thin. The morphological changes are those of secondary anæmias, as from hemorrhage. Various observers have noted the changes in the count of red cells in proportion to the severity of the disease, the duration, and the hemorrhages. Megalocytes and shrunken microcytes have been seen in grave cases. Red cells in solution in the plasma are reported by Albertoni. The Hb index is low, according to White, while several other investigators have made conflicting statements as to the relative ratios of iron, sodium, and potassium salts and leucocytes. Altogether, the present state of knowledge of the morphology of the blood is not enlightening, and further studies are necessary to determine the significance of the conditions which are claimed by them as pathognomonic.

A recent contribution to the discussion on this portion of the subject is that made by Albertoni, who has shown in some studies of the chemistry of the blood and of digestion that there is a serious deviation from normal in the free HCl of the gastric juice, that intestinal putrefaction is excessive and that the urine furnishes abundant evidence of the absorption of toxins, while the absorption of fats and carbohydrates is deficient. He concluded that the greenish-yellow color of the serum and the excess of pigments in the urine were proofs of active destruction of the blood cells.

As a corollary to this toxic indication may be mentioned the theory, worthy of investigation, that the disease is in reality a chronic ptomaïn poisoning due to putrefactive changes in badly preserved animal food, such as salt beef and canned meats. It is held that if these provisions were properly sterilized there would be no scurvy. It is not an infrequent complaint among seamen suffering from scorbutic conditions that the "salt horse" was of an offensive odor, and this observation was made among the laborers employed on the construction of a transcontinental railroad where scurvy appeared among foreigners who used this tainted meat with a plentiful supply of flour, beans, and peas.

Scurvy is not believed to be contagious or infectious. Thus far no micro-organism has been found to be of determining value in such investigations as have been made by investigators. The field has not proved to be an inviting or fertile one for bacteriologists of admitted skill. Some experiments have been made with the blood of scorbutic patients, with portions of the spongy gums and with material taken from the hemorrhagic lesions, but the results are not satisfying nor constant. It has been noted in epidemics that children suckling scorbutic mothers did not develop the disease, and in a given ship from which cases of scurvy have been taken, except in extreme conditions, only the forecastle, where the diet was restricted to certain kinds of food, would be invaded. Isolated cases of scurvy have been found dependent upon conditions that favor either the nutritional, the toxic, or the infectious theories of the etiology of the disease advanced by various writers, but thus far the deficient vegetable dietary offers us the most practical evidence in our search for a factor that responds to all the tests of probability. Ever since Bachstrom set forth this theory in 1734—viz., the lack of fresh vegetables in the food—it has held its ground through the successive investigations of Garrod, Buzzard, and Ralfe, each carrying on by successive steps the study of this phase of the question. The last-named investigator, last in point of time as well, has formulated this theory in the following terms: The alkaline salts of vegetable acids (malic, citric, tartaric, etc.) are concerned with the normal transformation of the carbonates of the blood; the actual factor is thus a chemical alteration in the quality of the blood, a diminution of its alkalinity; that this follows the withdrawal of salts having an alkaline reaction, such as the alkaline carbonates; that this scorbutic condition is the same as that produced experimentally by injecting acid into the blood of animals, feeding with acid salts, etc., viz., a dissolution of corpuscles, purpuric spots, and other particular signs of the disease. The morphology of the blood is disappointing in so far as it fails to afford any sure index of the condition.

While scurvy is a disease of diet and occupation, it is not a disease of country, race, sex, age, or season. It is found in all zones, among all peoples where the conditions favor it; it knows no sex, though males probably contribute a greater proportion to the statistical tables, for the evident reason that they are more usually subjected to the favoring conditions; and in the matter of age it is met with from infancy to dotage. Naturally, it prevails in those countries and among those peoples whose observances of hygienic laws are "more honored in the breach," but it is found among civilized races as well. Institutions for the aged furnish cases occasionally, but on the whole it can be said that it is a disease of adult life rather than of the extremes of age. The winter season, for obvious reasons, adds to the number of cases when the disease exists in epidemic or endemic form. As to occupation it was once thought to be a disease peculiar to the seafaring life, but it is found more on land than on the sea.

Clinical History.—A progressive upward and downward curve marks the course of a case of scurvy from its onset to its finish. It has no definite attack, no crisis. Unless the patient is under conditions known to him to be causative, as in the case of seamen on a long voyage, the approach is without warning. The preliminary symptoms are those general signs of decreasing strength, mental depression, pallor, loss of flesh, anorexia, and perhaps some gastro-intestinal disturbance. This is gradually followed by the more characteristic features of the disease. The skin becomes dry, there is "pinching" of the features, the complexion becomes of a dirty hue, for want of a more applicable term, and the gingival mucous membrane at the free margin becomes swollen and spongy. This is one of the typical features of a case of scurvy. The gums bleed upon slight pressure, appear bluish in spots, and often ulcerations follow as the scorbutic condition progresses. The gums seem to develop into this soft, necrotic texture around teeth that are broken and decayed, but it is a matter of observation that in the aged who have lost their teeth and in children before the eruption of teeth, these gingival symptoms are practically absent. In severe cases the gums swell, and rising around the teeth partially cover them with a proliferated mass of foul growth, during which time the teeth become loosened in their sockets and dislodgment may follow. The breath becomes intensely fetid as a result, the flow of saliva is increased, the salivary glands sometimes enlarge, and the tongue appears red and swollen. The eating of food is, under these conditions, not only a painful but a disagreeable function, and the sufferer seeks liquid nourishment as a relief. This condition of the gums, which usually begins near the median line at the incisors, is the first characteristic symptom, and hemorrhagic suffusions into the cutaneous, mucous, and deeper tissues is the second typical development of the disease. It is usually synchronous with or later than the gingival symptoms. These subcutaneous hemorrhages appear at first in the lower extremities, about the ankles, in the form of petechial macules, varying in size and most of them having a hair follicle in the centre. They resemble ecchymoses in some cases, in others purpura and similar cutaneous disorders. While they develop spontaneously they may be excited by blows or other injuries. The larger coalesced spots show chromatic gradations of brown, green, and yellow at the periphery similar to the "black and blue" marks following a contusion, but in scurvy there is, in the severe hemorrhagic cases, a distinct elevation of surface upon which vesicles sometimes form. Ulcerations of an indolent type follow this and often destroy a large patch of cutaneous surface. The hemorrhages may be deeper-seated, giving to the limb affected a bosselated appearance, and when the intramuscular, the fibrous and the subperiosteal tissues are involved the element of pain is introduced. These deeper hemorrhages constitute the one particular symptom of an advanced case of scurvy. At first they feel like doughy masses, pitting or yielding to pressure, but later the tissues lose this resiliency and, as the suffusions become more general and uniform throughout the muscular structure below the knee, the leg, when handled, feels as if it were made of wood. This scorbutic sclerosis, of which the text-books rarely make mention, may extend to the trunk and upper extremities, but it rarely invades the face or the scalp. The joints of the upper extremity, the wrist usually, may be œdematous, and this effusion may involve the serous surfaces, the pleura, pericardium, and sometimes the meninges.

Hemorrhagic suffusions into the tissues of a mucous membrane are less constant, but, in the form of epistaxes, often resulting in syncope and exhausting anæmia, they are not so uncommon. The tissues involved do not respond to the usual remedies. When the intestinal mucous membrane is the seat of scorbutic lesions, there may be bloody stools, and in advanced cases the kidneys, spleen, bladder, and other internal organs may be included in this process.

Other symptoms noted in well-marked cases are: articular swellings, with pain and local febrile movement, and ulcerations of mucous surfaces, the cornea even being involved. Disintegration of recent callus has been reported, and other similar destructive processes, too numerous to mention, have been seen in advanced stages of the disease and are cited to show how profoundly the disturbed nutrition manifests itself in constitutional effects.

While there are no marked symptoms involving the nervous system, the mental depression is noticeable and the patient seems to be indifferent to his condition and surroundings. Hemorrhages into the meninges may produce convulsions or other abnormal cerebral manifestations. Among seamen the symptoms of hemeralopia and nyctalopia are not uncommon accompaniments.

There is no constant type of temperature. In some cases it may be subnormal. The pulse is often rapid and always weak, and the heart action and respiration are affected by the slightest exertion. Hæmic murmurs, common to all anæmias, can be detected. The urine is usually albuminous, of high specific gravity, decreased in quantity and of a high color. It may show the results of suffusion into bladder or kidneys. Obstinate diarrhœa, sometimes dysenteric in type, showing mucus and blood in the dejections, supervenes, and the loss of appetite and distaste for the foods that constitute the sufferer's diet, particularly at sea, soon give place to nausea and vomiting. These extreme conditions are not uncommon if dietetic relief does not intervene to turn the tide. The sufferer then presents a terrible picture, with sunken orbits surrounded by blackened circles, parted lips, and dingy yellow skin. He looks like a "breathing cadaver," as one writer has graphically expressed it.

Death from exhaustion, septicæmia, or some intercurrent infection terminates these advanced cases that have not had treatment.

DIAGNOSIS.—When a number of persons come from a ship after a long voyage, presenting any of the characteristic symptoms above described, or others of a similar character but less pronounced, the difficulties in the way of diagnosis are not great. Single cases seen ashore, in the early stages, might easily be classed under the general diagnosis of "anæmia" or "debility" by one not familiar with the symptoms, or not on the lookout for a disease generally believed to be peculiar to sailors. Atypical cases may sometimes confuse the diagnosis, as in all other definite morbid processes, but the differential diagnosis need only be established between it and a very few diseases. The one which resembles it most in external appearance is purpura hæmorrhagica, but this disease has none of the special gingival manifestations, the deep hemorrhages into the substructures, nor the hard brawny feel in the lower extremities. In purpura the macules are brighter and the skin not involved is of a cleaner hue, and as a further difference the articular involvement in scurvy is much less marked than in purpura. Peliosis rheumatica (Schönlein's disease), nearly allied to purpura, may give rise to similar doubts of identity. A case recently reported by Surgeon Irwin, U. S. M. H. S., in a sailor, presented a concrete example of the confusion which may result. In peliosis the purpuric spots are distributed over the entire surface, in contradistinction to what is observed in scurvy; there is hydrarthrosis of the joints in the upper extremity with general muscular pains, and there may be œdema of the face and hands. The spongy condition of the gums does not obtain in peliosis, and the character of the eruption in scurvy differs from that of purpura hæmorrhagica. Cases from ships hailing from ports where beri-beri is endemic may require a careful differential diagnosis. In a suit for damages entered by the sailors against the ship for scurvy, the defence raised this point in answer and the writer acted as expert witness at the trial. In the œdematous form of beri-beri, where there is much emaciation, with swelling of the lower extremities, it is necessary to exercise careful scrutiny of the case with particular reference to conditions existing prior to presentation. There are no gingival symptoms in beri-beri and the œdema is different from the hard nodular feel in the legs of a scorbutic patient. It may be necessary, in cases involving litigation between seamen and vessel owners charged with furnishing improper food, and thus causing scurvy, to be able to eliminate the question of the syphilodermata and specific infection complicating the case. Such allegations are usually resorted to by defendants in these cases. It will only be necessary to mention the fact, as the differential diagnosis should be easy for the medical attendant.

PROGNOSIS.—The mortality from scurvy should not reach five per cent., except in epidemics, military campaigns, or in exceptional conditions on shipboard. During the civil war the rate was sixteen per cent., which considerably exceeds that obtained in our marine hospitals. In the ordinary cases met on land a favorable termination may be expected as soon as the proper measures are instituted for correcting the diet. Recovery is naturally slow and sometimes weeks and months elapse, especially in the aged and feeble, before health is fully restored. In the grave cases seen on shipboard after long voyages, or after rescues from shipwrecks, the patients may succumb to exhaustion, hemorrhages, or some intercurrent affection, but cases which seem hopeless from their general appearance quickly rally under appropriate treatment.

PATHOLOGY.—From what has been said of the nature of the disease it can be readily surmised that the pathology is unimportant. There are no characteristic anatomical changes, beyond the subcutaneous hemorrhages and suffusions into the deep structures and occasionally into the viscera. These have already been referred to. There may be serous effusions into the pleura or pericardium, but the peritoneum is not so affected. Parenchymatous degeneration takes place in the internal organs. The stomach and intestines present the hemorrhagic patches common to the cutaneous surface. The blood flows from these suffusions, when cut, as in a living subject. The spleen is soft and quite constantly enlarged. The condition of the buccal cavity is merely that which was previously observed at the bedside. Microscopical examination of the gingival tissues has revealed nothing worthy of special mention.

TREATMENT.—Scurvy is a preventable disease, and therefore the question of treatment partakes of two phases, the prophylactic and the curative. The first may be applied in the case of ships about to proceed on long "deep-sea" voyages, whalers bound for the frozen sea, merchant ships sailing "round the Horn," or in the case of large institutions for the poor and indigent in which, for economical reasons, the diet must be restricted to the actual necessities. The United States statutes contain certain requirements respecting these matters. One relates to the supply of lime juice and vinegar (Sec. 4,569), which must be provided on voyages across the Atlantic or Pacific oceans or around Cape Horn or the Cape of Good Hope. The other (Sec. 4,612) defines what shall be the daily minimum of articles and quantities of food supplied, a not altogether satisfactory or scientific table. As each municipal institution for the care of the poor has a medical officer in attendance it will be incumbent upon him to advise the managers as to the quality and variety of food required for the proper nourishment of inmates, in order to avoid the occurrence of scorbutic symptoms among these ill-conditioned people. This can be accomplished by a judicious variation in the daily diet schedule. This diet should include not only fresh vegetables in season, but, what is equally to the point, fresh meat. In all almshouses there will be found a large proportion of persons laboring under the depressing and degrading influences of such places, persons in feeble condition or advanced life, who may confine themselves to a portion of the prescribed diet for a long period, and in whom scorbutic symptoms are inevitably set up. Osler cites a case of a woman who subsisted for many months on bread and tea, and it has been noted that in logging camps and among charcoal burners, where a diet of bread, molasses, and bacon is staple, scurvy will be found. The old maxim that "variety is the spice of life" is the keynote to the prophylaxis of scurvy when considering the dietetic question. It is not quantity nor quality, but variety that is the inviolable canon in the alimentation of mankind. Scurvy is not a disease of starvation, it is nature's revolt against lack of dietetic balance. None of the professional "fasters" ever developed the characteristic signs of the disease.

The therapeutic indication in the curative treatment of scurvy is one of dietetics rather than of medication. When the patient is first seen he should be removed from the environment responsible for the condition, whether ship, house, or room, and given such benefits as arise from change of air and surroundings. If possible, a warm bath should be given and clean clothes and a clean bed provided. These attentions are possible if the case can be removed to a hospital. The first symptom that will claim attention in an advanced case is the spongy or bleeding condition of the gums and the consequent fœtor of the breath. The relief of this is a preliminary to attractive alimentation and may be accomplished by the use of any of the mild antiseptics in the form of gargles and mouth washes. It is not necessary to enumerate them. The juice of a lemon, which possesses some astringent as well as other useful properties, is a simple and effective aid in this process. More pronounced astringents, as catechu or krameria, may be employed by brushing them on the spongy mucous surfaces. Alum may be applied in the form of a powder to small ulcerative patches, and a weak solution of lunar caustic, pencilled with a camel's-hair brush, enables the operator to reach such surfaces between the teeth.

Food is to be administered cautiously at first, and the first indication is the exhibition of fresh vegetables in the form of a strained soup. The condition of the gums and teeth may not permit the process of mastication. Lemons or limes can be given in the intervals between regular meals. Spinach, boiled, is an excellent form of vegetable, possessing highly nutritious qualities and having the advantage of softness in consistence. Sauerkraut, and vegetables used as "greens," with vinegar, are also valuable variants. To this basis may be added, as a change, fresh milk, and well-cooked beef, in judiciously graduated quantities. Occasionally the vegetable diet may be distasteful, paradoxical as it would seem, but it must be enforced until the condition of the patient shows its good effects in an improved color, increased strength, and general resumption of normal conditions. That a plan of tonic treatment is indicated need hardly be said. Iron in some form, preferably the citrate, or the tincture of the choride, is an excellent medicament in scurvy. The use of potassium in one of its salts, to replace theoretically the loss of the vegetable potassium, as advocated by Garrod, an early authority on the disease, has not given very satisfactory results. If nausea and vomiting, due to a distaste for food previously constituting the patient's diet, be present they will soon cease after the proper alimentation is instituted; but if they continue they may be stopped by such gastric sedatives as bismuth, hydrocyanic acid, or the carbonated waters. The last named are preferable. If digestion be feeble, the bitter tonics—gentian, quassia, or strychnine—may give a necessary tone to this function. Constipation and its opposite condition, either of which may be present, are to be treated with care. The changed diet should be allowed to operate for a few days as a natural stimulus to normal action. According to my experience it may be expected to act in this way. Diarrhœa, if persistent, needs some astringent, but constipation should cause but little anxiety. Intestinal hemorrhages require more active handling, and ergot, iron, lead acetate, or any approved hæmostatic must be exhibited. Calcium chloride can be advantageously given in doses of gr. xx. t.i.d. for this condition. The stiffened joints should be treated with massage and passive motion. Gentle friction over the ecchymosed regions and at points where there are signs of deeper suffusions, will prove of benefit in promoting absorption. All treatment, however, beyond the dietetic, may be classed as symptomatic.

INFANTILE SCORBUTUS. — *General Considerations.*— Within the past two decades there has been added to the list of diseases, for the special consideration of pediatrists, the scurvy of infants, following prolonged artificial feeding. To a number of English physicians, notably Dr. Barlow, who reported thirty-one cases in 1883, our knowledge is originally due, and from this physician the disease has come to be known in medical literature as "Barlow's disease," from its first reporter. Since that period it has been the subject of special study by observers in Europe and America, and scarcely an issue of journals devoted to pediatrics is wanting in some reference to the disease, its etiology, pathology, or clinical history. The American Pediatric Society considered a lengthy report on the subject in 1891 made by Dr. Northrup, and among the conclusions of the author was this: "It is a significant fact that the country which furnishes most of the literature of scorbutus in children is the same which is posted from end to end with advertisements of proprietary foods." Indeed it may be said that the appearance of this disease has a close relation, chronologically, to the development of the industry of artificial feeding of infants and the growth of the sentiment for sterilization following the diffusion of knowledge concerning bacteria.

Etiology.—Like scurvy in the adult, this disease of infancy is due to the continued use of an artificially prepared food which lacks some essential element required for nutrition. It is a disease found oftenest among the children of the rich and well-to-do, because in their homes are found the mothers who cannot, or will not, nurse their children, and who are able to provide themselves with prepared infant foods and the apparatus for the sterilization of milk. It may be stated as a general proposition that infantile scurvy is a disease of affluence and rachitis a disease of poverty, for though having some general resemblance to each other, these affections are distinct. As scurvy is a disease due to improper feeding, it may be further said that neither age, sex, race, nor season has any causal relation to its manifestation. It may occur at any age, but is oftenest found in infants between the eighth and twentieth months, or during the period of the eruption of the teeth and before the child is put on the enlarged diet which follows the ability to masticate. Children who are fed on the bottle later than this may also have the disease. In nearly all the cases that have been reported the patient has been fed on some one of the following foods: Proprietary or cereal foods, condensed milk, peptonized milk, sterilized milk, any of the cereals (as barley water), or milk too much diluted with water. Of these causes it seems pretty safe to say that the sterilization processes enjoined by many physicians and adopted by the laity as a tribute to bacteria, in the preparation of these various foods, is responsible to a great extent for the conditions which follow. From observations made in cases which have developed in infants it has been found that the scorbutic symptoms will begin to manifest themselves in from six to eight weeks after the institution of the improper diet. As in scurvy of the adult the exact etiological factor is still undetermined, but it would seem that fresh milk when ingested possesses antiscorbutic properties not unlike those possessed by the vegetable elements when administered to adults.

Clinical Symptoms.—An infant fed on artificial food, and especially on sterilized cow's milk (brought to 212° F.), will begin to show, after six weeks or more of this diet, the general signs of systemic disturbance, pallor, restlessness, disinclination to be moved. This is followed by particular evidences of pain in the lower limbs, usually localized in the femur, and in an increasing immobilization of the legs as the disease progresses. The pains grow more intense, the knees are drawn up, held motionless, or rotated outward and fixed, simulating paralysis. It will be seen that there is a cylindrical swelling of the lower end of the diaphysis of the femur, due to hemorrhagic suffusions into the subperiosteal space, either in one or in both thighs, and as a result in advanced cases this condition is often accompanied by fractures of the bone underneath. Swelling and softening of the gums presents the typical scorbutic feature almost synchronously with the above condition, but this manifestation is not usually seen in infants in whom some of the teeth have not erupted, and this gingival symptom is usually most pronounced about the incisors or about the teeth that may have pierced through. The condition of the gums is the same as in adult scurvy, with this exception: If teeth are in the upper jaw and not in the lower, the latter will not show the spongy and bleeding and ulcerated condition surrounding teeth that are present in the former. This symptom is usually followed by another characteristic scorbutic sign—subcutaneous hemorrhagic suffusions showing purpuric spots and coalesced macules of greater or less size and the appearance of multiple tumefactions of the deeper tissues. The picture is not so different from that of the adult disease, viz., the ashen hue, the foul breath, the circles about the eyes, the swollen, tender joints, and the listless mental condition. There is no temperature characteristic of the disease unless it be subnormal. Examination of the blood affords no more satisfactory results than in adult scorbutus. Hemorrhages into the cavities of the body occur. Diarrhœa is more frequent than constipation.

Diagnosis.—From the description above given the recognition of this disease in a developed case should not be difficult. It may be confounded in the early stages with rheumatism, rachitis, purpura, acute anterior poliomyelitis, infantile paralysis, and possibly syphilis. The first named may offer the greatest field for error. In rheumatism the joint itself is affected; while in scurvy the tissues about the joints, especially the knee, are involved. In scorbutic hemorrhages the blood escapes practically always into the diaphysis of the long bones. With proper protection of the femur the knee-joint can be moved without discomfort in scurvy. The differentiation from purpura is made in the same way as it is in scurvy of the adult type. In purpura the maculations are more evenly distributed over the entire surface, in scurvy the lower limbs are mostly affected. In infantile paralysis and poliomyelitis the immobility of the limbs is due to palsy of the muscles, while the failure of movement in scurvy is because of pain. The disease may be distinguished from rachitis by the absence of the rosary and by the typical skeletal signs of that disease. The characteristic scorbutic signs in the gums should always enable the observer to exclude rachitis from the problem. Dietetic treatment will usually settle a diagnosis in a few days. Other diseases to be borne in mind are hæmophilia, erythema nodosum, leukæmia, and local periostitis.

Pathology.—The special lesions found post mortem are those relating to the hemorrhages occurring in the course of the disease, but differ in no way from those observed in the adult type. Up to the present time no characteristic signs have been found which add to our knowledge of the pathology of the disease.

Treatment.—Being a preventable disease it has its prophylaxis as well as its cure. The first relates to the use of proper food. If a child must be given artificial alimentation, it is necessary that it have the nearest succedaneum to human milk that can be readily procured. This to a certain extent involves the whole question of infant feeding, which cannot here be considered. This much may be said, that cow's milk is the best substitute because the cheapest and most easily procured, as well as because it contains all the necessary elements. The proportions of the constituents differ from those of human milk, but a scientific effort to "follow nature" has not been productive of happy results. Properly diluted with water and raised to a moderate degree of heat, not over 170° F., for ten or fifteen minutes, cow's milk is the most available and natural food for infancy. This heat will effectually dispose of all bacteria that need give cause for anxiety. The "pasteurization" of milk renders it truly a sterile product—a dead liquid—in which either the antiscorbutic properties are rendered inert or the low proportion of proteids favors the characteristic signs of scurvy. The effect, upon milk, of heat sufficient to sterilize it, is not entirely understood. It is a delicate complex form of protoplasm, and the effects which "pasteurization" produces upon the caseinogen, nucleins, and the calcium salts by which their combinations are disturbed, have undoubtedly to do with their efficiency as antiscorbutic agencies. This much has been learned by practical experience and points the way to the preventive treatment of the disease.

The curative treatment is upon the same order as that of the adult type—the restoration of the food that the infant has been deprived of, viz., *fresh* milk in properly diluted form. This milk may be given in alternation with a teaspoonful or two of orange juice every hour throughout the day. Raw beef juice, salted, may be used for a change, and barley water can afford a satisfactory alternative. But the main reliance must be upon fresh milk fed with due consideration to the condition of the infant's digestive apparatus. All other forms of treatment are symptomatic and need not be detailed. As in the adult type the most desperate cases, so far as may be judged from external signs, recover rapidly when proper food is furnished.

Charles E. Banks.

SEASICKNESS, or **NAUPATHIA** (*ναῦς*, a ship; *πάθος*, sickness. French, *Mal de mer;* German, *Seekrankheit;* Dutch, *Zeeziekte;* Spanish, *Mareo;* Italian, *Male di mare*), is the name applied to a definite syndrome group that occurs usually in persons on board a vessel at sea—but also occasionally when the subject is in a rapidly moving railway or trolley car, on the back of a camel, in a balloon, an elevator, a swing, a merry-go-round, etc.—and of which nausea and vomiting are the most marked phenomena. It is said that not more than five per cent. of human beings are entirely exempt from it; but while I have no statistics to offer, this proportion seems to me much understated. The same individual may differ in his susceptibility at different times. As a rule, those who make frequent voyages become acclimated; but some persons are always sick on board ship, even in smooth weather. As a rule, weather and the motion of the ship make considerable difference in the number of sick persons on a vessel, and in the severity of the attack in the individual. Age has some influence upon resistance. Very young children are rarely affected, and children below the age of puberty are not nearly so susceptible as adults. Lower animals differ in their susceptibility to seasickness; dogs, horses, cows, sheep, and chickens have been affected; but hogs, ducks, and geese are said to escape, as a rule. The attack varies in both degree and duration, according to the idiosyncrasy and the physical condition of the individual. Merely uncomfortable sensations may be experienced, or the condition may be one of mental and physical collapse.

Seasickness is not in itself dangerous to life—very few deaths having been recorded—nor, on the other hand, is it beneficial, as is sometimes stated.

Symptomatology.—Definite symptoms are presented by this affection. Abnormal increase of appetite may be the first sign, but anorexia—even active disgust for food—is more common. Headache is the rule, and is in many cases attended with a sense of fulness or congestion. It is often most intense, and usually constrictive, over the forehead or temples; sometimes the severity is greatest on the top or in the back of the head. Usually there are pain and a feeling as of pressure in the eyeballs. Often there is pain in the back of the neck. Soreness in the back and neuralgic pain in the extremities may also be present. Nausea and vomiting are, as a rule, most obstinate. Their onset may be preceded by general chilliness with pallor of the face and lips. Ptyalism occurs at times, and there may be a foul taste in the mouth. Constipation ordinarily accompanies the general disturbances; diarrhœa is less frequent. Chilliness and flashes of heat are sometimes complained of. Mental depression, despondency, and even despair are frequently observed. In addition there may be complete loss of will power and of the faculty of concentration. The pulse presents a diminished resistance, being small, feeble, and easily compressed. The skin is pale, cold, clammy, and often moist. The urine is diminished in quantity.

Causation.—Numerous theories have been advanced as to the cause of seasickness. All writers agree, however, that the complaint is aggravated by the physical and mental fatigue caused by the preparations for the voyage, by the emotional excitement of parting, by previous imprudences in diet, by constipation, and by want of proper food. The cause of naupathia is believed by some to lie in disorders of certain senses. It is given as visual disturbance caused by the constant mobility of surrounding objects; irritation of the semicircular canals caused by the frequent and varied movements of the ship, and confusion of the muscular sense, or a disturbance of the feeling of the relation of the body to surrounding objects, caused by the unstable conditions prevailing on board a vessel.

Irwin regards seasickness—or motion seasickness, as he calls it—as a disturbance of a supplementary special sense whose function is to determine the position of the head in space and to govern and direct the æsthetico-kinetic mechanism by which is maintained the equilibrium of the body. He holds that motion produces sickness by disturbing (*a*) the endolymph in the semicircular canals, (*b*) the viscera in the abdomen, and possibly (*c*) the brain and the subarachnoid at its base. The true primary cause of seasickness he believes to be irritative hyperæmia of the semicircular canals. By some the stomach has been regarded as the seat of the trouble. The view taken is that by the shaking of the contents of the stomach digestion is stopped and fermentation sets in, the undigested fermented food being thrown off by an effort of nature. According to this theory the headache, depression, and vertigo are due partly to the absorption of bile, or of some or many toxic products of metabolism or of fermentation, into the circulation, and partly to irritation of the pneumogastric nerve terminals. Some suppose that the play of the diaphragm and abdominal organs, caused by the movements of the ship, induce spasms and convulsions of the stomach. Another theory attributes the symptoms to a severe intramolecular shaking and irritation produced in the cells of particular organs by rapid movements arising from sudden change of direction of motion. The direct mechanical effects produced on the nervous tissues by the movements of the ship are given by many as the cause of seasickness. These include repeated slight concussions of the brain produced by its being shaken up and down in its bony case; a centrifugal jarring of the brain as a result of motion along the two arcs of a circle described by the axis lines of a ship; shocks inflicted upon the brain and spinal cord by the violent flux and reflux of the cerebro-spinal fluid, induced by the movement of the vessel.

Beard believed naupathia to be a functional disturbance of the central nervous system, the cause being purely physical or mechanical—a series of mild concussions—the agitation of the nervous system by the movements of the ship. Other theories ascribe the cause to effects produced on the nervous system by disturbances of the circulatory apparatus. It has been supposed that the irregular variations of barometric pressure produced by the rising and falling of the waves cause oscillations of the column of blood within the larger vessels. Seasickness has been attributed also to sudden and recurring changes of the relations of the fluids to the solids of the body, both of which obey the law of gravity when the body is subjected to alternate movements of ascent and descent; the blood, however, descending more rapidly and ascending more slowly than the solids. Pollarin believed the condition due to the lessening of the ascending force of the blood in the aorta and in the arteries springing from it, caused by the movements of the body and resulting in anæmia of the brain. Wallaston, on the other hand, ascribed it to cerebral congestion. Chapman held that the proximate cause of seasickness consists in an undue amount of blood in the nervous centres along the back, and especially in those segments of the spinal cord related to the stomach and the muscles concerned in vomiting. Skinner believes that the motions of the ship cause movements, slight or considerable, and repeated displacements, collisions, and stretching of various organs of the body, especially of the abdominal organs, and unequal and alternate increase and lessening of pressure exerted by the column of blood on the walls of the arteries and veins. This starts a reflex nervous act, an inhibitory influence, causing a paresis of the cardio-accelerator and vaso-constrictor centres. Thus are brought about enfeeblement of the heart's action and frequently a diminution in the number of cardiac pulsations, and a consecutive loss of vascular tone with relaxation of the walls of vessels of medium calibre. This results in a general lowering of the arterial blood pressure, which is the cause of naupathia, giving rise to anæmia of the medulla, anæmia of the brain, anæmia of the skin, diminution of the blood pressure in the kidneys, and the diminution or the absence of action of the sympathetic nervous system upon the unstriated fibres of the intestine and of the arteries, and also upon the intracardiac nerve ganglia. A vicious cycle is thus established.

Gilon considers seasickness a neurosis, and says that while the onset of mild attacks may determine a temporary increase of blood in the cerebrum, it is certain that the lessened arterial tension due to the vaso-motor disturbance later deprives the nerve cells of their proper stimulus, and the consequent anæmia of these centres results in weakness of the heart and dilatation of the vessels. Even miasmatic intoxication has been made responsible for seasickness (Lemonas).

The theory that seems to me the most plausible is that which attributes to *rupture of labyrinthine compensation* the principal phenomena; thus partially allying the condition to mountain-sickness and aëronauts' sickness, in which this factor plays a subsidiary part. *Concussion of nerve elements* probably adds to the sum total of disturbances; while *auto-intoxication* is added as a result of the failure of digestion and derangement of metabolism. *Lowered vascular tone* is both a symptom and a cause of other symptoms. Psychopathy (morbid suggestion) is not to be excluded entirely, but is not in itself a sufficient explanation.

Prophylaxis and Treatment.—Different forms of treatment—physical, physiologic, and medicinal—have been recommended, in accordance with the various theories as to the cause of naupathia. The exciting cause in every case being the motion of the vessel, a stateroom should be selected near the centre of the vessel, away from the engines. An inside room is said by many to be preferable, but in my opinion the lack of ventilation more than counterbalances its supposed advantages. As prophylactic measures, it is advised that all preparations be concluded at least twenty-four hours before embarking, so that the system may not be exhausted by overwork and want of sleep, and that as hearty a meal as possible be eaten before going on board. Those especially liable to seasickness are told to go to bed before the vessel gets under weigh, having previously arranged within easy access such things as may be needed for the first day or two; to eat regularly and heartily, but without raising the head for at least one or two days; to take a mild laxative on the first night out and to keep the bowels open; and, after being able to go on deck and to the table, not to rise in the morning without first eating something. If the sea should become unusually rough, they are to go to bed before getting sick. Some have advocated a spare and dry diet, one full meal being indulged in, and soup, pastry, milk puddings, and sweets being avoided. I have seen good results apparently due to the following prophylactic régime: (1) A calomel purge followed by a saline, one week before sailing, and again two days before sailing. (2) A saline irrigation followed by complete rest, the morning before sailing. (3) Saline laxatives or enemas daily for the first few days on board. (4) Spending all the time possible on deck. Those very susceptible should maintain a reclining posture in a steamer chair, but out of the direct sunlight. Those but slightly affected should try to move around from time to time, walking a little more each day. (5) Taking for the first day or two light, easily digested food at short intervals. (6) Sponging or bathing daily with cold water or with hot water preceded by cooling of the head and neck and followed by a cold friction rub or shower. (7) Taking minute doses of picrotoxin (gr. $\frac{1}{100}$ hourly) for ten hours daily during the week preceding the voyage, and for two or three days at sea. I should now advise instead epinephrin (commercially known as suprarenalin) in doses of from gr. $\frac{1}{24}$ to gr. $\frac{1}{12}$, absorbed from the tongue. For this purpose a fraction of a grain of sugar of milk may be added, and either powders or tablet triturates be dispensed.

It is usually advised that the horizontal position be assumed. Various physical expedients have been tried to lessen the motion of the vessel but without success. The twin ferry-steamer, the *Calais-Douvre*, the Bessemer suspended saloon, swinging state-rooms, swinging berths and bunks, and the always upright easy-chair, *fauteuil-de-mer* of Dr. Neveu Derotrie, have all proved failures. Various preparatory exercises to be practised by those intending to go to sea have been suggested. Swinging, turning around upon one foot, the use of rocking-horses, oscillating planks, gyratory chairs, and the like, have been advised. Dr. Hewitt devised a mirror, so hung as to swing on its oblique axis over a swinging platform provided with a seat and movable at will up and down, from side to side, backward or forward, or in a combination of these movements. The person contemplating a voyage was advised to use this contrivance daily for some time before tempting the winds and waves. Various expedients based on the visual theory are recommended. Thus, patients are instructed to keep their eyes closed or covered; to wear smoked glasses or blue or red glasses; or to fix their eyes on some object away from the vessel. The wearing of red spectacles has been advocated on the theory that the effect of the color on the blood-vessels of the brain would be to send the blood to the brain, relieving a cerebral anaemia. To lessen the irritation of the semicircular canals, Dr. Minor suggests dropping cocaine in the ear. To keep the intestines quiet, to support the abdomen exhausted by incessant retching and vomiting, to determine the flow of blood to the head, or to provide a substitute for the stimulus and distention of food, abdominal compression by means of a bandage, handkerchief, towel, or napkin has been advised and is really useful. If the abdomen be hollow, a soft folded blanket may be fitted into the depression. Inflating the lungs and holding the breath as long as possible have been suggested as a means of fixing the diaphragm. Hovent, indeed, advocates systematic inhalation and exhalation against pressure by means of my pneumatic resistance valves. In my own person the experiment was unsuccessful.

The *dietetic management* usually recommended after the onset of seasickness is that a moderate amount of easily digested food be taken at short intervals. Beard says that one should keep something in the stomach all the time, if possible. Thin soups, broths, and gruels usually may be given. Junket, matzoon, kumyss, clam juice, beef juice, curry, preparations of blood, and predigested preparations of milk, beef, peptones, and the like can often be taken in small quantities, even after nausea and vomiting have occurred. Many experienced ship surgeons advise against the exclusive or excessive use of liquid food and prescribe solids or semi-solids; they believe that liquids encourage vomiting. Some writers recommend mulled wine, grog, Curaçoa, eau de menthe, iced dry champagne, cider, and brandy. Acid or effervescing drinks, such as seltzer, ginger ale, and sweetened water, with the addition of lemon juice or a little citric or tartaric acid, are often refreshing when taken in moderation. Draughts of ice-cold water, or pieces of ice held in the mouth, may give comfort. Coffee and tea as hot as possible, and in small doses, are sometimes soothing and invigorating.

As *curative agents* various forms of counter-irritation have been employed, the commonest being a mustard leaf over the epigastrium. Electricity has been applied, chiefly as faradization of the epigastric and hypochondriac regions, in some instances combined with the painting of the parts with a solution of atropine sulphate for cataphoretic effect. Chapman advocated the application of an ice-bag to the spine, believing that thus he could lower the temperature of the spinal region. Baruch, however, asserts that cold applied to the surface of the body, instead of penetrating deeply, calls into action the heat-regulating machinery of the body for the purpose of resisting the invasion of cold into the interior. The success Chapman met with may have been due to stimulation of the spinal centres with increase of vascular tone. The spinal coil would probably be more comfortable than an ice-bag and more easily arranged. If the benefit lie in the elevation of depreciated nerve tone, the best hydriatic application would appear to be the douche. The Winternitz combination compress, so efficacious in cases of obstinate vomiting, should be of service in seasickness, though it will rarely be available. It consists of a stimulating cool trunk compress enclosing an epigastric coil through which circulates water at a temperature of from 122° to 132° F. The cold wet compress at first produces an anaemic condition of the skin beneath, with contraction of the cutaneous vessels and irritation of the peripheral nerves. Reaction quickly follows with tonic dilatation of the vessels, the part covered by the coil becoming hyperaemic. Dr. Edward Miller, in 1814, recommended the warm bath alone, or alternating with the cold bath, friction of the skin with oil and camphor, or dry friction with powder of mustard.

Various *drugs* and classes of drugs have been employed to meet certain supposed indications. Laxative treatment is usually recommended, and should be commenced as early as two weeks previous to the night before the contemplated journey. Podophyllin, aloes, rhubarb, and the salines have been used. Drastic cathartics, however, should not be administered. Various sedatives, analgesics, and hypnotics have been employed. Bromides (ammonium, potassium, sodium, strontium) are often given in doses of from ten to thirty grains three times a day. Beard advocated mild bromization and prescribed large doses of sodium bromide for three or four days before starting, keeping this up while at sea, until there is well-grounded reason to believe that all danger is over. Chloral hydrate, in doses of five or ten grains, has been used alone or in combination with the bromides. Chloroform is sometimes employed. Charteris prescribes "chlorobrom," a solution of chloralamid and potassium bromide, for three nights in hypnotic dose—a tablespoonful for women and a tablespoonful and a half for men, or a teaspoonful every ten minutes until the full dose has been given. Nelken gave half a grain of morphine twice a day. Cannabis indica, in doses of half a grain, has been employed. Antipyrin has been given in doses of from five to fifteen grains. Chloralamid, chlorodyne, paraldehyde, sulphonal, and the like, have also been used. Personally, I have seen benefit only from the bromides—of which strontium is the best—and morphine when needed.

Certain so-called neuro-muscular agents have proved useful. According to Skinner, they increase the activity of the nerve cell and of the unstriated muscular fibre, as well as that of the striated, and thus cause an elevation of the arterial blood pressure. The theory is of dubious worth, but the practice is useful. Cocaine, caffeine, strong black coffee, thin and strong infusion of black tea constitute this group. I have seen much good from fluid extract of erythroxylon coca and from wine of coca. Other remedies that act in a similar manner are theobromine, guaranine, kolaine, and preparations of kola Strychnine and atropine have been used. Skinner employed them simultaneously in order to raise the blood pressure by acting upon the nervous centres and the unstriated muscle fibres. On account of the frequent vomiting in seasickness he preferred the hypodermic method of administration, giving to an adult from 0.5 mgm. to 1 mgm. of atropine, and 1 mgm. of strychnine, dissolved in mint water. This he repeated in two hours if the patient was not well, and even again two hours later. He never exceeded three injections in one day. Amyl nitrite has been lauded by some writers. I have seen benefit from strychnine arsenate, 0.5 mgm. (gr. $\frac{1}{125}$) hourly by the mouth, and also from picrotoxin—which acts like a combination of strychnine and belladonna—in about the same dose. Crude adrenal preparations have failed in my hands, but it is probable that epinephrin absorbed from the tongue may be useful in many cases.

Agents used for their supposed effect on the stomach are dilute chloroform, hydrocyanic acid, tincture of iodine in drop doses, cerium oxalate, cocaine, sodium bicarbonate in doses of ten to twenty grains, creosote in drop doses given every hour, eucalyptus rostrata, the digestive ferments, the dilute mineral acids, Worcestershire sauce in teaspoonful doses, and preparations of Peruvian bark, calumbo, and quassia. The older writers gave emetics on the advent of vomiting, using infusion of chamomile, peppermint or ginger, or even sea-water. Lemonas recommended quinine to combat the hypothetic miasmatic intoxication. I have seen no recommendation of specific serum—neither of an antitoxin from an acclimated human being or lower animal, nor of an artificial combination of chemical salts!

As a rule, if patients keep on deck, keep their bowels clean, do not overeat, sponge or bathe daily with cold water—or with hot water, if preceded by cooling of the head and neck and followed by a friction or by a shower or general douche of cold water—and are subjected to cheerful rather than to depressing suggestion, they will recover quickly without medicines. I have seen attacks cut short by a calomel purge followed by thorough saline irrigation of the bowel. *Solomon Solis Cohen.*

SEAL, GOLDEN. See *Hydrastis.*

SEA VOYAGES.—Therapeutically sea voyages may be divided into three groups:

1. A voyage *incidental* to a change of residence or climate, or to a business or pleasure trip. Voyages of this class are usually, though not always, short, and apart from perils or discomforts of the particular voyage, need to be studied only from the view point of possible counterindications in the special case of a weak or delicate person, or one who has borne previous sea trips badly, or of an invalid affected with some lesion rendering the voyage hazardous. Such counterindications will be mentioned in the general discussion.

2. A voyage undertaken as a *restorative measure* in the case of an individual patient. Voyages of this class are to be studied from all possible view points, meteorologic, geographic, climatic, epidemiologic, therapeutic. The time of year, the special trip, the ship, the disease, the patient and his companions, must be given careful consideration, and indications and counterindications weighed against each other. Thus, voyages around Cape Horn in the winter of the southern hemisphere are to be avoided for invalids; and similar questions of route and season are always to be examined in detail. In this article space will not permit more than casual allusion to a few special voyages.

3. A voyage forming *part of a scheme* of climatic or other treatment. Voyages of this class stand midway between the other classes, and certain discomforts or other counterindications, not otherwise permissible, may be outweighed by the benefits expected from the measures to which it is a necessary introduction.

Ocean Climate.—The climate of the open sea possesses characteristics not to be found elsewhere: a peculiar equability of temperature due to absorption of thermal rays and surface evaporation in the day, and to convection with surface heating and diminished radiation at night; an abundance of light; a favorable degree of relative atmospheric humidity (the mean being 73.5 per cent.); and freedom of the air from dust, microbes, and other impurities. It is not necessary to call upon the presence of chemical factors in the atmosphere, ozone, iodine, or salines, to explain its beneficial influence; yet independently of chemical analysis the sense of smell finds an agreeable quality in the sea air, which doubtless indicates properties acting in an equally acceptable manner upon all nervous tissues, and possibly upon all cells. The breezes are always refreshing, and except in certain regions of latitude or current the midday temperature seldom exceeds 85° F., and is usually very much less. When the temperature is high upon the sea it is less distressing than an equal degree of heat upon the land; thus, at the tropics it is rarely oppressive even in the absence of wind. Similarly cold is often better borne at sea than on land, though from a therapeutic view point extremes of either heat or cold should be avoided. Against these qualities the depressing and distressing effects of storms—to say nothing of their dangers—must be taken into account.

Factors Other than Climatic.—The prolonged mental rest and the complete change of surroundings incident to a sea trip of moderate length are factors of no mean value in the sum total of restorative effects. On the other hand, in very long voyages, the monotony may become wearisome, and this contingency must be provided against. Ship, time of year, proposed voyage, and cost may not always correspond to desire. Light and air, while abundant and pure on deck, are not always so in the cabins. The food may not be suited to the needs of invalids, and the absence of fresh milk, fresh fruits, fresh vegetables, is often a serious drawback. Some individuals are peculiarly susceptible to seasickness, and others suffer with deranged metabolism during the greater part of the trip. Women generally feel the discomforts of life on shipboard more than men do, and can seldom be advised to take prolonged voyages. It is necessary in every case to exercise great care in the selection of ship, master, and route, to inspect the sleeping cabins and general accommodations, and to be sure that the dietetic arrangements are good. Other things being equal, well-equipped sailing vessels are to be preferred to steamers for therapeutic voyages. There should always be a trustworthy ship's doctor, and in many cases the invalid must be accompanied by a special attendant or a physician. When the patient owns a seagoing yacht, most difficulties vanish; and Sir H. Weber has suggested ships, specially built and equipped as ocean sanatoriums, to be sent on well-selected voyages according to season.

In the consideration of *seasickness*, the general precautions necessary to therapeutic voyages were considered. Here it may be emphasized in repetition that the pure air of the deck is preferable to the stuffy atmosphere of cabins; that exercise is necessary; that exposure to the sun is usually beneficial; that the skin should be cared for by regular and systematic baths, frictions, etc. In addition to the care necessary in choosing vessel and cabin, the provision of congenial companionship and of sources of intellectual interest as the inclination to mental activity returns, demands attention.

Indications.—Short voyages of from five to twenty days are useful chiefly to give mental and physical rest and recreation, and to prevent relapse or other accident after convalescence from depressing affections, as influenza. Voyages of moderate length, twenty to sixty days, are sometimes followed by strikingly good results in cases needing more prolonged rest, as in breakdowns from overwork, irritable conditions of the nervous system, even actual neurasthenia when the patient has good resisting power. In certain cases of asthma, in the conditions termed "scrofulous," in chronic tendencies to "catching cold," in suspected or actual pulmonary tuberculosis, such voyages are often beneficial.

In chronic catarrhal conditions of the upper air passages, in chronic rheumatic states, and sometimes in chronic rheumatoid arthritis, voyages to warm climates, as a winter trip to Mediterranean or Caribbean waters, may be advised. Hay fever has been reported to have been observed at sea, but the occurrence is so rare that its possibility may be disregarded and the general tonic effect of the ocean climate upon those susceptible to this affection is highly desirable. Some chronic forms of diabetes mellitus in middle-aged or elderly patients are ameliorated by ocean trips, especially those to warm climates in the winter.

Prolonged voyages, three months or more, are to be advised only when the patient is known to be a good sailor, is not too severely ill or too weak to undergo some discomforts, and has a fair degree of resisting power, as well as good digestive and eliminative functions.

The special trips of three and four months to north European waters in the summer and to Mediterranean and Oriental waters in the winter, made by well-equipped vessels and including in their itinerary stops at various important ports are, however, to be classed therapeutically with voyages of moderate duration, and are especially to be commended to convalescents and those needing rest and recreation. Long voyages on the open sea, as to Australia, for example, are to be advised chiefly for those who enjoy the sea, for dipsomaniacs and drug slaves, and in cases of pulmonary tuberculosis. It is especially in suitable cases of pulmonary tuberculosis that well chosen voyages are to be urged, sometimes as a means of recovery, sometimes as a means of palliation and of prolonging life. Some patients can "rough it" on sea and land with benefit; others must be carefully protected. The stage of disease, too, and the general characteristics of the patient make considerable difference. Hence general rules cannot be laid down. Certain main factors, however, may be presented. In febrile cases the temperature usually subsides after a few days upon the sea. In cases which show much general tendency to recovery, but in which limited areas of persistent activity remain, the local processes diminish and finally cease under the influence of the aseptic sea air and the general stimulation of nutritive processes. In cases of erethic temperament, unsuitable for mountain cures, especially those with a tendency to excessive cardiac action at altitudes, the sea exerts a beneficial sedative influence. No other measure is of equal value in early cases in robust males, especially in young men infected by chance, or when weakened by overwork, worry, or acute disease. In quiescent cases of a more advanced stage the general health and hence the local conditions are usually much improved. In certain far advanced cases with extensive softening and persistent fever, a voyage in equable waters—say upon the Pacific, as from San Francisco to Japan and return by way of Hawaii—has been known to mitigate symptoms and to prolong life. Sometimes such patients can even benefit by excursions into cooler regions, as to Alaska, Iceland, or Spitzbergen. When patients are to be sent to a special land climate, as from Europe to Colorado, or from America to the Alps, or from either to Australia or South Africa, the sea trip may be made a special feature of the cure; and, similarly, sea trips may be directed to well-chosen objective points, invigorative or protective as may be, where the patients may remain for a time before coming home.

Counterindications.—Grave lesions of the heart and blood-vessels interdict any ocean trip; nor should a longer voyage than the week between Europe and America be permitted in the great majority of cases of far advanced tuberculosis, chronic gastro-intestinal disorders, cholelithiasis, or chronic diseases of the abdominal viscera. Gouty patients may suffer more severely at sea than on land; neuralgias are often aggravated; hemorrhoids may become troublesome. Among other conditions necessitating caution, or even the prohibition of a voyage, are a marked tendency to hæmoptysis, great general weakness, special liability to seasickness or loss of appetite, epilepsy, maniacal tendencies, periodic insanity, suicidal inclinations, marine photophobia, and marine insomnia.

Solomon Solis Cohen.

SEBORRHŒA.—Definition. — For the purposes of this article seborrhœa may be defined as a functional disorder of the glands of the skin, characterized by the production of an excessive amount of fatty material, normal or abnormal in quality, which manifests itself upon the skin as an oily coating, scales, or crusts.

History.—The investigations of recent years have done much to determine the true limitations of this disease. Many points, however, remain unsettled, especially in the domain of etiology and pathology, and it is very probable that the future will render possible a definition of greater precision. The process of evolution of the present-day conception of seborrhœa is of interest, as showing the gradual differentiation of species from genus. The old Greek and Roman observers—Hippocrates, Galen, Celsus, Actuarus, and others—recognized the occurrence of falling of the hair; and by the Greeks the expression πιτυρίασις, *pityriasis* (that which is winnowed, *i.e.*, husks, bran), was used to designate a condition of the skin and scalp characterized by the formation of scales. This was, in the light of our present knowledge, a very broad application of the term, and probably included, among other morbid states, that disease which we know to-day as *seborrhœa sicca*. The name *porrigo* was given by the Roman writers, notably Celsus, to pathological conditions of the skin attended by scale formation. It was not, however, until the latter part of the eighteenth century that any suggestion of a differentiation of the general class into specific types was made. Plenck, in 1783, described, quite concisely, a condition very similar to, if not identical with, our *seborrhœa sicca*, and stated that the flaky material was to be regarded as a product of the sebaceous glands of the scalp. His view was not generally accepted by his contemporaries; the term *pityriasis* continued to be used in its comprehensive sense—including practically all squamous conditions—until well into the nineteenth century. A few investigators, however, seemed to have followed Plenck in the endeavor toward scientific differentiation. The terms *Teigne* (or *Tinea*) *amiantacée* and *T. furfuracée* were applied by Mahon to conditions apparently seborrhœic. Brett noted the occurrence of oily, scaling lesions upon parts of the body not covered with hair, and coined therefore the expression *acné sebacée*.

The terms *sécrétions morbides des follicules sebacées* and *flux sébacé* were used by Rayer in 1827, referring to morbid conditions of the sebaceous glands. In Hebra's time and during the period immediately preceding him, dermatologists were still seeking a better separation of *seborrhœa* from the general class *pityriasis*, with varying success. Fuchs, in 1840, it is said by Sabouraud, was the first to make use of the term *seborrhœa*.

In more recent years, largely as a result of the work of Unna, those cases formerly regarded as seborrhœa, in which an inflammatory process is present, have been set apart in a class by themselves, under the caption *eczema seborrhoicum* (which see). Unna himself would draw the line more closely, and would include in the class mentioned practically all types of *seborrhœa sicca*, since, he believes, inflammation is always present in these. His conception is not unanimously accepted in its entirety by dermatologists. The exclusion of the inflammatory process from seborrhœas, and their limitation strictly to functional disturbance, has greatly narrowed the field; it has imposed an added burden upon the diagnostician: that of determining where functional disorder ceases and organic change begins.

Symptomatology.—The classification of seborrhœic conditions clinically is not a settled one, especially as regards minor distinctions. For practical purposes, however, two general types may be considered: *seborrhœa oleosa* and *seborrhœa sicca*. These have been variously designated by authors; the former has been called *stearrhœa, steatorrhœa, seborrhagia, sebaceous flux, acné sébacée fluenté, hyperidrosis oleosa* (Unna); the latter, *pityriasis simplex, seborrhœa furfuracea seu psoriasiformis, erythema capitis, acné sébacée sèche, eczema seborrhoicum squamosum* (Unna).

Seborrhœa oleosa may affect both the hairy and the non-hairy parts of the body. It most commonly appears upon the face and scalp, but it may occur on the chest, back, pubes, genitals, and in the axillæ. Obviously, in these latter regions it is seen much less frequently by the physician. When the scalp is involved the hairs are covered with an excess of oil; they are greasy to the touch; tend to mat together into bunches and strands, and in the uncleanly an offensive, rancid odor may be present. The scalp itself is generally pallid and cool, and is covered with an oily secretion; when the head is bald this gives the skin a shining, though sometimes muddy appearance. Itching is either absent or of a very mild grade; redness is not commonly present; when these are found to any pronounced degree, it is a fair presumption that some irritating factor has entered in to modify the classical type. Neglected cases of this type of seborrhœa affecting the scalp generally result in a severe alopecia.

Upon the face, the parts most involved are the nose (especially the alæ nasi), the adjacent parts of the cheeks, the chin, and the forehead. The unusual flux of fatty material gives the face a yellowish, oily appearance; in addition, a dirty, "smudgy" quality is imparted, owing to the ready adherence of dust and soot particles to the greasy surface. The orifices of the sebaceous glands are large, and are generally filled with a visible, yellowish-white plug. Upon pressure these are discharged upon the skin surface, and oily material exudes from the patulous ducts. Some redness may be present, more frequently about the alæ nasi, but usually the skin is cool and without inflammatory changes. Should these appear the condition can no longer be considered a simple seborrhœa.

The domain of *seborrhœa sicca* is disputed territory. Inasmuch as the questions concern largely the matter of classification, the writer will seek to give that symptomatology which has been accepted by the majority of dermatologists of the present time.

The most frequent type of *seborrhœa sicca* is seen upon the scalp in the condition commonly known as "dandruff." It is here characterized by the formation of fine, pulverant or flaky, and slightly oily scales, grayish- or yellowish-white in color, about and between the hairs. They may be scanty, requiring the use of the nail or a blunt toothpick to demonstrate their presence; or so abundant, especially upon the vertex and the regions immediately anterior thereto, as constantly to shower the patient's shoulders with a flaky dust. Underneath the scales the scalp is pale, dry, and non-inflammatory. The hair appears to be deprived of its natural unguent, loses its lustre, becomes dry, thin, and atrophic, and eventually falls, the resulting alopecia being generally symmetrical and permanent. The subjective symptoms in mild cases are absent or very slight; if the scale formation is profuse there may be considerable itching and burning. This leads frequently to a modification of the clinical picture. The constant trauma from scratching in neurotic individuals who have neglected treatment soon induces a dermatitis, which, combined with already existing conditions, produces a type approaching *eczema seborrhoicum*. In these cases excoriated areas may be seen, usually small, upon which are formed yellowish, moist, friable crusts, distinctly greasy; beneath, a reddened, slightly exuding base may be found. The crusts, when removed, are quickly renewed; subjective itching and burning are quite pronounced.

Conditions similar to the characteristic *seborrhœa sicca* of the scalp are not uncommonly found in the eyebrows, eyelashes, mustache, and beard; it is more rarely seen in the pubic region. Upon non-hairy portions of the face, *e.g.*, the nose and adjacent parts of the cheeks, a continuous desquamation sometimes occurs; the scale is thin, grayish-white, and greasy; the skin is usually reddened and hyperæmic. The relation of this condition to *rosacea* is very close. However, upon non-hairy portions of the body the crusting forms are more commonly seen. These are best exemplified along the edge of the scalp, about the ears, upon the nose and adjacent folds, between the shoulders, and in the sternal region. The secretion over the diseased areas forms crusts, which are yellowish, greasy, friable, and often rather bulky; the skin beneath is pale or, more often, reddened slightly. If a crust be removed with care, prolongations may be seen extending from the under surface into the gaping sebaceous openings. The crusting forms frequently exhibit a serpiginous border, slightly raised, and somewhat more reddened than the central portions. The periphery, too, bears a bulkier crust, while the centre is either clearing or entirely free from scales. This form is best seen upon the chest, the back, and along the frontal hair border. The terms "flower-leaf" and "petaloid" have been used to designate the type.

Seborrhœa may occur upon the genitalia. In the male it is manifested by the formation of quantities of white, cheese-like, glandular secretion, and epithelial débris about the posterior portion of the glans, the corona glandis, and the sulcus behind the latter. In the normal and cleanly individual functional hyperactivity of the glands of these parts is practically without symptoms; but in the filthy, from want of proper ablutions, and in the phimosed, from the anatomical conditions present, the retention of this secretion leads to various reflex nervous disturbances, and very frequently sets up a severe local inflammation. In the female, the secretion forms about the clitoris and the folds of the labia minora. If the individual be cleanly, there are no symptoms; in neglected young children and in the uncleanly, a vulvo-vaginitis may develop.

A form of crusting *seborrhœa sicca* occurring in infants is called *crusta lactea*, "milk crust." Imperfect removal of the vernix caseosa from the head is the probable cause, though it is stated that the condition may arise after perfect cleansing of the new-born child. The crusts may cover nearly all the scalp or be confined to a small area. As to physical character, they are variable; they may be bulky or thin, moist or dry, tough or friable, and present a color dependent upon the complexion and surroundings of the child. Generally they are greasy and rather adherent; the surface beneath is reddened and moist. It is probable that these cases should be regarded as instances of *eczema seborrhoicum*, since they present the picture of a dermatitis planted upon a seborrhœic base.

Kaposi, under the caption *ichthyosis sebacea*, has described a condition of the skin in infants which he regards as a true seborrhœa, arising from the continued excessive production of the vernix caseosa. The skin is reddened, tense, and covered throughout with a greasy coating; it fissures readily, especially about the mouth, and subsequent inability to nurse leads to inanition and early death. That this is a seborrhœa is extremely doubtful. The same author has mentioned a seborrhœa occurring in the aged and marasmic, *pityriasis tabescentium*, characterized by scaling of the trunk and extensor surfaces of the limbs. The pathological position of this is also in doubt.

Neuman was the first to call attention to a peculiar seborrhœic condition found in the aged, which he designated as *verruca senilis*. Unna gives it the name of *verruca seborrhoica*. By the French it is known as *acné sébacée concrète*. The lesions are found upon the face, including all parts, the neck, the arms and hands, the trunk, and lower limbs. They vary in size and outline, may be single or grouped, are yellowish-brown or darker in color, sometimes nearly black. The skin between may be atrophic. Upon close inspection each lesion is seen to be raised, slightly verrucous, rough to the feel, and covered with a scale or crust, which is adherent and beneath which a reddened papillomatous surface is found. There may be slight itching. Hyde has called this a *pre-epitheliomatous seborrhœa*, an expression which is peculiarly apt, for if malignancy has not yet shown itself among the lesions it may be expected to appear in time; and the condition is almost invariably an accompaniment of cancer of the skin in those of advanced years.

ETIOLOGY AND PATHOLOGY.—*Seborrhœa oleosa* may occur at any age, but is most frequently seen in the second and third decades of life. The puberal epoch, so especially characterized by rapid growth of hair and hyperactivity of the sebaceous glands, often develops this form of seborrhœa. The disease occurs more commonly in women than in men, and brunettes are more susceptible than blondes. A tendency to oiliness of the skin is decidedly more marked in some races than in others; that shining, greasy condition of the negro's skin, which in him may be considered physiological, would be, in the white man, an evidence of abnormal glandular activity. Among certain classes of European immigrants to this country, *seborrhœa oleosa* is common. Various predisposing causes may be mentioned; disordered blood states, derangements of the digestive and assimilative functions, chronic constipation, convalescence from acute diseases, improper hygiene and habits of life, excesses in eating and in the use of alcohol; and, in women, menstrual disorders. Factors having a purely local action are sometimes efficient, as continuous exposure of a part to heat, local pressure tending to produce congestion, rosacea, etc. Elliott reports having observed its development on the site of a recently healed erysipelas.

Uncomplicated *seborrhœa oleosa* may be regarded as a functional disease, and pathological changes in the skin glands are not to be expected, though microscopic foci of inflammation are doubtless often present. It must not be forgotten, however, that the presence of an oily film upon the skin favors the entrapment of micro-organisms, and thereby predisposes to the implantation of an inflammatory process upon the pre-existing functional disturbance. Thus one may see a seborrhœa attended or followed by acne, folliculitis, furunculosis, sycosis, eczema, etc. Unna has ably championed the view that the coil glands participate in the formation of fatty secretion. He therefore proposes the term *hyperidrosis oleosa* as more accurately expressive of the true condition present when an excess of oil is poured out upon the skin.

Seborrhœa sicca, both the scaling and the crusting forms, may occur at any time of life. Blondes are more often affected than brunettes; men exhibit the disease rather more frequently than women, the probable reason being that with the former the pilary growth upon the body is more pronounced, their daily toilet of the hair is less thorough, and their headdress less hygienic. The same predisposing factors hold as for *seborrhœa oleosa*. Especially to be mentioned are convalescence from acute disease, syphilis, and the local influence of pressure and lack of ventilation about the head. A seborrhœic element is quite commonly found in the syphilides of the scalp and face, and one may see most typical forms of crusting *seborrhœa sicca* and *eczema seborrhoicum* beneath the stiff, unventilated head-dress of the nun.

The pathology of *seborrhœa sicca* is much in dispute. While there may be no clinical evidence of inflammatory action, the latter may be demonstrable microscopically. The view commonly held as to the origin of the scales is that they result from an imperfect metamorphosis of the epithelium lining the sebaceous glands into sebum, which abnormal product is extruded upon the skin, mixed with fat and horny epithelial débris. According to this conception, the essential process is found in a pathologic physiology of the glandular epithelium.

The most radical dissenters from this theory are Unna and Sabouraud, both of whom, for their originality of work, are entitled to great credit. The former's teachings may be summarized as follows:

All forms of *seborrhœa sicca* should be classed as *eczema seborrhoicum;* the coil glands are the source of fat in the scales (since seborrhœic catarrh with greasy scales may occur in the palm of the hand and sole of the foot), which fact he has repeatedly demonstrated by osmic-acid staining; the sebaceous glands and their secretion are normal, or the glands are filled with fatty cells and show no undegenerated epithelium; exit from the glands is blocked by an excess of horny cells in the follicles; the flow of fat from the coil glands is chemotactic; a definite tendency to acanthosis and parakeratosis is present within and without the hair follicle; the morococcus is practically always found, the bottle bacillus frequently; when the scalp is concerned, the openings of the hair follicles are choked and dilated with horny cells extending to the ducts of the sebaceous glands; there is a tendency, from pressure effect, to early separation of the papillary hairs, with failure of their new formation, hence the alopecia; after permanent fall of the hair, the sebaceous glands hypertrophy, and often form true sebaceous cysts.

Sabouraud's pathology, which is a still greater departure, is as follows:

There are two forms of seborrhœa: a moist type, *seborrhœa oleosa*, and a cystic type, *acne comedo;* of the first, the elementary lesion is a fatty sebaceous plug; this plug contains an enormous number of very small bacilli, which are constantly present in pure culture and are characteristic; the comedo is the cystic transformation of the sebaceous plug, the change occurring in relatively few of them; eventually the comedo becomes infected with ordinary cocci of the skin, among them the "gray-cultured" coccus, producing various types of acne; baldness is a microbacillar seborrhœa, each follicle from which the hair has fallen having been invaded by colonies of the bacilli; this bacillus grows on acid media, forming red colonies, and stains with Gram's method; the different forms of pityriasis are separated and distinct conditions from seborrhœa, but may be superimposed upon the latter; their lesion is the scale, an exfoliation of horny epidermis; this scale is produced by a special micro-organism, the bottle bacillus.

A description of the various organisms mentioned by these two observers would require greater space than the limits of this article will permit. It will suffice to state that dermatologists and pathologists are not at all agreed that these micro-organisms are specific for the conditions named, or even that they exist as distinct varieties.

DIAGNOSIS.—The recognition of *seborrhœa oleosa* presents no difficulties. *Seborrhœa sicca* must be differentiated from the following:

Eczema. In a pure eczema there is always evidence of inflammation, either in acute weeping or chronic infiltration; crusts are non-greasy, of coagulated serum; scales are dry, free from oil (unless treated with ointments,) and rather adherent; burning and itching are always present. However, the dividing line between *seborrhœa sicca* and *eczema seborrhoicum* is often very difficult to draw, since the former frequently merges into the latter.

The feature of greatest importance in the differentiation is the absence in the one and the presence in the other of visible evidence of inflammation and of itching, though these may be present only in a slight degree.

Psoriasis. Psoriasis of the scalp is seldom seen unaccompanied by patches elsewhere. In mild cases affecting the scalp the lesions are generally small, more or less isolated, covered by an adherent, silvery, non-greasy scale, beneath which an easily bleeding surface is found; between the lesions the scalp is normal or a true seborrhœa may exist. If the psoriasis is severe, parts of the head may be covered with a thick, dry, non-oily crust, through which the hair is growing vigorously; other regions of the scalp are clear. Alopecia, as a rule, does not result in a pure psoriasis, even though the scalp be severely and chronically affected. Psoriasis is not commonly seen upon the face, and very rarely about the nose, a frequent site of seborrhœa. Upon the body it is easily distinguished if it be remembered that the outlines of the lesions are more distinct, the scales copious, lustrous, and non-greasy, and the surface beneath reddened and easily torn.

Lupus Erythematosus. The *seborrhœa congestiva* of Hebra was probably *lupus erythematosus.* The differentiation is made by considering that in this disease the site of lesion is generally the face; the outlines are distinct and elevated; the scale is very adherent, non-greasy; the skin beneath is reddened to a marked degree; scar tissue may be present in the vicinity; and close inspection of the lesion will reveal atrophic changes in progress, for in *lupus erythematosus* structural alterations occur which lead to cicatrices on healing.

Ichthyosis. This disease is generally present from birth. The scale is universal, dry, non-oily; the skin reddened, dry, and tends to fissure readily along the lines of flexure and cleavage. Frequently, but not always, malnutrition is present, sometimes to a marked degree, especially in the young.

Syphilis. Seborrhœa often complicates well-defined syphilis, but cases are not common in which an absolute exclusion of the latter disease must be made. When such is the case, recourse must be had to the past history of the individual as to exposure, initial lesion, adenopathy, exanthem, mucous patches, headaches, alopecia, etc., and to careful searching for the relics of an ancient syphilis upon the skin and mucous membranes. The crusting lesions of syphilis about the face and scalp are more defined in outline, and generally present the copper hue about their borders, which is so characteristic in specific disease. It must not be forgotten that any ulcerating lesions upon the scalp may produce enlargement of the nearest lymph nodes, a knowledge of which fact will help in the avoidance of mistakes in diagnosis.

Tinea Tricophytina. Here the decisive proof is the demonstration of the fungus. Upon the scalp the lesions present a dull gray, non-greasy, adherent crust, through which broken, fragile hairs project.

TREATMENT.—In the management of *seborrhœa* due regard must be had for the patient's general condition. Much can be accomplished by a careful regulation of the diet, attention to personal hygiene, and such general measures as shall restore and maintain a normal physiology of the various bodily functions. Especial attention should be directed to the digestive tract.

Seborrhœa oleosa may be treated locally with mildly stimulating applications, the object being to restore the normal function by purging the glands. Such applications, however, should not be continuously used. The medicaments of most value are sulphur, resorcin, tincture of benzoin, and white precipitate. The first three may be used in pomades or in weak alcoholic lotion; the last in an ointment only. To accomplish results the application should be strong enough to produce a reaction with scaling, after which a milder treatment should be followed. The use of astringents is of doubtful value; if resorted to it should be certain that the secretions from the glands are thinner than normal.

Since the *x*-ray has a selective action on the more highly differentiated cells of the skin, causing atrophy, it has been suggested that conditions due to glandular hyperactivity were amenable, theoretically, to *x*-ray therapy. *Seborrhœa oleosa* would therefore be included in the category. The consideration is purely theoretical; the writer knows of no published reports of cases so treated.

Seborrhœa of the genitals disappears with cleanliness.

In the scalp *seborrhœa sicca* requires rather elaborate and persistent treatment. In severe cases crusts and scales must first be removed by maceration with an oil, followed by a shampoo; in mild cases by the shampoo alone. The official *tinctura saponis viridis* or Sarg's fluid soap will serve well as material for the shampoo. When the scalp is thoroughly cleansed a stimulating pomade should be applied. For this precipitated sulphur, resorcin, and the red sulphuret of mercury are most efficient, either singly or combined, the ointment base used being soft.

℞ Sulph. præcip.	1.00
Hydrarg. sulph. rubr.	.05
Ung. petrol. alb.	30.00
M. Sig.: Pomade for scalp.	

In severe cases this should be rubbed into the scalp every day for a week or more; afterward less often. Patients generally object strongly to the greasy condition of the hair following the frequent use of an ointment. It is advantageous in such cases to prescribe a lotion, which may be applied six days in the week, the shampoo and pomade being used on the remaining day. Sulphur, being insoluble in water and alcohol, cannot be made an ingredient of the lotion; resorcin and bichloride, combined with other stimulants, as tincture of cantharides, are the most efficient compounds available.

℞ Hydrarg. bichlor.	.10
Tr. cantharid.	20.00
Spts. vini. rect.	80.00
Aq. rosarum. ad	200.00
M. Sig.: Lotion for scalp.	

To this, if indicated, a small proportion of oil may be added; the amount should rarely exceed 10 gm. in 200.

Resorcin is credited with producing a slight change in the color of blond hair. For such the bichloride lotion is preferable.

For the crusting forms of seborrhœa of the face and body, sulphur and resorcin are the remedies *par excellence.* Crusts should be removed by softening with oil and the careful use of water in which some borax has been dissolved. A pomade containing the above-mentioned drugs in suitable proportions may then be applied. Care must be taken in treating these cases that an acute dermatitis be not awakened. Should this happen, soothing measures must be used until the skin will permit further treatment of the original condition.

The *crusta lactea* in infants may be avoided in the vast majority of cases by a gentle but thorough cleansing of the child after birth. Should characteristic crusts develop later, a mild course of treatment following the lines mentioned above will bring about a cure.

The *verruca senilis,* or the pre-epitheliomatous seborrhœa of advancing years, requires careful watching for epitheliomatous developments. For the purpose of keeping the lesions soft, a mild pomade may be used. Cauterization is not advisable. If an extensive removal of the lesions be contemplated, resource must be had to *x*-ray therapy.

The two forms of Kaposi—*ichthyosis sebacea* and *pityriasis tabescentium*—require careful attention to the general nutrition of the patient, and the use of such ointments locally as will keep the skin soft and pliable.

PROGNOSIS.—The outlook for *seborrhœa oleosa* is dependent largely upon the strictness with which the patient carries out general instructions. *Seborrhœa sicca* of the scalp requires faithful treatment; if it is neglected, recurrence is probable; alopecia is generally permanent. The seborrhœas of the body are more easily controlled. The same is true of *crusta lactea* in infants. *Pre-epitheliomatous seborrhœa* is not so unfavorable since the introduction of the x-ray as a therapeutic measure in skin diseases. In Kaposi's forms the prognosis is undoubtedly grave.

Stelwagon calls attention to the frequent presence of hypertrichosis in those suffering from seborrhœa of the face. It should be remembered that the prolonged use of greasy applications is certain to add to the hair growth already present. *Ernest Lewis McEwen.*

SECRETIN.—It has long been known that the introduction of acid into the intestine (duodenum) provokes a flow of pancreatic juice. Popielski and Wertheimer and Lépage demonstrated that this result may follow even after the exclusion of nervous impulses from without these organs. The secretion has therefore been attributed to the effects of a peripheral reflex brought about independently of central nervous influences. Since this flow of pancreatic juice will apparently follow even after inhibition of all nervous elements by atropine, it has been ascribed to a chemical stimulation of the pancreatic gland cells. The name *secretin* has been given by Bayliss and Starling to the chemical substance, as yet not isolated and identified, which is the direct stimulant to the gland. Wertheimer does not believe, however, that secretin acts independently of any nervous relations; and like Pflüger he points out the difficulty in obtaining complete isolation of an organ from nervous elements. The specific substance is obtained by extracting the mucous coat of the jejunum with 0.4 per cent. HCl. A very small portion of such an extract injected into the circulation suffices to call forth a copious flow of pancreatic juice. The active agent is not the HCl, since this alone does not provoke secretion when introduced directly into the blood current. Secretin is not present as such in the intestine, but is formed from a precursor, *prosecretin*, by the action of the acid. The transformation of prosecretin into secretin can also be accomplished by the action of boiling water or salt solution. The acid secretin solutions can be boiled and neutralized without undergoing a diminution in activity. The active substance thus does not behave like an enzyme. It is not precipitated by alcohol or ether; and presumably further investigation will demonstrate it to be a definite chemical individual of relatively low molecular weight. Camus has found that secretin may be formed in all animals examined by him, viz., the dog, cat, rabbit, guinea-pig, pig, pigeon, and frog. *Lafayette B. Mendel.*

REFERENCES.

Bayliss and Starling: Centralblatt für Physiologie, 1901, xv., p. 682.—Proceedings of the Royal Society, London, 1902, lxix., p. 352.—Journal of Physiology, 1902, xxviii., p. 325.
Camus and Gley: Comptes rendus de la Société de Biologie, 1902, liv., pp. 242, 465.
Wertheimer: *Ibid.*, 1902, liv., pp. 472, 474.
Pflüger: Archiv für die gesammte Physiologie, 1902, xc., p. 32.
Camus: Comptes rendus de la Société de Biologie, 1902, liv., pp. 442, 513.
Herzen and Radzikowski: *Ibid.*, 1902, liv., p. 507.
Fleig: Centralblatt f. Physiologie, 1903, xvi., p. 681.

SECRETION, PHYSIOLOGY OF.—By secretions we mean the products of the activity of gland cells. Usually these products are liquid or semi-liquid in character. In recent years a distinction has been made between internal and external secretions. By the latter term we designate a secretion that is discharged upon a free epithelial surface that communicates with the exterior. Such, for example, are the secretions of the glands of the skin or of the mucous membrane of the alimentary or respiratory tract. The name internal secretion is used to designate those secretions that are discharged into the blood or the lymph. The term is used especially in connection with the so-called ductless glands, such as the thyroids or the adrenal bodies, but it happens that in some cases a gland possessing a duct may form an internal as well as an external secretion. A good example of this combination of functions is found in the case of the pancreas. The external secretion of the pancreas, the pancreatic juice, is emptied through its duct into the duodenum, while its internal secretion, of an unknown character chemically, is discharged into the blood. As will be described later, the two secretions in this case are formed in all probability by two different kinds of gland cells. It will be convenient to consider these two kinds of secretion separately.

EXTERNAL SECRETIONS.

The composition of the external secretions varies greatly, but in general we may say that they consist of water, inorganic salts, and certain organic constituents. The organic elements in the secretions have aroused the greatest interest since they may be characteristic of the secretion. They are found in some instances (for example, the urea of the urine) preformed in the blood, and the function of the gland cell is a selective one, picking out this particular constituent and discharging it into the lumen of the gland. In other cases the organic element is not present in the blood or lymph, and must therefore be formed within the substance of the gland cell. In both cases there is a general agreement, speaking broadly, that the gland cells take an active part in the secretion and that the production or elimination of the organic products involves the expenditure of energy on the part of these cells. We picture this energy as dependent upon the chemical changes, the metabolism within the gland protoplasm, and naturally the character of these changes may vary greatly. General theories of secretion have concerned themselves chiefly with the physiological mechanisms by which the secretion is excited, and the means by which the inorganic constituents of the secretion are produced, whether in response to purely physical forces such as filtration, osmosis, and diffusion, or by means of unknown activities of the living protoplasm. The general nature of the theories proposed and the modifications suggested for the different secretions can be given best by describing the physiology of the most important secretions.

SECRETION OF THE SALIVARY GLANDS.—Under the designation salivary glands we must include all the glands whose ducts open into the mouth cavity and whose secretions contribute to the formation of the saliva. Ordinarily, however, the term is applied to the three large pairs of glands, the parotid, the submaxillary, and the sublingual. The duct of the parotid, duct of Stenson, opens opposite the second molar tooth of the upper jaw; the duct of the submaxillary, duct of Wharton, opens at the side of the frænum of the tongue; the duct or rather ducts of the sublingual, open into the floor of the mouth and are usually known as the ducts of Rivinus; although in some animals, and sometimes it is said in man, one of these ducts, the duct of Bartholin, may be especially conspicuous and runs parallel with the duct of Wharton. The portion of this gland which empties into the mouth by the duct of Bartholin is designated by Ranvier by the separate name of the retrolingual gland. Histologically these large glands show certain differences in structure. The secreting cells of the alveoli may belong either to the albuminous or to the mucous type. In the former the cells are relatively small and densely granular in appearance, so that in fresh sections of the living gland the outlines of the individual cells cannot be distinguished readily. In the mucous type the secreting cells are larger and much clearer. In the living condition they present a homogeneous ground-glass appearance, but on appropriate treatment display a few large granules much less opaque than those in the albuminous cells. These two types of cells may be found in the same gland or even in the same alveolus; but, speaking generally, the parotid in man contains chiefly albuminous cells, and the submaxillary and especially the sublingual, chiefly mucous cells. This difference in histological structure is associated with a chemical difference in the secretion. The saliva from the submaxillary and the sublingual contains mucin and is thick and stringy, while the parotid saliva, although it contains some albumin, is free from mucin and is thin and limpid. Each of these glands receives a double nerve supply one set of fibres coming from the cervical, sympathetic and the other directly from the cranial nerves. The parotid receives its cranial nerve fibres by a very indirect path. In the dog in which their course has been worked out experimentally the fibres arise from the brain in the glossopharyngeal, pass into the tympanic branch of this nerve, also known as the nerve of Jacobson, and thence to the small superficial petrosal through which they reach the otic ganglion. In branches from this ganglion they pass to the auriculo-temporal branch of the inferior maxillary, and thence by several small branches to the gland. This path is supposed to involve two nerve units, the first which may be designated as the cranial or preganglionic neurone ending in the otic ganglion; the second, the sympathetic or postganglionic neurone, arising in the otic ganglion and ending in contact with the gland cells. The cranial fibres for the submaxillary and sublingual are found in the chorda tympani nerve. They arise with this nerve from the facial and pass with it to join the lingual branch of the inferior maxillary. After running in the lingual for a short distance the secretory (and vaso-dilator) fibres branch off in several small strands which pass toward the hilus of each gland following the course of the ducts. This path also involves two nerve units. The cranial or preganglionic neurone ends in nerve cells of the sympathetic type, which, in the case of the submaxillary, are found in its hilus or along the duct, while in the sublingual they form a collection, conspicuous enough to be seen with the eye, and located in the angle made by the strands of fibres as they leave the lingual nerve. This collection of nerve cells was formerly designated as the submaxillary ganglion, but since Langley has shown by the use of the nicotine method that they are intercalated in the course of the nerve path to the sublingual gland, it is more appropriately named the sublingual ganglion. These sympathetic cells constitute the second or postganglionic neurone which ends in the gland cells. The sympathetic nerve supply to the three glands is in general the same. The fibres emerge from the spinal cord in the upper thoracic nerves, pass over to the sympathetic chain in the corresponding rami communicantes, ascend in the neck in the cervical sympathetic, and terminate, so far as the first neurone is concerned, in the cells of the superior cervical ganglion. From this ganglion sympathetic neurones pass out in strands that form a plexus in the coats of the arteries supplying the glands. These fibres are usually stimulated while in the cervical sympathetic or by applying the electrodes to the superior cervical ganglion.

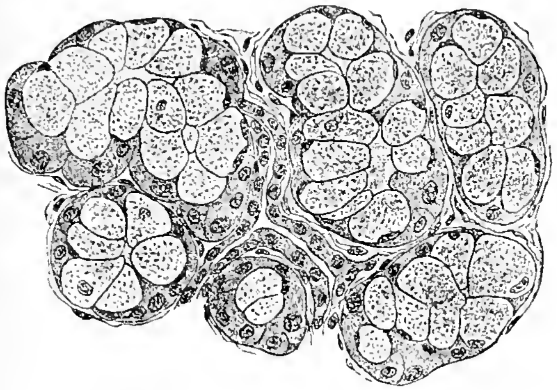

FIG. 4164.—A Section Through the Human Sublingual Gland. (Böhm-Davidoff.)

Composition of the Saliva. The saliva of the mouth consists, or may consist, of the mixed secretions from the large salivary glands together with the secretions of the small unnamed glands of the buccal mucous membrane. In addition to accidental constituents, such as epithelial cells, it contains mucin, a small proportion of albumin, an amylolytic enzyme known as ptyalin, and inorganic salts. The saliva of each gland may be collected separately by inserting a cannula into its duct. By this means it can be shown that the secretion of each gland has its own characteristics, the parotid saliva, for instance, being free from mucin, while the sublingual and the submaxillary saliva have varying proportions of this substance, but contain little or none of the ptyalin. Experiments by Pawlow indicate that the secretion of each gland may be excited differently under normal conditions. He found that in dogs the submaxillary secretion is readily excited by sapid bodies in the mouth, or by the sight or smell of food, while the flow of parotid saliva is especially marked when dry substances are placed in the mouth.

Secretory Nerves.—The discovery that these glands are supplied by secretory nerve fibres, we owe to Ludwig. In 1851 he found that stimulation of the lingual nerve causes a flow of saliva from the submaxillary gland. Bernard showed that the fibres in question belong to the chorda tympani, and discovered in addition that during the stimulation of this nerve there is a greater flow of blood through the gland. We now know that the chorda tympani conveys both secretory and vaso-dilator fibres to the submaxillary and sublingual. The natural suggestion that the increased secretion on stimulation of this nerve is due to the greater blood flow has been disproved by a series of experiments. It has been found, for instance, that after administration of atropine stimulation of the nerve is followed by a vascular dilatation without any secretion, and, on the other hand, that injection of quinine may cause a dilatation of the vessels without a secretion, which, however, is readily obtained if the nerve is stimulated. Evidently the glands possess true secretory fibres capable of starting and maintaining a secretion from the gland cells. It was found, subsequently, that stimulation of the cervical sympathetic nerve gives a small flow of saliva which is characterized by its large amount of solids and by the fact that during the stimulation the blood flow through the gland is diminished in consequence of the simultaneous stimulation of vaso-constrictor fibres. Corresponding to these facts, Heidenhain found for the parotid gland that stimulation of the cranial nerve fibres in the nerve of Jacobson, gives an abundant secretion of thin saliva, while stimulation of the cervical sympathetic gives little, or, in the case of the dog, no secretion. In the latter case, however, it was discovered that stimulation of the sympathetic fibres has an effect on the gland, although no visible secretion is produced. Sections of the gland, for instance, after

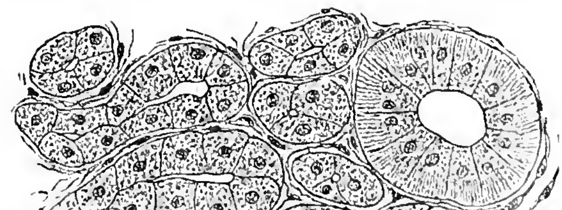

FIG. 4165.—A Section Through the Human Parotid Gland. (Böhm-Davidoff.)

such a stimulation show that the lumina of the alveoli and the ducts are distended with secretion, and if the cranial fibres are stimulated simultaneously with or subsequently to that of the sympathetic fibres, the secretion that forms instead of being thin and watery is thick, and on chemical examination shows a much larger percentage of solid matter. We are justified therefore in stating for all the salivary glands that each receives a double nerve supply, and that the sympathetic saliva, as it is called, is much smaller in amount and much richer in solids than that obtained by stimulation of the cranial fibres, the chorda or tympanic saliva. The physiological significance of this double supply of secretory fibres is not understood at present. The evidence that we have shows that reflex stimulation of these glands takes place through the cranial fibres alone, and, on the other hand, that injury to or experimental section of the cranial fibres is followed by a loss of function of the glands. In what way the sympathetic nerve supply participates in their functional activity is not explained.

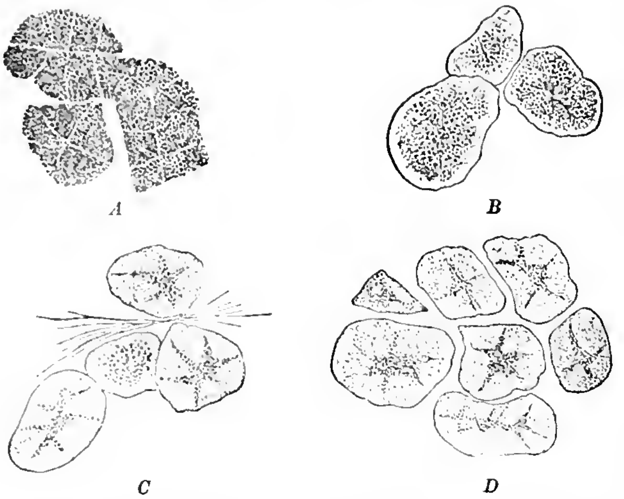

FIG. 1166. Parotid Gland of the Rabbit in a Fresh State, showing Portions of the Secreting Tubules. *A*, In a resting condition; *B*, after secretion caused by pilocarpine; *C*, after stronger secretion, pilocarpine and stimulation of the sympathetic; *D*, after long-continued stimulation of the sympathetic. (Langley.)

Relation of the Secretion to the Strength of the Stimulus.—As in the case of the neuromuscular apparatus, it is found that the extent of the secretion varies with the intensity of the stimulus, or, in other words, we can get a series of submaximal secretions by varying the stimulation. The experiments upon this relationship have been made in connection with the cranial nerve supply. According to Heidenhain, the quantity of water and the percentage amount of inorganic salts increase as the stimulus increases up to a certain maximum, while the percentage amount of organic substances shows a more variable relation. If the gland is unfatigued at the beginning of the experiment the proportion of organic substances increases rapidly as the stimulus grows, but the maximum reached is not maintained if the stimulation is continued. On the contrary, continued stimulation may give a saliva containing less and less of the organic constituents, although the water and salts may continue to show a maximal proportion. The absence of parallelism under these conditions led Heidenhain to conclude that the conditions controlling the secretion of the organic material are different from those governing the formation of the water and salts. This conclusion is expressed in his theory of salivary secretion which will be mentioned briefly below.

Normal Mechanism of the Secretion of Saliva.—The secretion of saliva may be excited reflexly by stimulation of various sensory nerves, particularly those of the mouth. The action in this case is, of course, reflex, and, as said above, the efferent path to the glands is through the cranial fibres, for if these fibres are cut a reflex secretion cannot be obtained. Although this reflex secretion may be obtained by electrical stimulation of the sensory nerves of the mouth, it may be produced most easily and abundantly by the chemical stimulation caused by sapid substances. We may assume therefore that under normal conditions the sapid substances of the food stimulate the sensory endings of the lingual and glossopharyngeal nerves in the mouth cavity and start afferent impulses to the medulla which reflexly stimulate the motor cells giving origin to the cranial secretory fibres. We have abundant evidence that the same motor cells may be stimulated reflexly through other sensory paths. The idea of food, for instance, or the sight or smell of agreeable food to a hungry person may make the mouth water, and, on the other hand, gastric irritation may give the same reaction, as is shown by the disagreeable flow of saliva that accompanies an attack of nausea. Under normal conditions the large salivary glands in man secrete only when reflexly stimulated; the secretion, in other words, is not continuous but is dependent on stimulation through the nerves. Since, however, the mouth cavity is always more or less moist even in sleep, it is probable that there is a continuous secretion from the smaller unnamed glands embedded in the buccal mucous membrane.

Histological Changes in the Gland during Secretion.—Much experimental work has been done upon the changes in microscopic appearance of the gland cells during secretion. This work was of great importance in proving that the gland cells take an active part in the secretion. Sections made of the fresh or of the hardened gland show that after prolonged secretion the gland cells are smaller than in the resting state. Moreover, in the gland at rest granules are formed within the cells, and during active secretion these granules slowly disappear. The most interesting observations are those made by Langley on sections from the living gland. He finds that in the parotid gland the cells during the resting stage are densely granular throughout. As the gland is made to secrete the granules begin to disappear first from the outer border, and after prolonged stimulation they may disappear almost entirely, the few that are left being clustered round the margin of the cells bordering on the lumen. In the mucous glands the granules are larger and clearer and much less numerous. They swell and disappear on the addition of water, and it may be assumed that they represent the mucin found in the secretion, or a preparatory material which during secretion is dissolved by the water formed, and is thus discharged from the cell.

Action of Atropin, Pilocarpin, and Nicotin on the Salivary Glands.—The three alkaloids named exert an interesting and typical action on the secretion of the salivary glands. Atropin injected into the circulation or into the gland directly through its duct will destroy its power of secretion. The gland cannot be made to secrete either by direct or by reflex stimulation. Inasmuch as the gland refuses to secrete when the stimulus is applied directly to the hilus, we may conclude that the action of the drug is either upon the gland cells themselves or upon the ending of the nerve fibres in their cells. Since stimulation of the sympathetic nerve supply may produce the usual flow of sympathetic saliva, we may conclude that the gland cells are still functional, and that the effect of the atropin is to paralyze the endings of the cranial secretory fibres. Pilocarpin or muscarin has a directly opposite effect. In proper doses each sets up a continuous secretion of saliva, and this effect may be prolonged by repeated injections of the drugs. It is assumed that these alkaloids stimulate chemically the endings of the nerve fibres in the gland cells. Atropin and pilocarpin exhibit toward these and many other glands the same antagonistic action that they exert upon the inhibitory nerve fibres of the heart. The action of nicotin has been studied chiefly by Langley. He finds that injection of this alkaloid causes first a slight stimulating effect followed soon by a temporary paralysis of both the cranial and the sympathetic fibres. After the stage of paralysis is reached it is found that stimulation of the second or post-ganglionic neurone of each path will give the customary secretion. It would seem from this result that the nicotin paralyzes the connection between the first or pre-ganglionic and the second or post ganglionic neurone. This action of nicotin takes place for other kinds of nerve fibres in which the path involves the union of a cerebro-spinal with a sympathetic neurone.

Paralytic Secretion.—After section of their cranial nerve supply, chorda tympani and nerve of Jacobson, the salivary glands give a slow continuous secretion which may keep up for several weeks. Eventually, however, the glands undergo atrophy and lose their normal structure in spite of the fact that they still possess a connection with the central nervous system by way of the sympathetic nerve fibres. This paralytic secretion occurs only when the cranial secretory fibres are destroyed, injury to the sympathetic supply alone has no such effect. The cause of the continuous secretion is not evident. Langley is inclined to the view that it is dependent upon a continuous excitation of the nerve cells within the gland, the post-ganglionic neurone. Section of the chorda, or the nerve of Jacobson, would be followed in a few days by a total degeneration of the pre-ganglionic neurone, but the second or post-ganglionic neurone would probably retain its structure and irritability for some time. Langley's view is not very satisfactory, inasmuch as it throws no light on the nature and origin of the supposed excitation.

Theory of Salivary Secretion.—Some of the constituents of saliva, *e.g.*, mucin and ptyalin, do not occur in the blood and must therefore be formed within the gland cells as a result of a special metabolism. The histological changes in the gland cells during secretion corroborate this conclusion. Heidenhain has suggested the hypothesis that the metabolism giving rise to the organic products in the secretion is under the control of a special variety of the secretory fibres for which he proposed the name of trophic fibres. A second set of fibres which he designated as secretory fibres proper control the formation of the water and salts. The action of the trophic fibres is readily understood. Like the motor fibres to the muscles, their impulses set up katabolic changes which result in the formation of mucin, ptyalin, and the peculiar proteid found in the secretion. The action of the fibres supposed to control the production of the water and salts is more difficult to explain. When the gland is at rest there is no flow of water through the gland cells from the blood and lymph. In this condition therefore the protoplasm of the cells is impermeable to the water and salts. When the secretory fibres are stimulated the flow begins promptly, and we might suppose that the action of the impulses conveyed by the nerve fibres causes a physical alteration in the gland cells, in consequence of which they become permeable to the water and salts. Since, however, under continuous stimulation of the secretory fibres the hydrostatic pressure in the occluded ducts may exceed the pressure in the capillaries and arteries, it is evident that mere filtration through the cells will not explain the flow of water. There must be some substance within the gland cells possessing a high osmotic pressure and capable therefore, if we may use the expression, of attracting the water. Heidenhain makes such an hypothesis. He assumes that normally the gland cell at rest contains water under tension in consequence of the osmotic pressure of its substance, but that this water cannot escape into the ducts in consequence of the impermeability of the limiting layer of the cells bordering upon the lumen of the alveolus. The effect of the secretory impulses is to alter the structure of this limiting layer so as to make it permeable, and the stream of water and salts will continue as long as this permeability is maintained. It would seem necessary for the completeness of the hypothesis to assume that the border of the cells resting upon the basement membrane is constantly permeable to the water, but only in one direction, that is, from the lymph toward the interior of the cells. Langley is inclined to believe that the hypothesis of two kinds of nerve fibres is unnecessary, and that it is preferable to assume that one and the same set of fibres may cause the katabolic changes leading to the formation of the organic products and at the same time control the flow of water and salts. On the histological side it may be said that there is no indication of two kinds of fibres or two sets of nerve-endings in the gland.

THE SECRETION OF THE PANCREAS.—The pancreas has much the same general histological structure as the salivary glands. The alveoli contain granular cells belonging to the albuminous type, but characterized in the resting stage by a clear non-granular zone on the basal side. The histological changes during secretion are especially distinct and resemble those described for the parotid gland. During active secretion the size of the cells is diminished, the granules disappear from the basal side, and the non-granular zone extends farther toward the inner margin of the cells. In the resting stage, on the contrary, granules are again formed within the cells, and the non-granular zone is reduced in size. Physiological evidence indicates that the granules within the cells consist of a preparatory material from which the several enzymes of the secretion are formed, and they are therefore designated usually as zymogen granules. In addition to this type of cell, which is undoubtedly responsible for the formation of the pancreatic secretion, the pancreas contains an entirely different kind of cell found in groups that are known as the islands of Langerhans. These cells seem to be connected with the production of the internal secretion of the pancreas, and will be described more fully under that head. The chief duct of the pancreas in man, the duct of Wirsung, opens into the duodenum together with the common bile duct at a distance of 8–10 cm. below the pyloric orifice. The nerves of the pancreas are derived from the solar plexus, but physiological experiments indicate that ultimately the gland receives nerve fibres from two sources, the vagus and the sympathetic nerves.

Composition of the Secretion.—The pancreatic secretion is an alkaline liquid, which in some animals is clear and limpid and in others thick and glairy. From a physiological standpoint the most important constituents are the enzymes of which three or four have been described. These are trypsin, a proteid-splitting enzyme; lipase, a fat-splitting enzyme; amylopsin, a starch-splitting enzyme, and in some animals chymosin, a milk-curdling enzyme. The strong alkaline reaction of the secretion is due to sodium carbonate. A number of organic substances may also be present in small amounts, such as albumin, peptones, leucin, tyrosin, xanthin, soaps, and fats.

Secretory Nerve Fibres.—Direct observations on animals like the dog, in which the processes of digestion are not continuous, have shown that the flow of pancreatic juice is intermittent and related to the periods of digestion. This fact would indicate that its secretion, like that of the salivary glands, is caused by reflex stimulation. Direct experimental attempts to prove the existence of secretory fibres were unsuccessful until the beautiful work done by Pawlow and his pupils. These workers found that stimulation of the peripheral end of the cut vagus or splanchnic under proper conditions causes a secretion of the juice. The latent period between the stimulation and the beginning of the flow from the pancreatic duct is quite long, from three to five minutes, and has been explained on the hypothesis that the nerves stimulated carry secretory as well as inhibitory fibres, both of which would be stimulated by the method used. The existence of inhibitory fibres is made probable also by the fact that when a secretion is in progress stimulation of the peripheral end of the cut vagus may bring the flow to a standstill. If the existence of both secretory and inhibitory fibres to the gland be accepted, recent work, which will be described in the following paragraph, makes it probable that these nerve fibres have only a regulating control over the secretion. Even when all the extensive nerve connections are severed the gland may secrete in connection with the digestive processes. Unlike the salivary gland the secretory fibres from the central nervous system are not apparently essential to secretion, but regulate it after the manner that the extrinsic nerves regulate the movements of the stomach or the heart.

Normal Mechanism of the Pancreatic Secretion.—After Pawlow's discovery of the secretory fibres to the pancreas the natural supposition was that the mechanism of secretion is analogous to that of the salivary glands, that is, some peripheral sensory stimulus in the intestines stimulates these secretory fibres reflexly. It was supposed, in fact, that the acid chyme ejected from the stomach acts upon the sensory fibres of the mucous membrane of the duodenum and sets going the normal reflex that causes the pancreatic secretion. This view was founded upon the fact, demonstrated by several observers, that acids applied to the duodenal membrane will start the pancreatic secretion. Popielski, however, asserts that the same reaction is obtained when the vagi and sympathetic are cut on both sides, so that if the reaction is effected by a nervous reflex this reflex does not involve the central nervous system. More recently an entirely new light has been thrown upon the subject by some most interesting investigations made by Bayliss and Starling. These authors find in the first place that acid (0.4 per cent. HCl) placed in the duodenum or jejunum will cause a secretion of the pancreatic juice when the loop of the intestine used (jejunum) has all of its nervous connections severed. Moreover, if the mucous membrane from the duodenum or jejunum is scraped off and treated with the acid, the solution so obtained when injected into a vein causes an active secretion by the pancreas, although the acid alone or the extract of the mucous membrane without treatment by acid is ineffective. The authors apparently have proved that normally the acid from the stomach or the acid formed (lactic) during digestion acts upon the mucous membrane and produces a substance which they designate as secretin. The secretin is absorbed, carried to the pancreas, and either stimulates the pancreatic cells directly, or, possibly, acts upon the intrinsic nerves of the gland. Secretin is not an enzyme; boiling or the action of absolute alcohol does not destroy it. According to this new and interesting discovery the secreting nerves play no necessary part in the normal mechanism of pancreatic secretion, and if this turns out to be the case we shall have to attribute to them merely a regulating influence upon the secretion. The flow of pancreatic juice caused by secretin is characterized by the fact that it does not contain an active trypsin, but recent experiments go to indicate that any normal flow of pancreatic juice possesses the same peculiarity. It would seem that in the normal secretion the trypsin is contained in the form of zymogen or pro-enzyme, and that it becomes converted to the active enzyme when it comes in contact with the intestinal mucous membrane. The conversion is made by the peculiar enzyme found in the intestinal secretion by Schepowalnikow and to which Pawlow has given the name of enterokinase (see heading of Intestinal Secretion). The normal sequence of events, then, in the secretion of pancreatic juice is, first, the formation of secretin by the action of the acid of the gastric juice on the mucous membrane of the small intestine; second, the action of this secretin, after absorption into the blood, upon the pancreatic cells; third, the conversion of the zymogen of the secretion into the active enzyme by the enterokinase of the succus entericus. This last act may be necessary only for the trypsin.

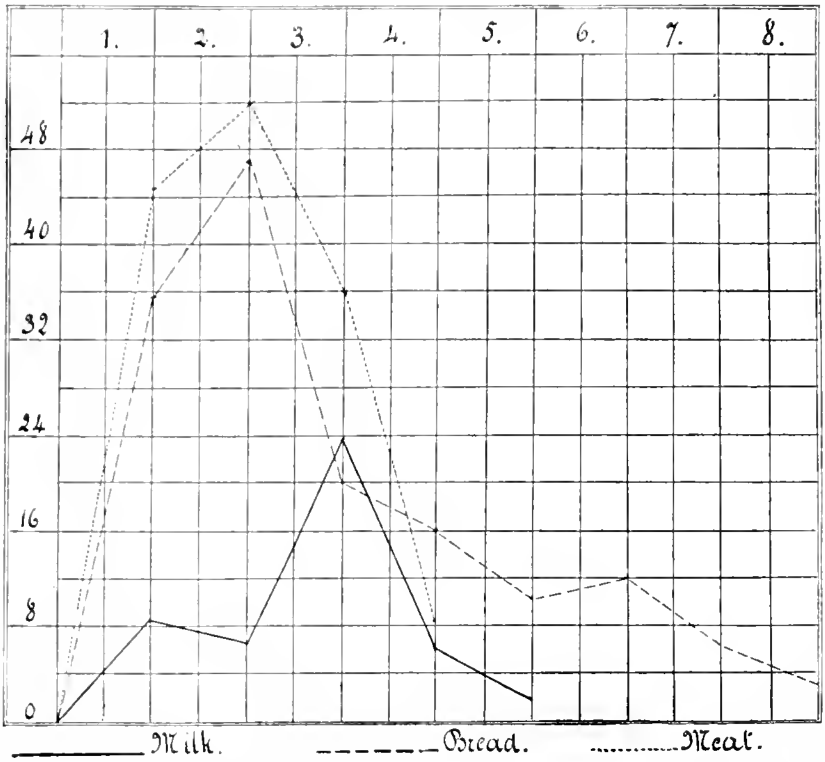

FIG. 4167.—Three Curves showing the Secretion of Pancreatic Juice upon a Diet (1) of 600 c.c. of milk; (2) of 250 gm. of bread; (3) of 100 gm. of meat. The divisions along the abscissa represent hours after the beginning of the meal; the figures along the ordinate represent the quantity of the secretion in cubic centimetres. (Walter.)

The curve of secretion of the pancreatic juice has been determined with care in the case of dogs. According to experiments made upon animals with a pancreatic fistula, the secretion begins shortly after the introduction of food into the stomach, and increases in volume to a maximum, which is reached between the first and the third hours. The curve then falls again more slowly to the base line, although there may be a second smaller rise from the fifth to the tenth hour. The general character of the curve is shown by the accompanying figure (Fig. 4167).

Relation of the Composition of the Secretion to the Character of the Food.—The work from Pawlow's laboratory indicates that the composition of the secretion varies somewhat with the character of the food, and that the variation has the appearance of a beneficial adaptation. That is, proteid foods cause in some way the secretion of a juice rich in proteolytic enzyme, and oily foods a secretion with an increased amount of lipase. This statement needs further experimental confirmation. If correct it shows a kind of biological reaction between the food and the secretion which it is difficult to explain satisfactorily. Pawlow maintains that similar specific stimuli in the food influence or control the composition of the gastric and salivary secretions. We have here a relationship which, when more fully investigated, may prove to be of much practical importance in dietetics.

Secretion of the Gastric Glands.—The accepted method of obtaining the gastric secretion dates from the famous work of Beaumont. His use of an accidental fistula in the case of St. Martin indicated at once that similar fistulas might be established upon animals for experimental purposes. Operations of this kind were performed first by Basson and by Blondlot in 1842, and were used subsequently by many investigators. At first, metal cannulas were placed in the fistulous openings to facilitate the collection of the secretion, but modern surgical technique has enabled experimenters to avoid this clumsy and often injurious device by converting a portion of the reflected mucous membrane into a tube opening on the surface of the skin. With a fistula of this character the stomach contents cannot escape to the exterior and yet can be drawn off at any time by the insertion of the catheter. The difficulty in such experiments is that the secretion becomes contaminated with the food, and its analysis is therefore difficult or impossible. Heidenhain obviated this difficulty and opened the way to successful investigation of the secretion by his device of cutting off a portion of the stomach, especially the fundic end, so as to form an isolated sac opening to the exterior. The remainder of the stomach was closed off by sutures so as to maintain the continuity of the alimentary canal. In such animals the food does not enter the isolated fundic sac, but nevertheless starts a secretion in it which may be obtained through its fistulous opening entirely free from mixture with the food. By this means the quantity, rate of flow, and composition of the secretion may be studied satisfactorily under various conditions. This operation was subsequently improved by Pawlow, who introduced a variation by means of which the nervous supply, as well as the vascular supply of the isolated sac, was maintained intact. The character of this operation is shown in the accompanying diagram (Fig. 4168). Pawlow devised also a secondary operation which in his hands has led to important results. In this operation the œsophagus was divided in the throat, and both upper and lower ends were brought to the surface of the skin to form permanent fistulas. After such an operation the food that the animal chewed and swallowed did not enter the stomach, but escaped to the exterior through the upper œsophageal fistula. By this means the effect of the act of eating upon the gastric secretion was determined. It was found that a fictitious meal of this character causes an abundant secretion of gastric juice in spite of the fact that none of the food enters the stomach, and this fact in turn led to the discovery of secretory nerves to the gastric glands.

Composition of the Secretion.—In addition to the mucus formed by the columnar epithelium on the surface of the mucous membrane, the secretion as collected contains water, inorganic salts, hydrochloric acid, pepsin, rennin, and usually a trace of peptones. The amount of the hydrochloric acid may be as great as 0.56 per cent. in the dog, but in the human gastric juice is usually given as 0.2–0.3 per cent. The secretion does not decompose easily—in fact, specimens may be kept for long periods without undergoing any putrefaction and without losing their digestive action. Evidently the secretion has marked antiseptic properties which are doubtless due to the free hydrochloric acid it contains. There has been considerable discussion as to the composition of the secretion from different parts of the stomach. The marked difference in histological structure between the glands of the cardiac and those of the pyloric end would suggest that their respective secretions might vary in character. According to most observers, the pyloric mucous membrane, when isolated from the rest of the stomach, gives a secretion that is alkaline in reaction but contains some pepsin and rennin. The hydrochloric acid, therefore, must be formed in the glands of the cardiac end. As far as is known, the glands of the pyloric end add nothing that is characteristic or essential to the secretion.

Nervous Control of the Secretion.—Much experimental work has been done to ascertain whether or not the flow of gastric juice is under the control of secretory nerves. The earlier experiments were inconclusive and need not be recalled, since in recent years Pawlow has obtained positive evidence of secretory nerve fibres. With the aid of his pupils and co-workers he has demonstrated the following facts: When a dog is given a fictitious meal by means of the œsophageal fistulas described above, there is a flow, often an abundant flow, of gastric juice, although no food gets into the stomach. If, however, the two vagi are cut previously, the fictitious meal does not cause a secretion. Evidently, therefore, the act of eating must occasion a reflex secretion of gastric juice, and the efferent paths in this reflex must pass to the stomach by way of the vagi. By the same means it was shown that the sight or smell of food will cause a reflex secretion in a hungry animal. After these preliminary experiments had indicated the existence of secretory fibres positive proof of their existence was obtained by direct stimulation of the peripheral end of a cut vagus. Under proper conditions of stimulation a flow of gastric juice can be obtained in this way, although the latent period of the secretion is unusually long, from four to ten minutes.

Normal Mechanism of the Gastric Secretion.—Beaumont and later observers held that mechanical irritation of the gastric mucous membrane is capable of provoking a secretion, and that the food therefore acts in part, especially in the beginning of digestion, as a mechanical stimulus. Pawlow, however, states positively that this belief is erroneous, and that mechanical stimuli are entirely ineffective. Heidenhain gave convincing evidence that the normal stimulus is a chemical one derived from the food, and this fact was afterward confirmed by the more detailed and satisfactory experiments made by Pawlow, who has given us a nearly complete account of the means by which the flow of gastric juice is started and maintained during digestion. According to this author, the first flow of the gastric juice is caused reflexly by the sight or smell of food, or more especially by the act of eating, and constitutes what he calls the psychical secretion. This term is used because the sensory nerves stimulated are the gustatory, olfactory, or optic nerves and the reflex is accompanied by the conscious and agreeable sensations associated with eating. The term seems to imply also that the reflex arc involves the cerebral cortex, and is thence continued to the secretory fibres in the

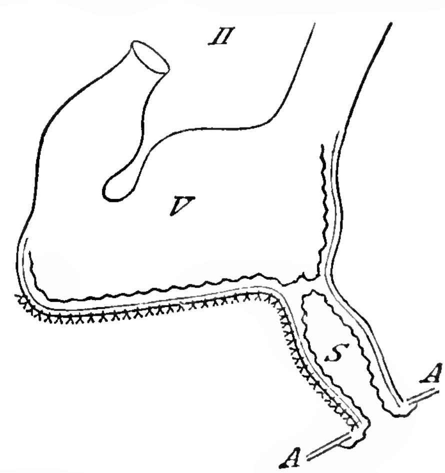

Fig. 4168.—Figure from Pawlow to show the Operation of Forming an Isolated Fundic Sac (S) and its Opening at the Abdominal Wall, A, A; V, cavity of the stomach.

vagus. The secretion produced in this way appears promptly, and under favorable conditions may be abundant in quantity. In one experiment in which the fictitious feeding was continued for several hours, it is stated that about 700 c.c. of pure gastric juice were obtained. A further flow of the secretion is caused by the action of the food upon the stomach itself. According to the experiments reported, there are some foods which contain substances capable of acting chemically upon the mucous membrane and arousing a flow of gastric juice, probably by a nervous reflex; such foods are the meats, meat extracts, milk, gelatin, and water. Other foods, such as bread or white of eggs, do not possess this power. If introduced into the stomach through a fistula without the animal's knowledge so as not to arouse a psychical

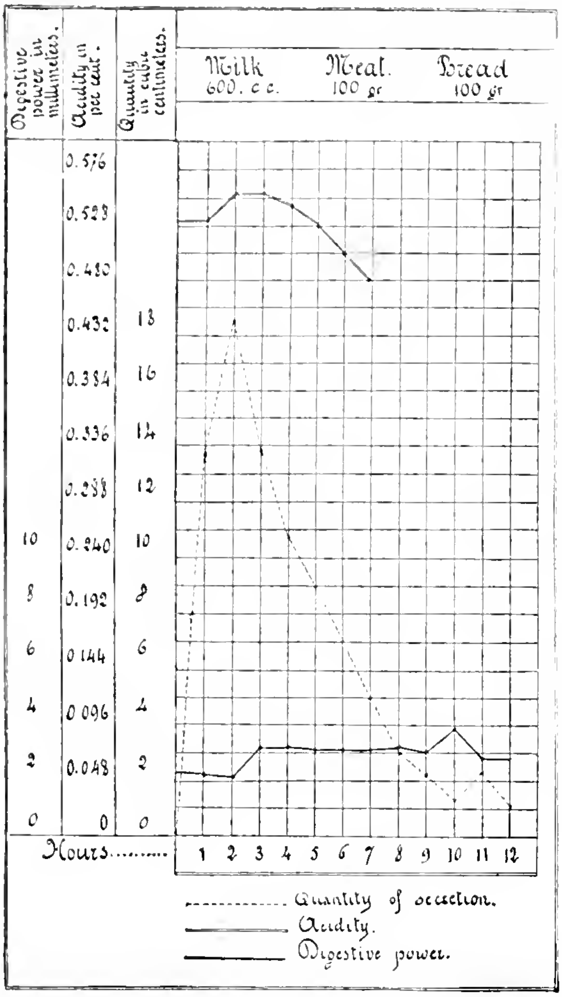

FIG. 4169.—Curve showing the Flow and Composition of the Gastric Secretion in a Dog Fed upon a Mixed Diet. (Klugine.)

secretion, they remain undigested. If, however, these foods are digested for a time they then acquire the power of stimulating a flow of gastric juice. Under the normal conditions of eating, such foods would first start a psychical secretion, and after they had begun to be digested by this secretion the flow would be maintained by the chemical stimuli developed from them in the process of digestion. These chemical stimuli upon which the flow of gastric juice depends mainly, which are present already formed in some foods and are developed in others by digestion, Pawlow groups under the general designation of secretogogues. He has not been able so far to ascertain their chemical nature. The dietetic value of meat extracts seems to lie largely in the fact that they contain much of these secretogogues and thereby favor the digestion of other foods.

Curve of Secretion and its Variation with the Character of the Food.—In its general features the curve of gastric secretion, so far as its quantity is concerned, resembles that of the pancreatic juice. The flow begins promptly after the act of eating, increases somewhat rapidly to a maximum, which in dogs fed on a mixed diet is reached at about the second hour, and then falls slowly toward zero as the stomach is emptied. The composition of the secretion during this period varies somewhat, the first flow being relatively weak in the two important constituents hydrochloric acid and pepsin. The illustration (Fig. 4169) gives an example of the way in which the secretion varies in a dog fed upon a mixed diet. Pawlow states that in a general way the quantity of secretion varies with the amount of food, a relation which is easily understood when we remember that the food itself supplies the stimulus for the secretion. The same worker has given some proof that the composition of the secretion is related to the composition of the food, and that it may be possible, when the relation has been more completely investigated, so to modify the food as to increase one or the other of its important constituents.

Histological Changes during Secretion.—The gastric glands in the cardiac end of the stomach contain two types of cells, the chief cells, and the cover or border cells. The latter vary in number in different regions, but in most cases form a discontinuous layer along the length of the tubes, and in the pyloric region they are lacking entirely. Histological and experimental evidence indicates that the chief cells are responsible for the secretion of the enzymes of the juice. During the resting stage these cells are filled with zymogen granules which disappear to a greater or less extent during active digestion. In accordance with this histological fact it is found that aqueous extracts of the mucous membrane in the resting stage may contain but little active pepsin or rennin, but that if this extract or the mucous membrane before extraction is treated with certain reagents such as dilute acids, an abundant yield of enzyme is obtained. In normal secretion the presence of the hydrochloric acid is sufficient in itself to convert the zymogen to enzyme, so that in the normal gastric juice no zymogen or proferment is found. With regard to the enzymes, therefore, we may assume that, as in the other digestive glands, they are formed within the cells as a result of their metabolism, that they are stored during rest as zymogen granules, and that, during or immediately subsequent to their secretion, the zymogen is changed to the active enzyme. With regard to the secretion of the acid prevalent theories are much less satisfactory.

Origin of the Hydrochloric Acid.—It is not known definitely which of the two cells found in the gastric tubules gives rise to the hydrochloric acid. The fact that the pyloric glands do not contain border cells and that their secretion is alkaline instead of acid suggests the view that these border cells are concerned in the formation of the acid, hence they are sometimes designated as oxyntic cells. No direct proof, however, has been furnished to show that these cells have anything to do with the production of the hydrochloric acid. On the chemical side also the mode of origin of the acid is still obscure. In general, it is believed that the hydrochloric acid must arise ultimately from the chlorides, especially the sodium chloride of the blood, and, according to one hypothesis, the acid is formed by a reaction between the chlorides and the phosphates of the blood according to the formula $NaH_2PO_4 + NaCl = Na_2HPO_4 + HCl$, the reaction being effected in some way through the activity of the gland cells. Another hypothesis is that the chlorides are decomposed by the mass action of the CO_2 formed in the metabolism of the gland tissue, and that the reaction is facilitated and the liberated base combined by an acid nucleoproteid known to exist in the gastric mucous membrane. Neither hypothesis helps us much to understand why the hydrochloric acid is formed only in this particular tissue and not elsewhere in the body. Acid indicators, such as acid fuchsin or a solution of ferric acetate and potassium ferrocyanide, show that the free acid is present only on the surface of the membrane and not within the substance of either the border cells or the chief cells. In view of this result it has been supposed that the acid is not actually formed within the cells, but in the secretion after its discharge; or if formed within the cells, it is eliminated as rapidly as it is formed, so that there is no accumulation within the cell itself as in the case of the zymogen. In accordance with this hypothesis it has been suggested that the hydrochloric acid is actually formed outside the mucous membrane from the chlorides of the stomach contents. This view assumes that the mucous membrane is impermeable to the chlorine ions, but permeable to the hydrogen ions, and that the latter passing through the mucous membrane from the blood, combine with the chlorine of the dissociated chlorides of the stomach contents. The hypothesis can scarcely be considered a probable one, since an abundant secretion of acid juice may be obtained by stimulation of the vagus nerve or in the isolated fundic sac when the stomach is entirely empty. Nor does the hypothesis help us to understand at all the part taken by the secretory cells. We must, in fact, confine ourselves at present to the general statement that the chlorine of the hydrochloric acid is derived ultimately from the chlorides of the blood.

Secretion of the Small Intestines—the Succus Entericus.—Although there is no question that the cells of the small intestine form enzymes which take an active part in the digestion of the food, there is some doubt whether these substances are actually discharged in a liquid secretion upon the inner surface of the intestine. Some mucus is formed and secreted by the epithelial cells, particularly those of the large intestine, but this mucus is not known to have any digestive action of a chemical nature. To ascertain whether a liquid secretion other than the mucus is formed in the small intestine, recourse has been had usually to experiments with a Thiry-Vella fistula. In this operation a loop of the intestines is isolated and the two ends are sutured into the skin of the abdominal wall, giving thus a portion of the intestine whose contents can be examined without possibility of contamination from the food or from the secretions of the pancreas or liver. Experiments of this kind agree in showing that an alkaline liquid forms in the loops, and indeed more abundantly in loops from the lower than in those from the upper portions of the small intestines. From experiments of this kind Pregl estimates that as much as three litres may be secreted in twenty-four hours from the entire intestine. The estimate must be received, however, with caution. Most observers agree that this liquid has no digestive action on proteids, but may contain an amylolytic enzyme. Extracts of the walls of the small intestine, on the contrary, give solutions that contain four or possibly five important enzymes. There are, first, the essential group of sugar-splitting enzymes capable of converting the disaccharides to the monosaccharides, namely, maltase which converts maltose to dextrose, invertase which converts cane sugar to dextrose and levulose, and possibly lactase which converts lactose to dextrose and galactose. In addition it has been shown recently by Cohnheim that these extracts contain a powerful proteid-splitting enzyme, erepsin, which splits the peptones and proteoses into simpler crystallizable substances—leucin, tyrosin, arginin, etc. Whether or not these enzymes are actually discharged into the intestines as a liquid secretion, they must be regarded as formed within the substance of the intestinal epithelial cells by a metabolism peculiar to these cells and analogous to the process of secretion in other glands. We must place the intestinal epithelium among the important digestive glands. Quite recently also the intestinal secretion from the upper part of the small intestine at least has been found to contain an enzyme-like substance, enterokinase, which, while it has no digestive action of its own, seems to be able to increase greatly the activity of the enzymes of the pancreatic juice. This effect is particularly marked in regard to the important proteolytic enzyme trypsin. Apparently this latter enzyme is secreted entirely in the form of a zymogen and can have no effect upon the food until it is "activated" by the enterokinase. We owe this important addition to our knowledge of intestinal digestion to Schepowalnikow, working under Pawlow's directions. This work has since been confirmed by several observers, and it is claimed by Delezenne that the enterokinase can be obtained also from leucocytes and lymph glands, and in the small intestine is found most abundantly in the mucous membrane overlying the Peyer's patches.

Secretion of Bile.—As in the case of the other glands many efforts have been made to demonstrate the existence of secretory fibres to the liver controlling the flow of bile. The secretion of bile is continuous, the metabolic processes in the liver cells leading to its formation and discharge are in progress at all times, although the velocity of the flow varies. Experimentally the velocity of the secretion may be increased or decreased, but the variations are so strictly parallel to the concomitant changes in the circulation that a causal connection between the two is rendered most probable. Stimulation of the spinal cord or the splanchnic nerves diminishes the flow of bile in proportion as it causes a diminution in the blood supply. Section of the splanchnics, on the other hand, which causes a dilatation in the blood-vessels of the abdominal viscera, is said to increase the secretion of bile. The usual view, therefore, is that the velocity of secretion of the bile varies with the volume of the blood flow through the liver. This belief seems to imply that the secretory activity of the liver cells as regards the bile is controlled by the composition of the blood. With regard to the excretory products of the bile, the bile pigments, lecithin, and cholesterin, one can understand that the greater the quantity of blood flow through the organ the greater will be the excretion. It is more difficult to comprehend the relationship between the blood flow and the increased secretion of water, salts, and bile acids, and no satisfactory hypothesis has been suggested to explain the relationship.

Curve of the Secretion of Bile.—Owing to the ease with which a biliary fistula may be established in man as well as in the lower animals, our knowledge of the daily curve

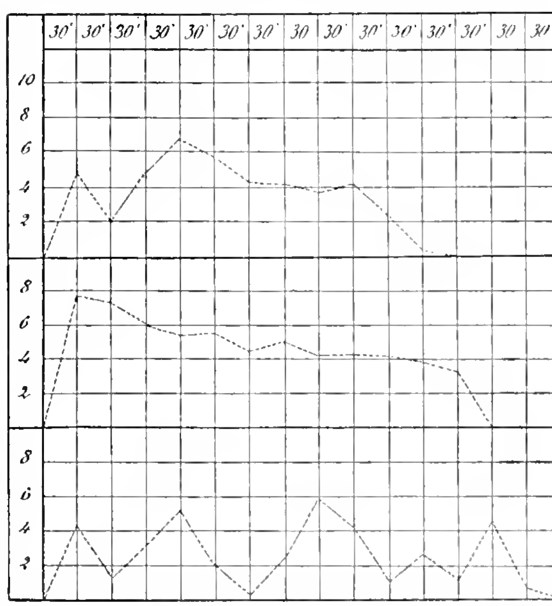

Fig. 4170.—Curves showing the Rapidity of Secretion of Bile into the Duodenum on (1) a diet of milk, upper curve; (2) a diet of meat, middle curve; (3) a diet of bread, lower curve. The divisions on the abscissa represent intervals of thirty minutes; the figures on the ordinates the volume of the secretion in cubic centimetres. (Bruno.)

of the secretion is fairly accurate. In man the quantity secreted varies between 500 and 800 c.c. in the course of a day, or taking into account the weight of the individual the secretion averages from 8 to 16 c.c. per day for each kilogram of body weight. Although the secretion is continuous, it shows a marked acceleration during the period of digestion between the third and the fifth hours after the ingestion of food, that is, during the period of maximal activity in the small intestine. Upon the general theory of secretion stated above, this increase in the secretion should be related to the greater blood flow through the liver at this period, and the altered composition of the blood following absorption of the digested products. Absorption, which is at its maximum during this time, must lead to a greatly increased metabolism in the liver cells, and the augmented secretion of bile is one expression of this increased activity. Although the secretion is continuous, the actual injection of bile into the duodenum through the common bile duct is intermittent in those animals which possess a gall bladder. The secretion in such animals is stored in the gall bladder, and by means of a definite nervous mechanism this reservoir is emptied at intervals during the course of digestion.

Ejection of Bile into the Duodenum.—The mechanism by which the bile is emptied into the intestine does not seem to have been investigated by recent observers. According to Bruno, the ejection through the common bile duct is dependent upon the passage of chyme from the stomach into the intestine, and varies with the character of the food. As long as the stomach is empty no bile is found in the duodenum. The chyme therefore must contain substances which, acting upon the sensory surface of the duodenum, lead to a reflex contraction of the gall bladder. Bruno thinks that the digested proteids (proteoses and peptones) and fats furnish the efficient stimuli. Acids, alkalies, and starches were found to be ineffective. There seem to be no data regarding the frequency of occurrence of these contractions during digestion or the action of stimuli other than the chyme. The nervous mechanism involved in this reflex has been studied by Doyon and by Oddi. It appears from their work that the afferent fibres for the reflex run in the vagi, since stimulation of the central end of a cut vagus causes a reflex contraction of the gall bladder together with an inhibition of the sphincter supposed to exist at the opening of the common bile duct into the duodenum. The efferent path, on the contrary, is through the splanchnics. Stimulation of the peripheral end of a cut splanchnic causes a contraction of the gall bladder and bile ducts.

Modification of the Bile in the Gall Bladder.—It is well known that the so-called mucin of the bile is not formed in the liver cells but from the epithelium of the mucous membrane of the gall bladder and ducts. The chemical nature of the substance seems to vary in different animals; in some cases it is a glyco-proteid of the general nature of the mucin of the salivary glands, but in most cases, according to Hammarsten, it is a form of nucleoproteid. According to Naunyn, the cholesterin of the bile is also added through the epithelium of the bile passages, and does not constitute a portion of the bile as secreted by the liver cells. According to the analyses published, the bile of the gall bladder (bladder bile) contains more solids than that of the hepatic ducts (hepatic bile). As this increase affects the constituents known to be furnished by the liver cells, it may be supposed that the bile undergoes a certain amount of concentration while in the bladder in consequence of the absorption of water.

Cholagogues.—Numerous experiments have been made upon the effect of various drugs upon the secretion of bile. These experiments have shown that substances which cause a destruction of red corpuscles increase the flow of bile. Direct injection of dissolved hæmoglobin into the circulation has the same effect. The increase in the secretion in such cases is said to be transient. The substance that has the most marked and prolonged effect upon the secretion of bile is bile itself. Bile fed to an animal or injected into the circulation accelerates the secretion of bile, and the same effect may be obtained by using solutions of the bile acids alone. Since the so-called bile acids have a distinct hæmolytic action it might be supposed at first that their effect as cholagogues is due to this action on the red corpuscles; but their effect is so much greater than that of other hæmolytic agents that we must believe that they exert a specific stimulating effect upon the liver cells. Many other substances seem to occasion a slight increase in the flow of bile, but no direct cholagogue of importance has been discovered other than the bile salts themselves. Perhaps an exception will be found to this last statement when further investigations are made upon the physiological action of the secretin formed in the duodenum and jejunum. Attention is called to this substance under the head of pancreatic secretion, and there is some indication that it may play a part as a normal chemical stimulus in the secretion of bile. At the present writing no more precise statement can be made.

Secretion of the Kidney.—None of the secretions of the body has been studied with more care than that of the kidney. The especial interest which this secretion possesses for pharmacology and internal medicine as well as for physiology accounts in large part for the attention it has received. In addition it has seemed to offer the best opportunity for testing one of the fundamental questions of secretion, namely, the extent to which the physical processes of filtration, diffusion, and osmosis participate in the act of secretion. Most of the discussion on this point has been along the lines of the two main theories of urinary secretion which have been under discussion now for many years. One theory, proposed first substantially by Bowman and afterward supported vigorously in a modified form by Heidenhain, holds that the water and salts of the urine are actively secreted by the epithelium of the capsule surrounding the glomerulus, while the urea and the other specific organic constituents of the urine are secreted together with some water by the epithelium of the convoluted tubules. The other theory we owe to Ludwig. According to him all the constituents of the urine are formed by filtration through the glomerulus. The two layers of epithelium through which this filtration occurs, the capillary or vascular, and the glomerular epithelium, act simply as a membrane through which the constituents of the urine are filtered off from the blood by the excess of pressure in the blood capillaries. The urine so formed is very dilute, and as it passes along the convoluted tubules it becomes concentrated by absorption. In both theories a difference of function is supposed between the capsule and the convoluted tubule. It will be convenient to discuss the functions of these two parts separately.

Function of the Glomerulus.—The arrangement of the glomerulus and the capsule presents a structure peculiar to the kidney and suggestive of a special purpose. The glomerulus is a knot of capillary vessels which do not form a plexus but rather a rete mirabile with a single afferent and a smaller efferent vessel. For physical reasons the blood in passing through the glomerulus suffers a diminution in velocity, on account of the sudden increase in the width of the stream bed, and yet maintains a high hydrostatic pressure on account of the resistance offered by the narrow efferent vessel and the capillary plexus with which it connects. Moreover, there are no lymph spaces round the glomerulus. The epithelium of the blood capillaries is directly adherent to the epithelium of the capsule into which the glomerulus is inserted, so that the cavity of the capillaries is separated from that of the uriniferous tubules by a double layer of endothelial cells. The arrangement suggests a filtering mechanism, and Ludwig's theory supposes that it acts in this way for all of the constituents of the urine. Bowman's theory supposes that only the water and salts are formed here, and Heidenhain, moreover, has given reasons for believing that the water is not formed by mechanical processes, but by an active secretory process on the part of the glomerular epithelium. If attention is paid only to the water and salts it is evident that if Ludwig's theory is correct the pressure tending to force them through the epithelium may be expressed by the formula $P - p$, in which P represents the pressure in the glomerular capillaries and p the pressure of the urine in the capsular end of the tubule. According to this theory, the amount of urine formed should vary directly with P and inversely with p. It is obvious that the factor P may be increased by raising arterial pressure in the renal arteries or by obstructing the flow in the renal veins, and, according to theory, each change should cause an increased flow of urine. Experiments of this kind have been made. It has been found that raising arterial pressure in the kidney arteries does increase the flow of urine, and vice versa. However, it must be borne in mind that this relationship holds only when the pressure in the glomerular capillaries varies in the same direction as in the renal arteries. All experimental variations which may be safely assumed to raise the pressure in the glomerular capillaries are followed by a greater flow of urine. The reverse experiment, however, of raising P by blocking the venous outflow fails entirely to support the theory. When the renal veins are compressed the capillary pressure in the glomeruli must be increased, and if the veins are blocked entirely, we may suppose that the capillary pressure is raised to the level of that of the renal arteries. In such experiments, however, the flow of urine is diminished instead of being increased, and indeed may be stopped altogether when the veins are completely blocked. The adherents of the Ludwig theory have attempted to explain this unfavorable result by assuming that the swollen interlobular veins press upon and block the uriniferous tubules.

According to the antagonistic theory of Heidenhain, blocking the veins suppresses the secretory activity of the glomerular epithelium by depriving it of oxygen and the chance for removal of CO_2, and thus producing local asphyxia. The latter explanation seems the simpler of the two, and it is very strongly supported by the opposite experiment of clamping the renal artery. When this is done the blood-flow through the kidney ceases and the secretion of urine also stops as would be expected. But when after a few minutes' closure the artery is unclamped the secretion is not restored with the return of the circulation. On the contrary, a long time (as much as an hour or more) may elapse before the secretion begins. This fact is quite in harmony with the Heidenhain theory, since complete removal of their blood supply might well result in a long-continued injury to the delicate epithelial cells. On the mechanical theory, however, we should expect the contrary. Injury to the cells should be followed by greater permeability and an increased filtration, as is found to be the case with the production of lymph. These two experiments, blocking the renal artery and the renal vein, seem at present to discredit the filtration theory and to support the secretion theory. If we accept this latter theory it may be asked how it agrees with the experiments mentioned above upon the variations in capillary pressure brought about otherwise than by obstructing the venous outflow. Heidenhain has emphasized the fact that all of these experiments involve not only a variation in capillary pressure, but also in the blood flow, and that it is open to us to suppose that the effect upon the secretion of urine is dependent upon the rate of flow rather than upon the capillary pressure. If we adopt this explanation we are led again to the secretion hypothesis, since mere rate of flow should not influence filtration, but should affect secretion, since it would alter the composition of the blood flowing through the glomeruli and also the supply of oxygen and carbon dioxide. An important fact, which seems at first sight to show the influence of pressure, is that when general arterial pressure falls below a certain point, about 40 mm. of mercury, the secretion of urine ceases altogether. Such a condition may be brought about by surgical shock, by hemorrhage, or by section of the spinal cord in the cervical or thoracic region. But here again the great vascular dilatation causing this fall of pressure is associated with a feeble circulation, and the effect upon the kidney secretion may well be due to this latter factor.

In addition to varying the factor P in the formula given above, it is possible also to increase the factor p. Normally the pressure of the urine in the capsule must be very low owing to the fact that the secretion drains away as rapidly as it is formed. If the ureter is occluded, however, the pressure of the urine will increase, and the filtration pressure $P - p$ will diminish. When this experiment is performed and the pressure in the ureter is measured by a manometer, it is found to rise to 50 or 60 mm. of mercury and then to remain stationary. This fact might be explained by supposing that when $p = P$ the secretion stops on account of the failure of the filtration pressure. Little weight, however, can be given to this argument, since it is quite possible that under these conditions the urine may still continue to form, but is reabsorbed under the high tension reached. The experiment simply serves to show the secretion pressure of the urine, and the fact that this pressure rises as high as 50 to 60 mm. mercury, while the fact that the capillary pressure is probably somewhat lower would rather serve as an argument against the filtration theory. Exact figures, however, regarding the capillary pressure in the kidney cannot be obtained, so that the experiment on the whole gives us no satisfactory information regarding the theory of secretion. Dreser has used a different argument to prove that the production of the water involves the performance of work on the part of the epithelial cells. He points out that in some conditions, *e.g.*, after drinking beer, the urine may be very dilute, as shown by the fact that its freezing point may be only 0.18° C. or 0.16° C. below that of pure water, that is, $\Delta = -0.18°$ C. or $-0.16°$ C. Since blood serum has $\Delta = -0.56°$ C. the difference in concentration between the blood and the urine in such a case of extreme dilution shows an osmotic pressure in favor of the blood equivalent to $\Delta = -0.4°$ C. Measured in mechanical units this would indicate an osmotic pressure of 49.08 metres of water tending to drive the water from the uriniferous tubules into the blood, whereas the filtration pressure driving the water in the other direction could not at a maximum exceed 2.72 metres of water. Evidently if this argument is just, the elimination of the water takes place against a strong opposing osmotic pressure, and the energy necessary for its secretion can be referred only to the activity of the epithelial cells.

Function of the Convoluted Tubules.—By convoluted tubule is meant that portion of the uriniferous tubule which extends from the capsule to the straight or collecting tubes. Its epithelium varies, but is distinguished in general from the flat, thin epithelium of the capsule by a larger amount of granular protoplasm. According to the Ludwig theory, this portion of the tubule functions as an absorption membrane and serves thus to concentrate the dilute urine filtered through the glomerulus. The fact that the urine is often more concentrated than the blood proves that this absorption, if it occurs, is not due to simple hydro-diffusion, and later adherents of this theory have been obliged to abandon the simple physical theory proposed by Ludwig and to suppose that the absorption effected by these cells is a physiological process dependent upon their living structure and properties. The Bowman-Heidenhain theory, on the contrary, assumes that these cells are secretory in function and serve for the excretion of the urea, uric acid, etc. With regard to the absorption theory it may be said that positive evidence is lacking, and it is difficult to present briefly the facts that are quoted from time to time in its favor. On the other hand, there is much probable evidence that the secretory hypothesis is nearer to the truth. This evidence may be summarized briefly as follows: 1. It is stated that if the ureters are ligated in birds the urates will be found deposited in the uriniferous tubules, but never at the capsular end. 2. Heidenhain has given proof that the convoluted tubules are capable of excreting indigo-carmine after this substance is injected into the blood. His experiment consisted essentially in injecting the material into the blood after dividing the cord so as to reduce the rapidity of secretion. After a certain interval the kidney was removed and irrigated with alcohol to precipitate the indigo-carmine *in situ* in the organ. Microscopic examination showed that after this treatment the granules of the indigo-carmine are found in the convoluted tubules, but not in the capsules round the glomeruli. 3. Several observers (Van der Stricht, Disse, Trambasti, Gurwitsch) have described microscopic appearances in the cells lining the tubules indicative of an active secretion. They picture the formation of vesicles in the cells and appearances which indicate the discharge of these vesicles into the cavity of the tubules. 4. Nussbaum made use of the fact that in the frog the glomeruli are supplied by branches of the renal artery, while the rest of the tubes are supplied by the renal portal vein. He stated that if the renal artery is ligated the glomeruli are deprived completely of blood, and that as a result the flow of urine ceases. If under these conditions urea is injected into the circulation it is excreted together with some water, thus proving the secretory activity of the tubules with regard to urea. Later experiments by Adami and by Beddard have thrown doubt upon this otherwise crucial experiment. Adami claims that ligature of the renal arteries does not shut off completely the glomerular circulation, while Beddard, although he corroborates Nussbaum in the point that complete occlusion of the renal arteries suspends entirely the secretion of urine, finds that under these conditions injection of urea into the circulation is not followed by a secretion. 5. Dreser has shown that the acidity of the urine is due to an action of the epithelium of the tubules. If an acid indicator, such as acid fuchsin, is injected into the dorsal lymph sac of a frog, and an hour or so later the kidneys are examined, it will be found that the convoluted tubules are colored red, while the capsular end is colorless, indicating that the secretion at that point has an alkaline reaction. The experiment shows that the acid phosphate of the urine is produced in the convoluted tubules. The simplest explanation is that it is formed by a secretory activity of the epithelial cells, although one may adopt the less probable view that the cells produce the acid phosphates by a selective absorption of alkaline salts. On the whole it must be admitted that the weight of evidence is in favor of the Bowman-Heidenhain theory of secretion, and it remains for future investigations to explain more definitely what is meant by the obscure term, secretory activity.

Under pathological conditions it has been shown satisfactorily that albumin and sugar which may be present in the urine are secreted or eliminated at the glomerular end of the tubule.

Influence of the Nervous System on the Secretion of Urine.—Although Berkley states that terminal fibrils of the nerves distributed to the kidney may be traced to the epithelial cells of the convoluted tubules, the physiological evidence at present is opposed to the existence of secretory nerve fibres. The kidney receives a rich nervous supply by way of the sympathetic, but experiments indicate that these fibres are vaso-motor in function. Both vaso-constrictor and vaso-dilator fibres have been described, and inasmuch as the secretion of urine varies directly with the rapidity and volume of the blood flow, it follows that these vaso-motor fibres must exercise normally an important regulatory influence upon the amount of secretion.

Action of Diuretics.—An important side of the theories of secretion of urine is their application to the action of diuretics. Water, various soluble substances, such as salts, urea, and dextrose, and certain special drugs, such as caffein or digitalis, exert a diuretic action on the kidneys. Much experimental work has been done to ascertain whether the action of these substances can be explained mechanically by their influence on the blood flow or the blood pressure in the kidney capillaries, or whether it is necessary to fall back upon a specific stimulating effect exerted by them upon the epithelial cells of the tubules. Adherents of the original Ludwig theory are forced to explain their action by the effect they produce upon the pressure in the kidney capillaries, and indeed it has been shown with reference to the saline diuretics that their effect upon the secretion is in proportion to the osmotic pressure they exert. It has been suggested, therefore, that the action of these diuretics lies in the fact that they attract water from the tissues into the blood and thus cause a condition of hydræmic plethora. But whether the elimination of this excess of water is due to filtration or to an active secretion by the glomerular epithelium simply revives the discussion that has been presented briefly above. Most observers find that the vascular changes in the kidney, particularly after the administration of caffein and digitalis, do not explain satisfactorily the phenomenon of diuresis, and although it is necessary to admit that the diuretics, or some of them, act in part by the changes which they cause in the circulation in the kidney, those who adopt the Bowman-Heidenhain theory assume usually that these substances exert also a direct stimulating action on the secretory cells.

Secretion of the Sebaceous Glands.—Practically nothing is known of the mechanism of secretion of these glands beyond the results furnished by histological examination. It is believed that the secretion is formed not by a liquid discharge from the cells, but by the casting off of the cells themselves. The cells upon the basement membrane multiply, and the daughter cells are displaced toward the lumen of the gland. Gradually these latter cells disintegrate, and their débris forms the thick, oily secretion.

Secretion of the Sweat Glands.—The secretion of sweat is important, partly because it helps to regulate the water contents of the body, but mainly because it is an effective means of controlling the body temperature. In accordance with these regulative functions we find that the formation of sweat is governed by the central nervous system, by means of which a reflex adaptation of the process to the needs of the body is made possible. Definite experimental proof of the existence of sweat nerves was obtained first by Goltz. He showed that electrical stimulation of the peripheral end of the divided sciatic in dogs or cats causes the formation of visible drops of sweat on the balls of the feet. This result has since been confirmed for other parts of the body, and it has been shown that the sweat nerve fibres take much the same course anatomically as the vaso-motor fibres. They take origin in the cord or the medulla, pass over to the sympathetic ganglia where they end round the sympathetic nerve cells. Thence their course is continued by a sympathetic neurone, so that they reach their destination probably as non-medullated fibres. Their course for different regions of the body is known with a fair degree of exactness. All the evidence that we have indicates that the sweat glands, like the salivary glands, do not secrete normally except under the influence of these secretory fibres. Ordinary profuse sweating due to a high external temperature must be explained as a reflex act. The high temperature stimulates sensory nerves in the skin, and the impulses thus generated are transmitted to the cord and returned to the sweat glands by the efferent sweat fibres. Attempts have been made to ascertain whether the general activity of these sweat fibres is controlled like that of the vaso-constrictors by a medullary nerve centre. The work done is not conclusive, but it seems to indicate that the reflex centres for the system are found in different regions of the brain and cord. In all probability the nuclei of origin of the sweat fibres for each skin area constitute the sweat centre for that region. These nuclei or centres may be stimulated reflexly by incoming impulses from the skin or from the higher nerve centres, or they may be acted upon by changes in the composition of the blood as is shown by the effect of dyspnœa and certain drugs. Atropin and pilocarpin exert their well-known antagonistic influence in the sweat secretion, the latter causing a flow of sweat and the former inhibiting it. As in the case of other glands, the action of these drugs is supposed to be peripheral, pilocarpin stimulating the endings of the sweat fibres, and atropin paralyzing them. Nicotin also in proper doses suspends the secretion of sweat, and it is probable that this alkaloid acts upon the connection between the spinal or pre-ganglionic neurone and the sympathetic or post-ganglionic neurone.

SECRETION OF THE MAMMARY GLANDS.—The development of these glands in connection with the processes of gestation and their functional activity for a variable period after the act of parturition, are the points of greatest physiological interest. It seems evident that the causal connection between the changes in the uterus and in the mammary gland must be established either through the central nervous system or through the blood. During the development of the fœtus sensory stimuli may be developed in the reproductive organs of the mother which act reflexly upon the mammary gland and stimulate its growth and secretion; or, on the other hand, the changes in the reproductive organs may result in the formation of an internal secretion, which being discharged into the blood, acts upon the tissue of the gland either directly or through the nervous system. The crucial experiment of destroying the nerve supply of the gland in a pregnant animal has given somewhat unsatisfactory results, but it seems to show that the development and functional activity of the gland proceed as under normal conditions, although the quantity of milk produced is less. As far as it goes this evidence indicates that the bond of connection is furnished by the blood rather than by the nervous system, and we may adopt provisionally the hypothesis of an internal secretion. Assuming that this hypothesis is correct, it still remains possible, of course, that the activity of the gland in lactation may be regulated by extrinsic nerves. Many facts speak for this possibility. It is known, for instance, that in women during lactation the flow of milk is influenced by emotional conditions, and, on the other hand, histologists have described nerve terminations round the gland cells which look like secretory nerve fibres. The physiological evidence for secretory fibres is, however, quite meagre. Mironow in experiments upon goats has stated that stimulation of sensory nerves causes a diminution in the secretion, but that when the nervous connections of the gland are destroyed this reflex cannot be obtained. Röhrig finds that section of the inferior branch of the external spermatic increases the secretion, while stimulation of the same nerve causes a diminished secretion. These experiments might be regarded as proving the existence of inhibitory fibres to the gland, but it is equally, or indeed more probable, that the fibres in question are vaso-constrictors. The known influence of the central nervous system on the secretion of milk may therefore consist only in the control of the circulation in the gland by means of vaso motor fibres as in the case of the secretion of urine.

INTERNAL SECRETIONS.

The term internal secretion seems to have been employed first by Claude Bernard, but the essential idea conveyed by it, namely, a secretion discharged into the blood or lymph, had long been entertained in connection with the so-called ductless glands, such as the thyroid. About 1889 the term and the idea implied by it were emphasized by Brown-Séquard in connection with work upon testicular extracts. This author suggested that not only the glands but all tissues may have internal secretions of greater or less importance in the general nutrition of the body. This extension of the original conception was not justified by subsequent experiments and to-day we must limit the use of the term to the distinctly glandular bodies. Experience has shown, however, that not only the ductless glands but some at least of the typical glands with well-defined ducts may produce internal secretions. There is no *a priori* way of determining whether or not a glandular structure produces an internal secretion. The matter must be decided by experiment and observation.

Internal Secretion of the Thyroid Tissues.—Under the term thyroid tissue we may include the thyroid bodies, the accessory thyroids which have a similar, indeed identical structure, and the parathyroids whose structure is peculiar, but whose function seems to be closely related to that of the thyroids. The history of the discovery of the functions of the thyroids, so far as we know them, is most interesting and illustrates admirably how experimental physiology may co-operate with experimental and clinical work in medicine and surgery. The early work indicated that removal of the thyroids is followed quickly by marked symptoms of disturbed metabolism, cachexia, muscular tremors and spasms which soon end in death. Later work has shown that a rapidly fatal result is obtained only when the operation removes all of the thyroid tissues, and that the characteristic symptoms and their duration before a fatal termination depend somewhat upon the species of animal used and its age. In human beings it is known that atrophy or loss of function in the thyroids leads to cretinism and myxœdema, and that these distressing conditions may be removed completely by feeding thyroid tissue to the patient. In the lower animals the precise results of removal of the thyroids proper and of the parathyroids are not yet clearly known. Upon many animals, dogs, cats, rabbits, rats, operations that remove both the thyroids and the parathyroids result in the rapid death of the animal with the symptoms of cachexia and muscular convulsions mentioned above. In the higher mammals (the monkeys, for instance), the symptoms are said to develop more slowly and to resemble more nearly the myxœdema of man. One observer claims that in those animals, such as dogs, in which the fatal result of thyroidectomy is most prompt, a distinction may be made between removal of the thyroids and removal of the parathyroids. Removal of the former causes a slowly developing malnutrition, a progressive cachexia whose fatal termination may be long deferred. Removal of the parathyroids, on the contrary, occasions more acute symptoms including muscular convulsions and a rapidly fatal result. This distinction needs, however, further confirmation before it can be accepted. It is stated also that the fatal outcome of complete thyroidectomy may be deferred or obviated completely by grafting a portion of the gland under the skin. These results upon man and the lower animals are usually explained upon the assumption that the thyroid tissues furnish an internal secretion which plays an important and indeed essential part in the metabolism of the body, particularly perhaps of the nervous system. There is histological evidence to show that the colloid material contained in the vesicles of the glands is emptied into the lymphatics and thence reaches the blood. On the other hand, it has been proved that the beneficial material in extracts of the glands is obtained from this same colloidal material. We may therefore regard this substance as a secretion which is discharged into the blood by way of the lymphatics. Bauman has succeeded in obtaining from the gland a peculiar organic compound containing iodine to the amount of nine per cent. of the dry weight. He designated this substance as iodothyrin and showed that in the gland it exists in combination with proteid. Inasmuch as the iodothyrin, when used upon animals or patients, has much the same beneficial effect as the crude thyroid extract, we must believe that it represents one at least of the essential constituents of the internal secretion. How it or other substances affect normally the metabolism of the body is not yet explained. We know only that complete loss of this substance is followed by a perverted metabolism and finally by death. There is much evidence to show that feeding thyroid extracts to normal individuals leads to an increase in physiological oxidations, hence its use in cases of obesity. This fact is a further indication of the influence of its secretion on normal metabolism, but the means by which it influences the nutrition of the cells cannot be determined without further work.

The Adrenal Bodies.—Brown-Séquard was the first to show that removal of these bodies in dogs is followed by the death of the animal within a day or two. Subsequent observers have confirmed this fundamental fact, and have shown that the symptoms preceding death are great muscular weakness, a loss of vascular tone, and a feeble heart beat. On the clinical side these results agree well with the observation that in Addison's disease, which is accompanied by a lesion of the adrenals, there is also marked asthenia with feeble heart beat and loss pressure seems to be due to a direct action on the musculature of the small arteries and veins, causing a contraction and therefore an increase in peripheral resistance. This effect is only temporary; in a few moments the press-

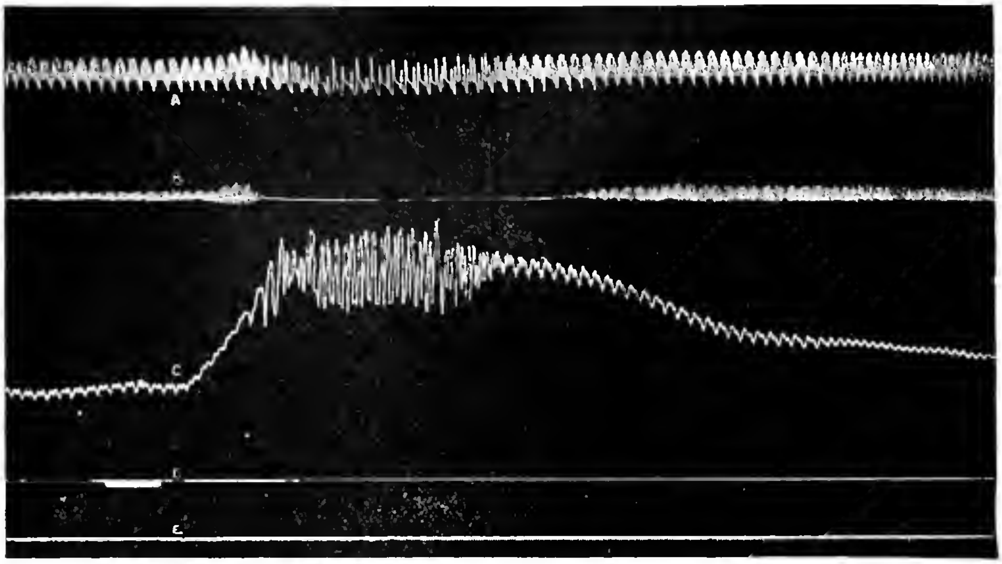

Fig. 4171. Curve to show the Effect of Intravenous Injections of Extract of the Adrenal, when the Vagi are Intact. The time of the injection and the duration are represented by the white space on line *D*; the effect on blood pressure and pulse rate is represented by line *C*; the effect on the contractions of the ventricle and the auricle are represented respectively by lines *A* and *B*; *E* gives the time in half-seconds. (Schaefer.)

of vascular tone. As in the case of the thyroids physiological investigations of recent years tend to show that the adrenals produce an internal secretion of importance in metabolism, particularly the metabolism of the muscular tissues. Extracts of the medulla of the gland injected into the circulation of a normal animal cause a marked slowing and strengthening of the heart beat and a rise of blood pressure. The heart effect, so far at least as the slowing of the beat is concerned, is due to an action of the extract on the inhibitory centre of the vagus, since ure returns to normal, showing that the active substance is quickly neutralized or destroyed within the body. This active substance in the medulla of the glands is normally secreted into the adrenal veins, since blood collected from these veins and injected into a normal animal gives the effects described above. There is some evidence that the secretion of this substance is under the control of secretory nerve fibres. A number of investigators have attempted to isolate the active substance. Abel has succeeded in preparing from the extracts a basic

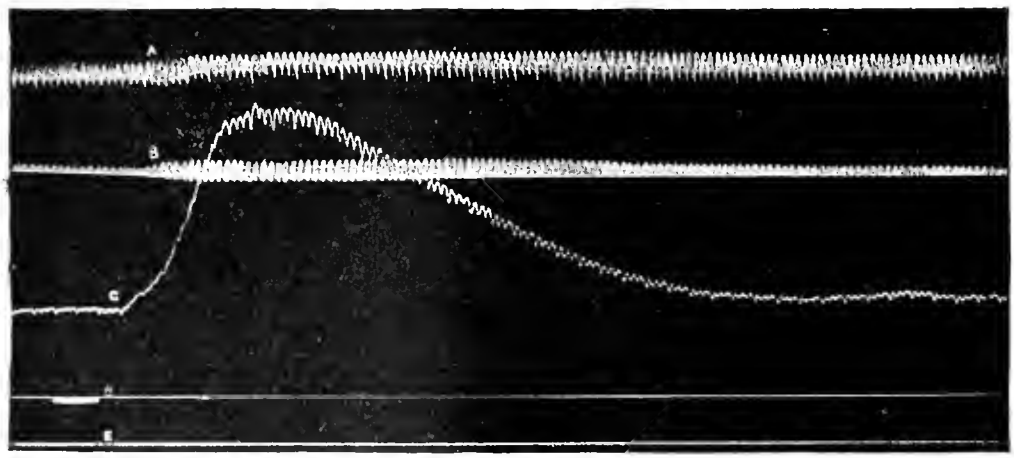

Fig. 4172. Curve to show the Effect of Intravenous Injections of Extract of the Adrenals when both Vagi are Cut. The designation of the curves is the same as in the preceding figure. (Schaefer.)

it disappears on section of these nerves or after the administration of atropin. After section of the vagi injection of the extracts causes a quickening of the heart rate and a great rise of blood pressure. The effect on blood substance to which he gives the name of epinephrin and to which he assigns the formula $C_{10}H_{11}NO_3$. The salts of this substance, when injected even in minute doses, give the characteristic effect upon the heart and blood-vessels. Other crystalline products—adrenalin and suprarenalin—have been prepared from the extracts of the glands and used upon a commercial scale. They show very active physiological properties, but their exact composition and their relations to epinephrin are at present not fully determined. The conclusion commonly drawn from the above facts is that the adrenals secrete continually into the blood a substance that is normally necessary to the proper metabolism of the muscular tissues. When it is completely absent, as in removal or disease of the adrenals, a perverted metabolism ensues, and this expresses itself in a marked loss of muscular tone. The fatal result may possibly be attributed directly to the effect on the circulation, the feeble heart beat, and the loss of vascular tone, giving a condition analogous to that caused by vascular shock. It should be added that some physiologists give a different interpretation to these facts. They hold that the normal function of the adrenals is to produce an antitoxic secretion capable of neutralizing or destroying certain poisonous products of body metabolism, particularly the metabolism of muscular tissue. According to this view the fatal result of removal of the adrenals is due not to the absence of the normal stimulating or regulating action of their secretion, but to the accumulation of toxic products. This theory is designated sometimes as the auto-intoxication theory, but no convincing proof has yet been produced to show that in animals deprived of their adrenals there is present any toxic substance in the blood or the tissues. Attempts to use adrenal extracts therapeutically in cases of Addison's disease, that is, to substitute injections of the extracts in place of the normal secretion, have given negative or uncertain results. This failure may be due to the fact mentioned above, namely, that the effect of injections is quite transient. According to Battelli, continuous injections of adrenal extracts fail to prolong life to any noticeable extent in animals whose adrenals have been removed experimentally, and Christiani reports that grafts of the adrenals under the skin or in the peritoneal cavity fail to ward off the rapidly fatal results of extirpation. The explanation of this last result, however, seems to lie in the fact that when the organ is grafted the medullary portion undergoes a retrogressive change, although the graft as a whole may seem successful. The marked effect of adrenal extracts in causing vascular constriction has been utilized practically in producing local blanching of vascular membranes in the case of the eye, nose, throat, etc.

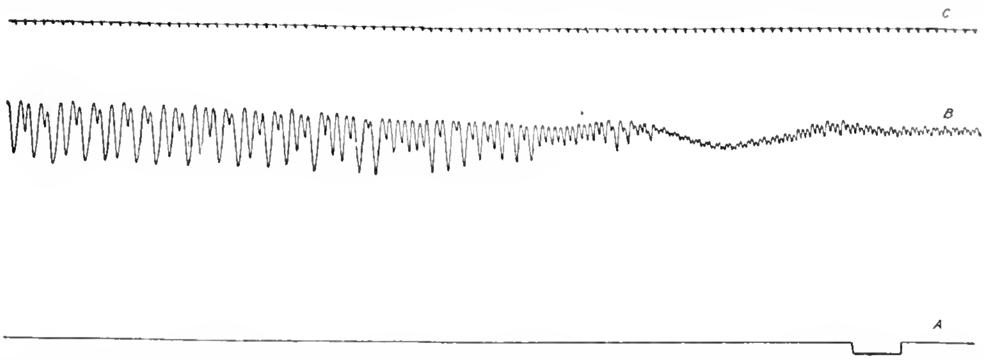

FIG. 4173.—Curve showing the Effect upon Blood Pressure and Heart Beat of an Injection of an Extract of the Infundibular Body when the Vagi are Intact. The point of injection is shown upon line *A*; *B* is the blood-pressure record and *C* the time record in seconds. (Howell.)

The Pituitary Body.—The pituitary body so called consists in reality of two quite distinct structures that possibly have different functions. The anterior lobe or the hypophysis cerebri is a glandular structure that develops in the embryo from the epithelium of the mouth cavity. The posterior lobe or the infundibular body is a mixed structure of nerve cells and glandular cells which develops from the infundibular process of the brain. It is very difficult to experiment upon these structures owing to their position. Vassale and Sacchi state that removal of the entire pituitary body is followed soon by a group of symptoms resembling those caused by thyroidectomy, namely, muscular tremors and

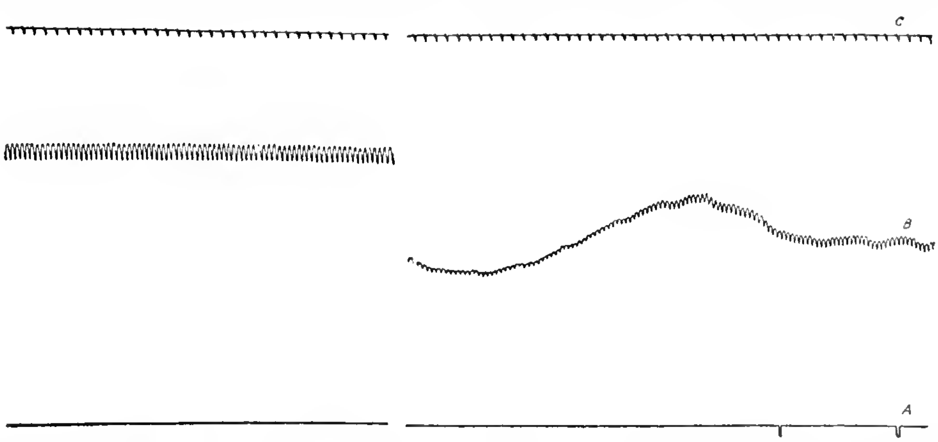

FIG. 4174.—Curve showing the Initial and Final Effect of an Injection of Extract of the Infundibular Body when the Vagi are Cut. The designation of the curves is the same as in the preceding figure. (Howell.)

spasms, apathy and dyspnœa, which soon result in death. It has been suggested, therefore, that the functions of this body may be related to those of the thyroid tissues, but no convincing evidence is at hand to make this view probable. On the clinical side it has been asserted that the peculiar disease known as acromegaly is associated with lesions of the pituitary body, but a causal connection between the two is still very uncertain. Injections of extracts of the body give results that vary with the lobe used. Extracts of the anterior lobe or hypophysis proper give little or no effect when injected into the circulation of a normal animal. Extracts of the infundibular lobe, on the contrary, give a marked effect upon the heart and blood pressure similar in many respects to that caused by extracts of the adrenals. This difference in the effect of the extracts suggests that the two bodies may have different functions in spite of their close anatomical connection. We have no direct evidence that these bodies furnish an internal secretion, but the absence in the adult mammal of a duct would imply that any product formed by them must affect the body by way of the circulation. Cyon, however, contends that the chief function of the pituitary body is to co-operate with the thyroids in regulating the blood flow through the brain. His idea seems to be that the pituitary body fulfils a double function. In the first place it serves as an automatic regulator of intracranial pressure, acting in two ways—mechanically, in that a rise of intracranial pressure stimulates the pituitary body and brings about a slowing and strengthening of the heart beat, and chemically, by secreting substances which act upon the vagus and accelerator centres. In the second place it affects general metabolism also by an action of these last-mentioned substances on the vagi and sympathetic. For the experiments which lead him to this somewhat elaborate theory it will be necessary to consult the original paper, a reference to which is given at the end of this article.

Internal Secretion of the Pancreas.—Few discoveries in physiology have been more interesting and significant than that made by von Mehring and Minkowski regarding the internal secretion of the pancreas. Briefly stated, they found that complete removal of the pancreas brings on a condition of serious glycosuria known now as pancreatic diabetes. Acetone and β-oxybutyric acid are also present in the urine, and, as in the diabetes mellitus of man, the animal shows polyuria and an abnormal thirst and hunger. These symptoms are followed by muscular weakness, emaciation, and in a few weeks by death. If the pancreas is removed incompletely the glycosuria may be serious, or slight and transient, or absent altogether, according to the amount of the gland extirpated. If so little as one fourth or one-fifth of the gland is left in the body the glycosuria may not show itself, and since the portion so left may have no connection with the intestine, this fact as well as others shows that the mere suppression of the pancreatic juice has nothing directly to do with the diabetes that results from complete removal of the gland. In pancreatic diabetes the glycogen disappears from the liver. The blood shows an increase in its sugar contents from 0.15 per cent. to 0.3 or 0.5 per cent., and the urine may continue to contain sugar in quantity when carbohydrate food is withheld completely. On the basis of these and similar results it is believed that the pancreas forms an internal secretion which is given off to the blood. This internal secretion is supposed to play an essential part in the metabolism of the carbohydrates. It has been suggested, for instance, that the internal secretion contains an enzyme of some kind which is necessary for the dissociation or oxidation of the sugar of the body so that in its absence the sugar accumulates in the blood and is lost through the urine. A specific form of this hypothesis has been advanced by Lepine. It has long been known that sugar in the blood disappears on standing, and Lepine has shown that this glycolytic action of the blood is due probably to the presence of a definite enzyme. He assumes that this glycolytic enzyme is formed *intra vitam* from the leucocytes of the blood, but that its formation is a function of the internal secretion of the pancreas. When the internal secretion is prevented the blood loses its glycolytic power, and the sugar escapes oxidation. This hypothesis would seem to demand that in diabetes mellitus the glycolytic power of the blood, when tested out of the body, should be absent or distinctly below the normal. Several observers who have tested this point state, on the contrary, that the glycolytic action of diabetic blood is not less than that of normal blood. Other observers have adopted an entirely different view, holding that the pancreatic secretion normally regulates the output of sugar from the liver and other sugar-producing tissues. In its absence this output is increased and raises the sugar percentage in the blood to such an extent as to cause glycosuria. We must admit at present that the way in which the internal secretion of the pancreas affects the sugar consumption of the body is not known satisfactorily, although there is no doubt that in some way it is absolutely necessary in the process. Considerable experimental and histological evidence has accumulated tending to show that the cells concerned in this important function of the pancreas are not the pancreatic cells proper, but the so-called islands of Langerhans. In man these islands are scattered through the pancreas and form round or oval bodies that may reach a diameter of as much as 1 mm. The cells are polygonal and their protoplasm is pale and finely granular, while the nuclei show a thick chromatin network which stains deeply. In each island there is a capillary network resembling somewhat the glomeruli of the kidney.

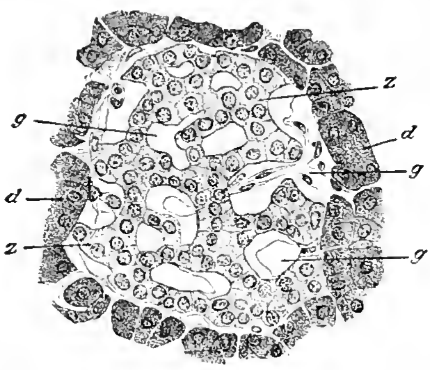

FIG. 4175.—Section Through an Island of Langerhans. *d*, The gland cells of the surrounding pancreatic tissue; *g*, blood capillaries; *z*, the columns of cells composing the island. (Kölliker.)

According to Ssbolew, ligation of the pancreatic duct is followed by a complete atrophy of the pancreatic cells proper, but does not affect to any marked extent the islands of Langerhans. Since under these conditions no glycosuria occurs, while removal of the whole organ including the islands is followed by pancreatic diabetes, the obvious conclusion to be drawn is that it is the removal of the islands that causes the pancreatic diabetes, and that therefore it is these cells that form the normal internal secretion of the pancreas. This conclusion is further corroborated by pathological results upon the lesions of the pancreas in human beings in connection with diabetes mellitus. A number of recent observers (Opie, Ssbolew, Herzog, *et al.*) find that in diabetes mellitus the islands are markedly affected. They show signs either of hyaline degeneration or of atrophy, and indeed may in severe cases be absent altogether.

The Reproductive Glands.—The general interest in the subject of internal secretions in recent years was aroused largely by the work of Brown-Séquard upon the effect of testicular extracts (1889–92). The results of his experiments seemed to indicate that these extracts possess a marked stimulating or dynamogenic action upon the neuro-muscular apparatus. The effect was said to be pronounced not only upon sexual power but upon general muscular and mental vigor. Pohl claims to have obtained from such extracts a definite substance, spermin, to which he assigned the formula $C_5H_{14}N_2$, and which he believes has a general tonic effect upon body metabolism. Similarly Zoth and Pregel report that these extracts increase the power of doing muscular work when measured quantitatively by means of an ergograph. These and other similar experiments give us some reason to believe that the testes may form an internal secretion of importance in regulating and stimulating the metabolisms of the body. If such a secretion is formed, however, its action is not absolutely necessary to normal metabolism as is shown by the fact that castrated animals live in apparently good health. Our natural inference would be that a secretion of this kind might act as a regulator of sexual desire, but it is very uncertain whether such an effect takes place. In the experiments reported the possibility of suggestion playing a part in the results obtained is not excluded entirely, and we must speak therefore of the internal secretion in these glands as a possibility only and not as a demonstrated fact. The evidence is perhaps stronger that an internal secretion is formed by the ovaries. Loewy and Richter have shown that ovariotomy in dogs results eventually in a marked diminution in physiological oxidations as measured by the amount of oxygen consumed. And when an animal is brought into this condition, the administration of ovarian extract is sufficient to bring the consumption of oxygen to its normal figure or to cause an increase beyond normal. Further probable evidence is found in the numerous gynecological cases involving the removal of the ovaries. Quite frequently in such cases disagreeable symptoms ensue, extreme nervousness, vaso-motor flushes, etc., and these results have been sufficiently marked to cause many gynecologists to be cautious in the removal of both ovaries. If one can be left the after-results of the operation seem to be less serious. This general fact, together with the undoubted influence of the ovaries upon menstruation and probably upon lactation, speaks strongly for the existence of an internal secretion; but we lack at present definite scientific proof, such as we have in the case of the thyroids and adrenals. *William H. Howell.*

REFERENCES.

The following general treatises contain references to the very extensive literature of the subject of secretions:
Heidenhain in Hermann's Handbook der Physiologie, vol. v., part i., 1883.
Langley, Edkins, Paton, Starling, Schaefer, Reid: Schäfer's Text-book of Physiology, vol. i., 1898.
An American Text-book of Physiology, vol. i., 1901.
Howell, Chittenden, Adami, Putnam, Kinnicutt, Osler: Internal Secretions. Transactions of the Congress of American Physicians and Surgeons, fourth session, 1897.
Pawlow: Die Arbeit der Verdauungsdrüsen, 1898. Contains the literature of the special work of the St. Petersburg laboratory, also English translation, 1902, by Thomson.
Oppenheimer: Die Fermente und ihre Wirkung, 1900.
Recent literature of importance not found in the above sources, and used in the preparation of this paper are as follows:
On the Mechanism of Pancreatic Secretion. Bayliss and Starling, Journal of Physiology, 1902, vol. xxviii., p. 325. See also Comptes rendus de la Société de Biologie, 1902, vol. liv., No. 9.
Cohnheim's Discovery of Erepsin. See Zeitschrift f. physiol. Chemie, 1901–1902, vol. xxxiii., p. 451 and vol. xxxv., p. 134.
Beddard: On the Secretion of Urine. Journal of Physiology, 1902, vol. xxviii., p. 20. See also Gwaritch: Archiv f. d. ges. Physiol., 1902, vol. xci., p. 71, and Cushny: Journal of Physiology, 1902, vol. xxvii, p. 429.
For Cyon's theories regarding the hypophysis see Archiv f. d. ges. Physiologie, 1901, vol. lxxxvii., p. 565.
For the recent work on the Relation of the Pancreas to Diabetes mellitus see Opie: Journal of Experimental Medicine, 1901, vol. v., pp. 397 and 527. Also Ssbolew: Virchow's Archiv, 1902, vol. 168, p. 91.

SEDATIN, para-valeryl-amido-phenetol, para-valeryl-phenetidin, $C_6H_4.OC_2H_5.NH.C_4H_9CO$, is obtained by the action of valeric acid on para-amido-phenetol. It is insoluble in water, sparingly soluble in ether, chloroform, and benzin, and readily soluble in hot alcohol. It is analgesic and antipyretic in dose of 0.2–0.7 gm. (gr. iij.–x.). Sedatin is also an old name for antipyrin. *W. A. Bastedo.*

SEGMENTATION OF THE BODY. Segmentation of the body, or metamerism, is an expression used to convey the idea that the body is composed of a series of segments, also called *metameres*, or *somites*, that are arranged in a series along the principal axis, and in each one of which the principal organs are repeated. Familiar examples of metamerism are furnished by the earthworms and tapeworms. A better example is a typical marine annelid like Polygordius or Nereis, in which each somite, beside the integument, ventral nerve cord, main blood-vessels, and gut, which are continuous through the length of the body, has its own body cavity separated by a partition from its neighbors fore and aft, a pair of limbs (parapodia), a pair of nephridia, a pair of gonads, and several pairs of lateral blood-vessels and nerves, the same arrangement being found in each somite except the terminal ones.

In the vertebrates there is an indication of a similar metamerism. Thus in all vertebrates the vertebræ, the ribs, and the spinal nerves are arranged metamerically, and in the fishes the trunk muscles are divided by transverse tendinous plates into myotomes, which are likewise metamerical in arrangement. This metamerism of the musculature is present to a less degree in the amphibia, but in the higher vertebrates, including man, it has almost disappeared in the adult, as the result, doubtless, of adaptive modifications. But in the embryo metamerism is very evident, even in the highest forms, and has its foundation in the primitive segmentation of the mesoderm, forming the so-called protovertebræ. The divisions of the body being thus outlined at an early stage the spinal nerves, lateral blood-vessels, vertebræ, ribs, and the primitive nephredial tubules are developed in definite relation to them.

The body of a vertebrate may be divided into three main regions—head, trunk (extending from the first cervical vertebra to the anus), and the tail. The segmentation of the trunk and tail is very evident in the embryo, if not in the adult, and the number of segments may be counted. Thus in man there are thirty-seven or thirty-eight originally, of which four or five are caudal segments that disappear during the second month of fœtal life.

The segmentation of the head is not so clear, even in the embryo, and has been a subject for earnest investigation and discussion for a long time. While it is evident that the head is a segmented structure, the actual number of segments and the organs appertaining to each one can be determined only after very minute comparative study of the development of the whole complex of muscles, nerves, ganglia, sense organs, and other structures composing the head, and it is not surprising, therefore, that there should be considerable difference of opinion. Thus Rabl denies that the head contains any segments in front of the ear that can be regarded as homologous with the trunk segments. This opinion is contrary to that of Minot and Hertwig, who regard the whole head as composed of homologous segments. But Hertwig estimates the number as nine, while Minot makes it thirteen.

The segmentation of the body in vertebrates has been held to indicate the descent of this group from the annelids. Comparative anatomy shows, however, that the most primitive known allies of the vertebrates present no likeness to the annelids, but, on the contrary, resemble in some respects the echinoderms, or rather their larvæ; therefore the annelid theory of the origin of the vertebrates seems of very doubtful validity. It is more probable that the metamerism of the body arose independently in the primitive forms of the two groups in adaptation to a similar mode of life.

Robert Payne Bigelow.

BIBLIOGRAPHICAL REFERENCES.

Froriep, A.: Entwickelungsgeschichte des Kopfes. Erg. Anat. und Ent., vol. i., 1892, *loc. cit.*, iii., 1894.
Gaupp, E.: Die Metamerie des Schädels, *loc. cit.*, vii., 1898.
Kupffer, C. von: Entwickelungsgechichte des Kopfes, *loc. cit.*, ii., 1893; *loc. cit.*, v., 1896.

SEGMENTATION OF THE OVUM.—The segmentation, or cleavage, of the ovum is the first stage in the development of an embryo from an egg. It begins with

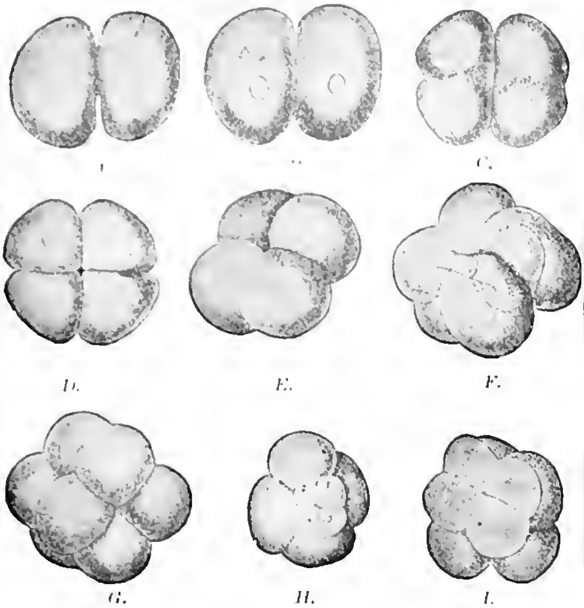

FIG. 4176.—Cleavage of the Egg of an Irregular Sea Urchin, Echinocardium. *A*, First cleavage furrow; *B*, two-cell stage; *C*, beginning of second furrow; *D*, *E*, four-cell stage; *F*, third cleavage, two cells have divided and two are in process of division; *G*, eight-cell stage complete; *H*, sixteen-cell stage, seen from animal pole; *I*, same from vegetative pole. Magnified. (After Fleischmann.)

the first cell division after fertilization (or after the last maturation division in case of parthenogenesis, *q. v.*) and ends with the beginning of differentiation of organs (see *Ovum*, *Gastrula*, and *Area embryonalis*).

The course of cleavage differs greatly in different groups of animals. Eggs having comparatively little deuto-

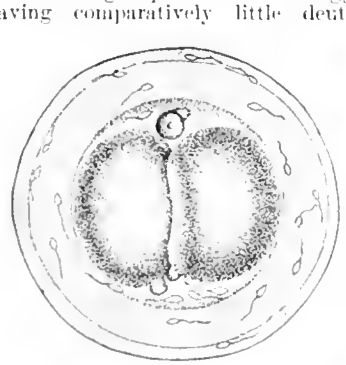

FIG. 4177. Egg of a Rabbit of Twenty-four Hours: the first cleavage has been completed. (After Coste.)

plasm, or yolk, divide completely into two, four, eight, sixteen, . . . etc., cells. The cleavage is then said to be *total*, and the egg is described as *holoblastic*. The cells derived from the division of the ovum are called *blastomeres*. The blastomeres may be very nearly of the same size or some may be much smaller than the others. In the first case the cleavage is said to be *equal*, in the second it is *unequal*. When the blastomeres are not of the same size, the smaller ones are called *micromeres* and the larger ones *macromeres*; and usually they differ in the parts they play in the development of the embryo. Equal cleavage

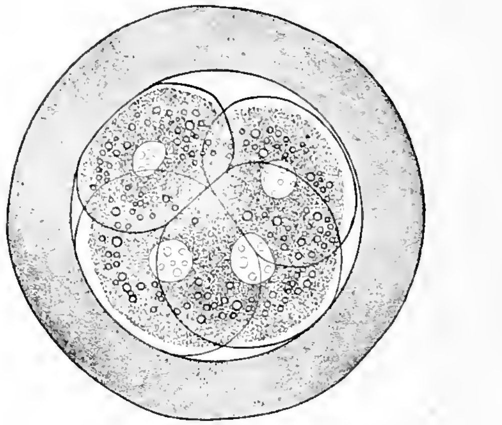

FIG. 4178.—Egg of a Bat, Vespertilio Murina, in the Four-cell Stage. (After Van Beneden and Julin.)

is found in the eggs of sponges, cœlenterates, echinoderms (Fig. 4176), truncates, amphioxus, and mammals (Figs. 4177 and 4178), and in some annelids, crustacea,

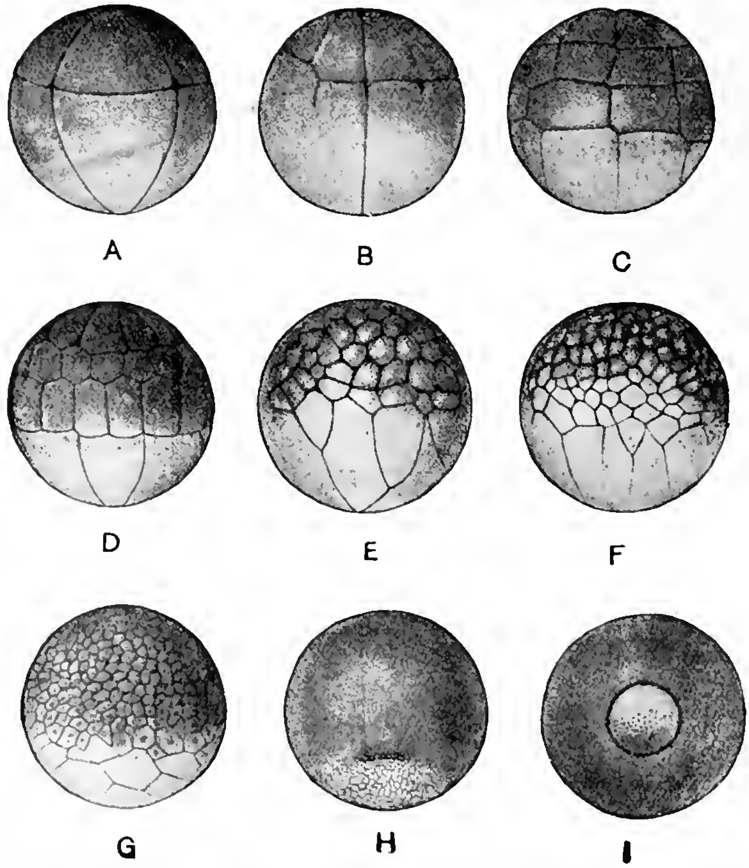

FIG. 4179.—Segmentation of the Frog's Egg and Formation of Blastopore. *A*, Eight-cell stage; *B*, beginning of sixteen-cell stage; *C*, thirty-two cell stage; *D*, forty-eight cell stage (unusually regular); *E*, *F*, *G*, later stages; *H*, *I*, stages in the formation of the blastopore. Magnified. (From Morgan.)

and molluscs. Unequal cleavage is typical of the annelids, molluscs (Fig. 4180), lampreys, gonoid fishes, and amphibia (Fig. 4179).

Other animals produce eggs that contain a very large proportion of deutoplasm. In such cases only a part of

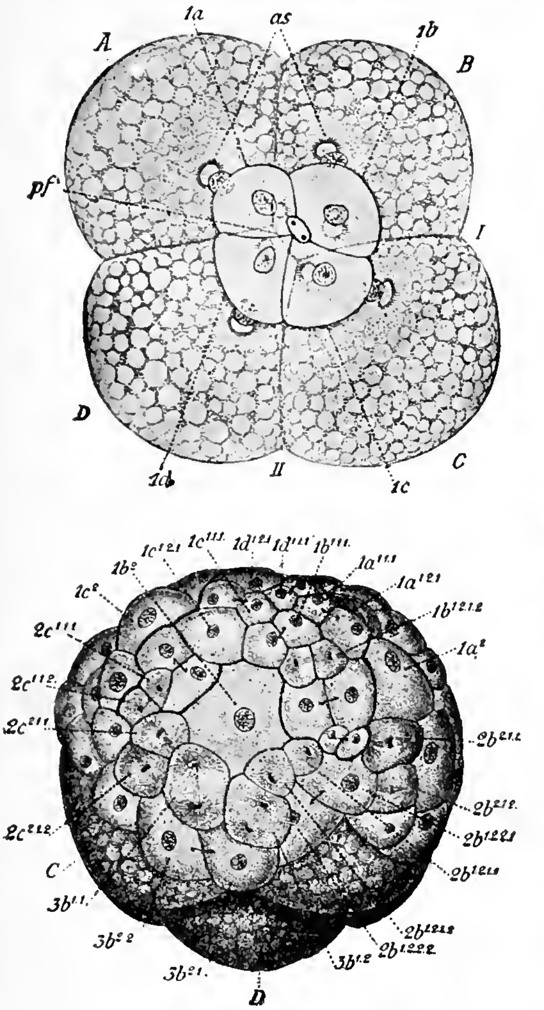

FIG. 4180.—Two Stages in the Development of Crepidula. Upper figure, four-cell stage viewed from above; lower figure one hundred and nine-cell stage, viewed from the side. *I.* and *II.*, first and second cleavage furrows; *A, B, C, D*, macromeres; *1a, 1b, 1c, 1d*, micromeres; *as*, aster. Highly magnified. (From Conklin.)

the egg undergoes segmentation, the rest of the yolk dividing incompletely and being finally absorbed as food by the growing embryo. This form of cleavage is called *partial*, and the egg is described as *meroblastic*.

Meroblastic eggs may be *centrolecithal*, having the yolk chiefly at the centre, or *telolecithal*, having it concentrated toward the vegetative pole (see *Ovum*). Centrolecithal eggs have a *superficial* cleavage, the blastomeres forming a layer of cells, the *blastoderm*, surrounding the unsegmented yolk. This form of cleavage is characteristic of the arthropods. Telolecithal eggs have a *discoidal* cleavage, the blastoderm forming a disc at the animal pole of the egg. This is the form of cleavage to be found in the eggs of cephalopods (Fig. 4181), sharks and rays, bony fishes, reptiles, and birds (Fig. 4182).

The position of the planes of cleavage depends somewhat upon the type of the egg. In centrolecithal eggs the cleavage nucleus takes a position near the centre of the egg previous to division. Then follows a number of nuclear divisions without division of the cytoplasm. The resulting nuclei migrate to the surface of the egg, and the mass of cytoplasm gathered around each nucleus becomes separated from its neighbors by cleavage furrows starting from the exterior.

In alecithal and telolecithal eggs the first two planes of cleavage are always at right angles to one another and cross at the animal pole of the egg (Fig. 4176, *A*, *E*). In the subsequent stages there are developed three types of cleavage—radial, spiral, and bilateral. As examples of the radial type we may take the eggs of sea urchins and of frogs, both holoblastic eggs, the one having equal cleavage, the other unequal. Any one provided with a good microscope can easily observe the cleavage of the eggs of sea urchins or of starfish. The eggs are obtained by cutting up the ovaries of a ripe female. If these are placed in a dish of clean sea water and a small piece of the testis of a ripe male is cut into small pieces and mixed with the eggs, fertilization will take place, and then it requires only a little patient watching of eggs placed from time to time under the microscope for one to observe all

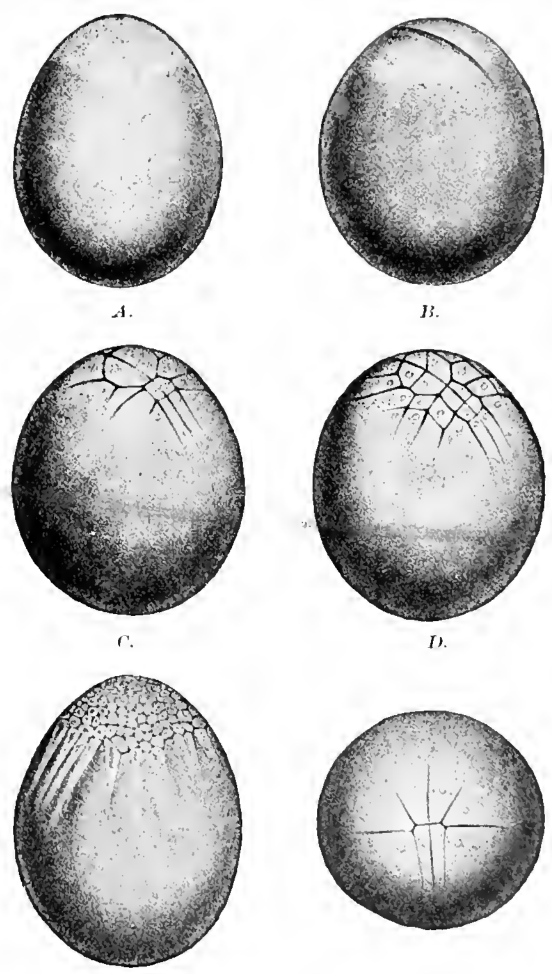

FIG. 4181.—The Discoidal Cleavage of the Egg of a Squid. *A*, Unsegmented egg and polar bodies; *B*, first cleavage furrow; *C, D, E*, later stages; *F*, eight-cell stage viewed from the animal pole and showing the marked bilateral symmetry of the cleavage furrows. × 30. (After Watasé.)

stages up to the formation of the larva. Freshly laid and fertilized frog's eggs may be obtained by careful search of the ponds in early spring. By packing the eggs with ice, development may be delayed until the laboratory is reached. After the eggs have been placed in fresh water at the normal temperature, the cleavage will proceed and may be followed easily with a hand lens or a microscope.

The first indication of cleavage is the appearance of a slight furrow at the animal pole—the position of the polar body in the echinoderm's or the centre of the black half

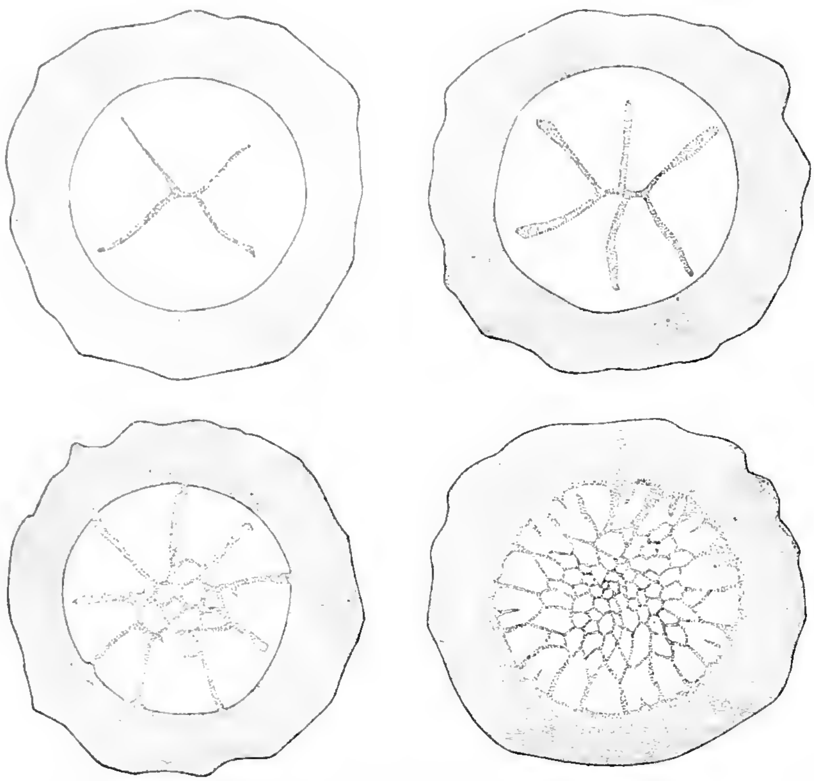

FIG. 4182.—Four Stages of the Segmentation of the Hen's Egg. Only the germinal disc, seen from above, and part of the surrounding yellow yolk are represented. (After Coste.)

in the frog's egg. This occurs in the frog's egg between two and a half and three hours after fertilization. This furrow quickly deepens and extends around the egg to the other side (Fig. 4176, *A* and *B*). Sections of an egg made just before and during this stage show that the nucleus had divided previously by a typical mitosis, and that the plane of cleavage is at right angles to the spindle, so that each blastomere contains one of the daughter nuclei. During the division the blastomeres become more or less rounded. But when it is completed they flatten against one another, so that the line of division becomes indistinct, and the egg rests for a time. At the end of the resting period, about three-quarters of an hour after the appearance of the first furrow in the frog, the blastomeres round up again and the second furrow makes its appearance at right angles to the first at the upper, animal, pole of the egg (Fig. 4176, *C–E*). This furrow extends around the egg like the first, dividing each blastomere into two. The egg is now in the four-cell stage. After another period of rest, the third cleavage furrow appears in a horizontal plane at right angles to both the first and the second. In the echinoderm egg this is very nearly at the equator of the egg, but in the frog it is somewhat above the equator, so that in the eight-cell stage we find four black micromeres and four white macromeres. Compare *F* and *G*, Fig. 4176 with *A*, Fig. 4179. The fourth cleavage in the frog occurs from one-half to three-quarters of an hour later. When this is regular each blastomere is divided into two in a plane at right angles to the preceding one. The planes of division form two great circles bisecting the angles between the first two. But in the frog the eggs are seldom so regular as this and the following cleavages are quite irregular (Fig. 4179).

The spiral form of cleavage is characteristic of the worms and molluscs (Fig. 4180). In these groups the third cleavage plane is not a continuous horizontal circle, but is tilted in each blastomere, to the left usually, looking at the egg from the side. Thus the blastomeres of the two quartets in the eight-cell stage do not lie directly one above the other, but they break joints. The lines of division in the next cleavage are tilted in the opposite direction, and are thus at right angles to the preceding ones. This alternation of spirals may continue for several generations of cells. In these forms the blastomeres are frequently unequal to a marked degree, and the rhythm of cleavage may vary in the blastomeres of different sizes, with the result that there is developed a very complex type of cleavage.

In the bilateral form of cleavage there is but one plane of symmetry, usually coinciding with the first cleavage furrow. The blastomeres are arranged in a bilaterally symmetrical pattern on the two sides of this plane. This form of cleavage is found in both holoblastic and meroblastic eggs, namely, those of tunicates and cephalopods (Fig. 4181).

The cleavage of the hen's egg is not easy to observe, for it takes place before the egg is laid, but it appears to be of an irregular radial type. As in other meroblastic eggs, the earlier cleavage furrows are incomplete, so that the blastomeres are not separated from the undivided yolk. It is only after several radial furrows have formed that concentric ones appear, dividing the blastomeres into a central group of superficially complete ones surrounded

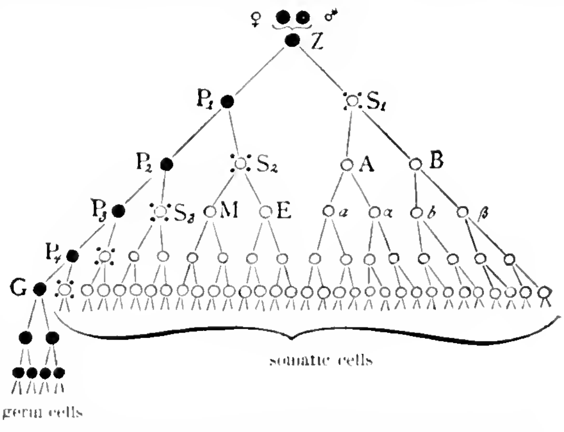

FIG. 4183.—Diagram representing the Determinate Segmentation of the Ovum of Ascaris. *Z*, Fertilized egg; P_1, P_2, etc., protogonocytes; *G*, primordial germ cell (P_5, Fig. 2614, article *Heredity*); S_1, S_2, etc., primary somatic cells; *A* and *B*, primary ectodermal cells; *a*, *b*, daughter cells of the right side; *α*, *β*, of the left side; *E*, primary endodermal cell; *M*, cell which produces mesoderm and part of ectoderm. (Modified from Boveri.)

by a circle of larger blastomeres still connected with the yolk at the surface (Fig. 4182); and it is still later when a horizontal division occurs, separating the central blastomeres from the yolk beneath.

The segmentation of the ovum differs also among the various groups of animals in being either *determinate* or *indeterminate* in character. Typically determinate types of cleavage are found in the eggs of worms (Fig. 4183) and molluscs. In these forms the cleavage is often very complex, and at first glance appears very irregular, but careful study shows that each cell division follows a law that is perfectly definite within the species. Thus the history of each cell may be traced from the first cleavage to the formation of the organs. Conklin, for example, has constructed a remarkable genealogical tree showing the history of each cell in the eggs of Crepidula, the common slipper shell, to the one-hundred-and-nine-cell stage (Fig. 4180), and from the groups of cells present at that stage he was able to observe the development of various important organs.

In the echinoderms and vertebrates, on the other hand, the cleavage soon becomes irregular and no one has succeeded, so far, in tracing the history of the blastomeres. So, for the present, the cleavage of these forms must be regarded as indeterminate. In the frog it has been found that the first cleavage furrow coincides with the principal axis of the body, but this rule is not true for all individuals. So we cannot say that even the first two blastomeres always give rise to certain parts of the body.

Robert Payne Bigelow.

BIBLIOGRAPHICAL REFERENCES.

Conklin, E. G.: Embryology of Crepidula. Journ. Morph., vol. xiii., 1897, pp. 1–226.
Morgan, T. H.: Development of the Frog's Egg. New York, Macmillan, 1897.
Wilson, E. B.: The Cell in Development and Inheritance, second edition, New York, 1900.

SEIGLER'S SPRINGS. — Lake County, California. Hotel.

These springs are located at the foot of Seigler Mountain, at an elevation of 2,372 feet above the sea. They are in the neighborhood of Adams and Bonanza Springs, and lie in Seigler Valley, which is about one mile and a half long by half a mile in width. The surrounding country affords many excellent drives, and magnificent views are encountered on every hand. There are twenty or more springs, which yield approximately three thousand gallons per hour. The "Arsenic" Spring has a temperature of 96° F., and is much used for syphilis, scrofula, and cutaneous disease. The "Soda" Spring is alkaline and carbonated, and forms a delicious drinking-water. It has been much in vogue for Bright's disease, bladder troubles, etc. The "Magnesia" Spring is heavily charged with Epsom salts and carbonic acid gas. A glassful before breakfast insures an easy and painless evacuation of the bowels. The Sulphur Spring is mostly used for bathing and for lung, liver, and rheumatic troubles. There are very good accommodations at the springs.

James K. Crook.

SEMILUNAR GANGLIA, PATHOLOGY OF.—A search through the literature of recent years for the results of work on the pathology of the semilunar ganglia is not very satisfactory. The facts that these organs are such near neighbors of the suprarenal capsules and the pancreas, and that they have such intimate nervous relations, especially with the former, have led to many efforts to establish their pathological association; but these attempts seem to have failed of convincing demonstration, the conclusions reached being largely theoretical. The result is that while the journals contain many articles showing extensive research and experimentation and faithful observation of cases and autopsies, the number of established facts bearing on this subject which can be found in the systematic treatises is small and disappointing.

Romberg was among the earliest to ascribe to the semilunar ganglia definite pathological manifestations. Under the title of NEURALGIA CŒLIACA he describes "a sudden and violent epigastric pain or one preceded by a sense of oppression. It generally extends to the back and there are a sense of fainting, cold extremities, and small intermittent pulse. The region of the stomach is either swelled or sunken and the abdominal parietes are tense. Pulsation at the epigastrium is common. Pressure gives relief. Sympathetic sensations occur often in the thorax, under the sternum, or in the pharyngeal branches of the vagus, but seldom in superficial parts. It lasts for from five minutes to half an hour, and is succeeded by extreme exhaustion. If it breaks off suddenly it is followed by eructations of gas or fluid, by vomiting, gentle perspiration, or copious enuresis. The suppression of accustomed hemorrhages gives rise to it, also it often precedes rheumatism and melæna. Gout predisposes to it, and the development of carcinoma ventriculi is often preceded for years by cœliac neuralgia. The peculiar sense of fainting and annihilation which accompanies it is pathognomonic of this disease, and distinguishes it from such neuralgia of the vagus as is included in the term cardialgia."

Byron Robinson also includes neuralgia cœliaca among the functional disturbances connected with the semilunar ganglia. After remarking that "there may be postmortem findings of lesions of the sympathetic, but these may not have been preceded by records of physical complaints in life, and they may be secondary," he continues:

"Hyperæsthesia or exalted irritability of the sympathetic nerves is liable to manifest pain irregularly, periodically, spasmodically, and yet retain some irritability during the intervals. Anatomically we know little of the characteristic changes in structure in hyperæsthesia. Its etiology also is obscure, although malnutrition is probably a bottom fact. The active hyperæsthesia of the great ganglia of the sympathetic system is characterized by an overpowering sense of prostration, a sense of impending dissolution, as if the centre of life would be destroyed."

These views are quite in line with those of Romberg, and correspond closely with those given by F. A. Hoffmann in discussing the diagnostic significance of subdiaphragmatic pain. He considers radiating pain as characteristic of irritations of the retroperitoneal structures as distinguished from those originating in affections involving the mucous membranes or the parenchyma of organs, the muscular tissue of hollow organs, or the peritoneum. Moreover, he finds that the tendency of pain originating in the aorta, the adrenals, and the solar plexus is to extend downward. He finds that little attention has been paid to a neurosis of this plexus, although it is one comprising very numerous sympathetic filaments, and the neuroses of which must exhibit sensory, motor and vasomotor lesions, suggesting the analogue of migraine.

The characteristic site of the pains which belong to a neurosis of the cœliac plexus is the upper part of the abdomen, and from this point they radiate to the sacral and gluteal regions behind, but not to the genital organs or legs in front. These, with sheeps'-dung fæces and polyuria form a group of symptoms pointing, in the absence of hysteria and tabes, to a diagnosis of a neurosis of the cœliac plexus. He cites three cases in support of his views, two of his own, in which the symptoms mentioned were present, and I would call special attention here to the excessive discharge of urine of low or moderate specific gravity (1.008–1.012) containing neither albumin nor sugar and unaccompanied by great thirst, as one of the pathological features ascribed to the semilunar ganglia.

With reference to the pathological relations said to exist between the semilunar ganglia and the kidneys, as shown in the occurrence of *diabetes insipidus*, the following quotations voice the prevailing opinions: Shapiro says, "that physiologists ascribe an especially weighty influence to the splanchnic nerve in regulating the quantity of urine secreted by the kidneys." He gives the history of a case of diabetes insipidus, the patient having also pulmonary tuberculous disease and becoming greatly emaciated. "The autopsy showed no interstitial inflammation, nor amyloid degeneration of the kidneys, nor pathological changes in the brain or spinal cord, by which the polyuria could be explained, but the microscope revealed noticeable changes in the peripheral nervous elements of the kidneys. The cœliac plexus seemed to be surrounded by a bundle of small lymph glands. The most interesting changes were found on microscopic examination of the cœliac ganglion. There seemed to be thick bundles of connective tissue crossed with many granules. On section, there were seen many enlarged and developed vessels in the neighborhood of which the ganglion cells were distinctly diminished, shrunken, and separated from the capsule. All the cells showed a marked mass of granular pigment. There was also pigment accumulation in the interstitial connective tissue; also fatty degeneration of the axis cylinder of the splanchnic nerve." In this connection it is well to recall the anatomical relations of these nerves and ganglia, viz., that the upper part of each semilunar ganglion is joined by the greater and lesser splanchnic nerves, filaments from them going to the renal plexus and suprarenal gland; also to the inner side of each semilunar ganglion the branches of the solar plexus are connected. The cœliac plexus is a direct continuation of the solar plexus (Gray's "Anatomy"). Futcher quotes from Ralfe as follows: "The sympathetic plays the most important rôle among the peripheral nerves in the etiology of diabetes insipidus. . . . The nerves forming the renal plexus are derived chiefly from the solar plexus. As the right vagus and greater and lesser splanchnics join the solar plexus, it is probable that branches of these nerves enter the kidney by way of the renal plexus. Dickinson reported a case of diabetes insipidus in a patient with *carcinoma of the liver and involvement of the solar plexus;* carcinomatous metastases were found in the retroperitoneal glands which involved branches of the solar plexus. There was marked hyperæmia of the kidneys. . . . Ralfe also refers to tumors pressing on the thoracic and abdominal nerve ganglia, which probably agree in disturbing the vaso-motor governance of the renal vessels."

Pigmentation of the skin, notably that observed as a feature of Addison's disease, has also been ascribed pathologically to the semilunar ganglia. Byron Robinson includes it in his list of the functional disturbances of these organs. Thompson says: "The fact has been confirmed by many observers (Lancereau, Nothnagel, Fleiner, and others) that the pigmentation occurs most prominently in those cases [of Addison's disease] in which the sympathetic nerves are found diseased." Byron Bramwell quotes two French observers, Alezais and Arnaud, as concluding that the essential cause of the pigmentation and other characteristic symptoms of Addison's disease is implication of the pericapsular nervous ganglia, which they describe, by a tuberculous process extending from the adrenals. Marchand, on the other hand, reports *in extenso* a case of disease involving the sympathetic nerves, the suprarenal capsules, and the peripheral nerves, without any bronzing of the skin. Fleiner also reports cases of bronzing of the skin in which there was found no disease of the adrenals, although the cases were ranked as Addison's disease. In fact, until very lately among German writers the pigmentation seems to have been generally regarded as a regular feature of the disease, and the name "bronze Haut" used for it. T. H. Green, however, says that "the cause of the pigmentation in Addison's disease is not satisfactorily explained. Irritation of the abdominal sympathetic is believed to cause increased pigmentation, and the pigmentation in Addison's disease is merely an exaggeration of the normal."

The trend of opinion most recently, however, appears to be that the pigmentation does not belong to Addison's disease as an essential feature, though it may often be noted in connection with it, very probably because of irritation of the sympathetic plexuses and ganglia in the vicinity of the adrenals, which are so often involved in the morbid processes associated with that disease. Neusser says that the formation of pigment in man is controlled by the vaso-motor nerves; in other words, by the sympathetic system acting through the medium of chromatophore cells. Every case of "bronzed skin" does not justify the diagnosis of Addison's disease. Pigmentation is due to a disturbance of innervation in the sympathetic tract.

The pathology of *Addison's disease* has been held to be closely related to the semilunar ganglia since the earliest commentaries were written on the group of symptoms to which that name was given. Thomas Addison's original essay on "The Constitutional and Local Effects of Disease of the Suprarenal Capsules" speaks of an abnormal condition of the semilunar ganglia in but one case, in which they were the seat of fatty degeneration. The writer of the introduction to this essay in the New Sydenham Society's edition remarks that Addison merely noted the correlation as cause and effect of the post-mortem findings of diseased capsules with the group of symptoms he had observed during life, for which he had been able to find no satisfactory explanation. He adds that "true Addison's disease has essential peculiarities of its own, and those not belonging to tuberculous or cancerous capsules." Rolleston quotes Habershon as the first to show that as a result of inflammation spreading from the suprarenal bodies the semilunar ganglia and their branches may become surrounded by dense fibrous tissue. Subsequently to this, and based to a greater or less extent upon the fact noted by Habershon, arose many theories of the pathological relations supposed to exist between the adrenals and the semilunar ganglia, and to account for the various symptoms grouped under the name of Addison's disease. It will be necessary to refer to the more prominent of these, and to some of the cases cited and the arguments adduced for and against them. One of the chief theories was called the "nervous," and Eulenburg and Guttmann say that it "regards Addison's disease as *depending on an affection of the nervous system, especially of the great abdominal plexuses of the sympathetic.* . . . The ganglion semilunare sends a considerable number of twigs to the suprarenal bodies and these form a close network, which is, as Virchow discovered, richly supplied with ganglia. . . . These observations tend to strengthen the theory that Addison's disease is intimately connected with structural changes in the sympathetic. This is not supported, however, by any very good *physiological* reason. . . . Still, *pathological* anatomy has furnished some support for this theory. . . . The results of the examination of the sympathetic still remain, however, antagonistic to each other, at one time negative, at another positive. But even should the positive evidences accumulate in the future, or if it be shown that the changes in the plexuses of the sympathetic are primary and those of the suprarenal capsules secondary phenomena, the question would still be *how* the symptoms of Addison's disease are caused by such changes, a question toward the solution of which we have not advanced one step." This question had to wait some twenty years for an answer.

I quote from Fleiner some account of the pathological findings in two cases of Addison's disease to show in a measure on what this discussion was based. He says: "The facts have been observed that well-marked cases of 'bronzed skin' have post mortem presented no pathological conditions in the adrenals, and, on the other hand, in spite of pathological findings in the adrenals after death the patients presented no symptom of the disease during life."

Fleiner reports two cases of Addison's disease, one slightly and the other much advanced. In the first case on post-mortem examination, tuberculosis of both adrenals was found and noticeable *enlargement* of the semilunar ganglia. In the second case, there was angiosarcoma of the left adrenal, which constituted a metastasis of an extraperitoneal tumor. Here the semilunar ganglia were *diminished* in size. In both cases microscopical examination showed inflammation as well as degeneration of the medullary nerve fibres, not only in the semilunar ganglia but in the whole upper regions of the sympathetic as well as also in the intervertebral ganglia. He also speaks of the degenerative changes in the splanchnic, the cervical ganglia and portions of the posterior columns of the cord, at the entrance points of the posterior roots and in the peripheral nerves. He then expresses the opinion that the principal groups in the symptom complex known as Addison's disease—viz.: (1) The lesions on the part of the digestive organs; (2) the manifestations on the part of the nervous system; (3) the pigmentation—can be satisfactorily explained by the facts he has brought forward in discussing these cases. As a summary he concludes "that for the reasons he has given he feels warranted in regarding as characteristic of Addison's disease a condition of chronic inflammation, which, advancing from the degenerated adrenals, exhibits its highest degree in the semilunar ganglia of the sympathetic and in the intervertebral ganglia, and is appreciable in slighter degrees in the ganglia of the pectoral sympathetic and in the cervical ganglia, and which is emphasized in connection with the alterations in the connective tissue, especially in an intense atrophy of the ganglion cells and in an extensive degeneration of the medullary nerve filaments in the sympathetic and in the splanchnics."

As opposed to these views we find C. Alexander quoting Kahlden to the effect that the assumption that certain symptoms of Addison's disease are referable to the semilunar ganglia is false, that the cœliac ganglion has nothing to do with Addison's disease. He also calls attention to the fact that in various other diseases the semilunar ganglia are involved in pathological changes, as shown by Hale White. That author made microscopical examination of the cervical sympathetic and semilunar ganglia in thirty-three patients dying from various diseases, such as diabetes, cancer of the bladder, aortic disease, sarcoma of the pelvis and breast, chronic Bright's disease, phthisis, tumor of the brain, diphtheria, anthrax, myxœdema, cerebral hemorrhage, etc. "Of the thirty-three semilunars three came from children, and in all of them the ganglion cells were excellent examples of normal nerve cells, some of them showing processes as distinct as those of the cells of the spinal cord. In six only of the remaining thirty were all the nerve cells normal; all the other ganglia showed more or less degeneration of their cells, which in many sections were reduced to minute masses of non-nucleated granular pigment, free in the middle of the capsule. Often there was a large amount of fibrous tissue. In a few instances the section was crowded with leucocytes, but no cause for this could be made out. . . . We may probably conclude that although the semilunar ganglia in the lower mammals and in young human beings are functionally active, in human adults their nerve cells have degenerated and become functionally inactive, but the nerve fibres always retain their structure and function."

So much of the discussion we are tracing out turned upon the question whether the pathological changes in the semilunar ganglia were primary or secondary to those in the suprarenal capsules that I quote the views of Long Fox as follows. He says: "The sympathetic often gives in its coarser lesions evidence that the influence is not that of the sympathetic on disease, but of disease on the sympathetic and its ganglia, and cites such instances as inflammation of the semilunar ganglia associated with headache, increase of their size in case of a tuberculous suprarenal capsule or of cancer of the stomach. Such secondary lesions may in their turn excite certain reflex phenomena, such as flushing, sweating, faintness, palpitation, diuresis. Also the sympathetic, in its character as a connecting link for function between all organs, and subject to various influences, perhaps emotional, perhaps due to altered conditions of the blood, may modify the functional activity of a ganglion or series of them, leaving them even microscopically unchanged. These effects may be motor, sensory, or vaso motor manifestations."

Ziegler also supports the statements of Fleiner and others as follows: "Inflammation of the *sympathetic ganglia and fibres* induces changes in these structures similar to those produced in the spinal nerves. Thus tuberculous caseation of the suprarenal capsules extending to the surrounding tissue sometimes leads to inflammation and proliferation in the solar plexus and semilunar ganglia, resulting in degeneration of the fibres and ganglion cells of the sympathetic. So, too, tuberculous disease of the bones of the vertebral column is apt to extend to the sympathetic nerves and ganglia."

Bramwell distinctly favors the view that the changes in the semilunar ganglia are secondary. He says: "The nerves which pass in such abundance between the capsules and the semilunar ganglia themselves are in a considerable proportion of cases implicated in these inflammatory changes. On naked eye examination they may be seen to be enlarged, thickened, indurated, and sometimes injected and redder than normal. On microscopic examination appearances clearly indicative of inflammatory induration (increase of connective tissue, infiltration with leucocytes, enlargement and engorgement of the blood-vessels) may be present in the fibrous covering of the nerves; in some cases the proper nervous elements (nerve tubes and ganglion cells) are also inflamed, degenerated, or atrophied. These inflammatory changes in the nerve tubes and semilunar ganglia are probably secondary. Sometimes no pathological alterations have been found in the semilunar ganglia or large nerve trunks forming the solar plexus, even when the adrenals have been completely destroyed, and in other cases the solar plexus has appeared quite normal when the adrenals have been completely atrophied, absent, or replaced by fat."

Thompson's study of Addison's disease leads him to the conclusion that the group of symptoms characteristic of the disease, while all pointing to a common origin in a lesion which excites or irritates the sympathetic nervous system, yet are not necessarily referred to the semilunar ganglion alone, but at times to the stomachic, hepatic, or mesenteric plexuses, including irritation of the diseased suprarenal capsules. In a small proportion of cases the adrenals may even remain normal, while the sympathetic nerves and ganglia are alone diseased.

When opinion had reached about the stage represented by authors as quoted above, certain new conceptions and explanations of facts previously observed were brought forward, notably by Rolleston. Attention had been called by Jaboulay to the occurrence of accessory suprarenal glands sometimes to be found upon the semilunar ganglion and in the midst of the solar plexus, and it had been suggested that their presence might explain the absence of the symptoms of Addison's disease in some cases in which the capsules themselves had been found seriously degenerated. Rolleston says "they are often so small as to be found only when carefully looked for, about the size of a grain of corn attached to the main organ by vascular tags and perhaps due to compensatory hypertrophy when the main organ is in a state of caseous degeneration." He quotes Wilks and Greenhow as believing that the *lesion* is primary in the suprarenal capsules and always of the same nature, while the *symptoms* of the disease are due to the secondary effect on the adjacent sympathetic, the solar plexus, and semilunar ganglia. As to the question of the "nervous theory" he concludes that "it is untenable; it does not explain the numerous cases recorded of typical Addison's disease, in which special attention has been paid to the condition of the semilunar ganglia and adjacent sympathetic, and in which they have been found to be normal, since a continued irritation could not last for any time without setting up inflammatory changes *in situ*."

The following quotation from Rolleston indicates the introduction into the discussion of the relations of the semilunar ganglia with Addison's disease, of a new element. It originates in the greater attention paid during recent years to the study of the ductless glands and the results which follow when their secretions are prevented from fulfilling their exact offices in the economy. Rolleston says: "Obstruction to the efferent vessels of the suprarenal capsules is quite a possible cause of Addison's disease." At this point the following of more recent date from Hektoen will show the growth of new views. He says, "Because Addison's disease occurs without any apparent changes in the adrenals, and because the adrenal changes present often involve the abdominal sympathetic, it was attributed to chronic degenerative and inflammatory changes in the semilunar ganglia and abdominal sympathetic" (Wilkes, Jaccoud, Tizzoni, Semmola). This "nervous theory" quite held the field until recently; but the changes described by some in the nerves are frequent in apparently healthy individuals (Hale White, quoted above), and extensive chronic fibrous inflammation in the vicinity of the adrenals might lead to destruction of the efferent vessels, the sequence of events being comparable to Bonnet's experimental ligature of the veins of the adrenals with fatal effects. Addison's disease may occur without any changes in these nerves."

It has been almost impossible amid all these often conflicting theories to disentangle the pathological relations of the semilunar ganglia to the adrenals from those of these latter bodies to degenerative processes in themselves or to the result of pressure upon their efferent vessels by external agencies. It seems justifiable to express the belief, however, that the semilunar ganglia can no longer be regarded as the sole or chief and efficient causes of Addison's disease. Osler, in fact, in 1896 wrote as follows: "Although the view of disturbed innervation consequent upon the involvement of the abdominal sympathetic meets the case theoretically better than any other and is at present widely held, yet there are signs of a return to the old view of Addison."

Most recently, however, we have in Neusser's article such an elaborate and important review of Addison's disease, with independent and theoretical developments also, as cannot be overlooked, although a few brief extracts must suffice. As far as they concern the special topics treated in this article the following embody some of his conclusions and the reasons for them. He quotes from Brauer the opinion that there is no constant relation between Addison's disease and changes in the sympathetic, but reasons out the relations which he regards as intimate though not quite clear between the adrenals and the cœliac ganglion in this way: "Lesions of the sympathetic system have been observed both in connection with and in the absence of disease of the suprarenal capsules. They may affect, first the sympathetic ganglia in the substance of the suprarenal capsules and the pericapsular ganglia occasionally present, then the nerve fibres running from the suprarenal bodies to the cœliac ganglion, the ganglion itself, and the solar plexus, in addition to the sympathetic tracts extending from this point even as far as the cervical ganglion of the ganglionated cord, and finally the splanchnic nerve. . . . Many of these changes are dependent upon tuberculous disease of the suprarenal bodies and the resulting cicatrization. . . . In every case the symptoms of Addison's disease result from impairment or eventually complete suppression of the functions of these capsules brought about by disease of these capsules themselves or of the nerve tracts controlling their function This impairment of function causes most symptoms."

Although this exposition throws the light of modern physiological research upon the question that has occupied us, still it cannot be considered so complete or simple as to be wholly satisfactory, although it does clear away many of the mists of the last half-century. Neusser's article is most careful, comprehensive, and readable, and has the fullest possible bibliography.

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BIBLIOGRAPHY.

Addison, Thomas, Collection of the Published Writings of, London, 1868, New Sydenham Society.
Alexander, C.: Die Nebennieren und d. Bezieh. z. Nervensystem. Ziegler's Beitr., xi., 1892.
Bramwell, Byrom: Anæmia and Some of the Diseases of the Blood-forming Organs and Ductless Glands, Edinburgh, 1899.
Brauer, L.: Deutsche Zeitschr. f. Nervenheilkunde, 1895, vii., Hefte 5 u. 6
Eulenburg and Guttmann: Physiology and Pathology of the Sympathetic Nervous System. Transl. by A. Napier, London, 1879.
Fleiner, W.: Ueber die Veränderungen des sympathischen u. cerebrospinalen Nervensystems bei der Addison'schen Krankheit, in Deutsche Zeitschr. für Nervenheilkunde, vol. ii., 1891–92.
Fox, Edward Long: Influence of the Sympathetic on Disease. Med. Times and Gazette, September 2d, 1882.
Futcher, J. B.: Johns Hopkins Hospital Reports, vol. x., 1902.
Green, T. H.: Pathology and Morbid Anatomy, Philadelphia, 1900, p. 79.
Greenhow, E. H., on Addison's Disease, being the Croonian Lectures for 1875, London, 1875.
Habershon: Guy's Hospital Reports, 1864.
Hektoen: American Text-book of Physiology (Hektoen and Riesman), Philadelphia, 1901.
Hoffmann, F. A.: Ueber hypophrenische Schmerzen u. Neurose der Plexus Cœliacus. München. med. Wochensch., February 18th, 1902.
Jaboulay: On Accessory Adrenals Situated on the Semilunar Ganglia, etc. Lyon. Méd., November 2d, 1891.
von Kahlden: Virch. Archiv, 114, 1888, p. 67.
Lloyd, J. H.: Diseases of the Cerebro-spinal and Sympathetic Nerves. Twentieth Century Practice, New York, 1897, xi., 3, 476.
Marchand, F.: Ueber eine eigenthümliche Erkrankung des Sympathicus, der Nebennieren u. der peripherischen Nerven (ohne Bronzhaut). Virch. Archiv, 81, 1880, p. 477.
Neusser, E.: Addison's Disease, in Nothnagel's Encyclopedia of Practical Medicine, American edition, 1903, vol. ix.
Osler, W.: Internat. Med. Magazine, vol. v., 1896–97, p. 3; Practice of Medicine, third edition, New York, 1898.
Ralfe: Allbutt's System of Medicine, vol. iv., pp. 236, London, 1897.
Robinson, Byron: A Classification of Diseases which may Belong to the Domain of the Sympathetic Nerves. Kansas City Med. Index, 1897, xviii., p. 317.
Rolleston: Brit. Med Journ., i., 1895, p. 630 *et seq.*
Romberg, M. H.: Manual of the Diseases of the Nervous System. Transl. by Sieveking, London, 1853, vol. i., p. 128.
Schapiro, H.: Zur Lehre von der zuckerlosen Harnruhr, in Zeitschr. f. klin. Med., vol. viii., 1884.
Thompson, W. G.: A Study of Addison's Disease and of the Adrenals. Transactions Assn. of American Physicians, vol. viii., 1893, p. 352.
White, William Hale: Journ. of Physiology, x., 1889, p. 341.
Ziegler, E.: A Text-book of Special Pathological Anatomy. Trans. and edited by McAlister and Cattell, London, 1896, p. 475.

SEMINAL INCONTINENCE. See *Sexual Organs, Male, etc.*

SEMINAL STAINS, MEDICO-LEGAL EXAMINATION OF.—This examination is often of great importance in connection with cases of alleged rape or sodomy. The substances which are usually submitted to the expert to be examined for seminal stains are articles of bedding or of underclothing of the supposed victim, but it often happens that other substances are also to be examined. Seminal fluid, after it has become dried, adheres very tenaciously to any substance with which it was in contact when fresh, so that it sometimes happens that specimens of hair or scrapings from the skin require to be submitted for expert examination. In some cases it is also necessary to examine scrapings from the mucous membrane of the supposed victim taken in some cases during life, and in other cases, where a homicide also has been committed, after death. Therefore it often happens that the stain examined is not a simple but a compound one. This stain may consist of pure dried seminal fluid, or it may be an admixture of seminal fluid with blood, pus, or cells from various mucous membranes, or of all combined.

As a general rule, a dried seminal stain upon white cloth does not cause much change in the general appearance of the cloth. It may be slightly tinged, or in rare instances it may be slightly bloody. Upon unstarched cotton or linen cloth it will generally be noticed, however, that the cloth has a stiffer feel than the same cloth in the neighborhood of the stain, and, if it be held up to the light, it will be seen that the meshes of the cloth are filled up to a greater extent than those in the cloth surrounding the stain. If seminal fluid happens to fall on a non-absorbent surface, such as starched cloth, and heavy woollen fabrics as in cases of certain articles of outer clothing, or upon the skin or hair, and dries, the stain forms a nearly white deposit upon the fabric. This white stain would be very readily perceptible upon dark clothing.

Up to within a few years no chemical test was known which could be applied to a seminal stain, but in 1897 Dr. Florence, of Lyons, proposed a new test applicable to human seminal stains, which he considered to be a positive test for human seminal fluid. According to the experience of the writer, it always does produce a positive reaction with human seminal fluid, whether dried or fresh, but it also gives the same reaction with certain other substances. It is, therefore, like the guaiacum test for blood stains, an extremely valuable preliminary test for seminal stains, because, if a negative result is obtained, we know immediately that the stain in question does not contain dried seminal fluid.

The reagent recommended by Dr. Florence is a solution of iodine in iodide of potassium, made as follows: Pure potassium iodide, 1.65 gm.; iodine (previously washed), 2.54 gm.; distilled water, 30 gm.

The test is performed in the following manner: If the stain is on a non-absorbent surface, so that it forms a layer of more or less thickness, a minute fragment can be scraped off with a penknife and transferred to a microscope slide, treated with a drop of water, and then a minute drop of the reagent brought in contact with the edge of the drop of the water containing the fragment of the dried stain. If the stain contains dried seminal fluid, there will be formed a brownish precipitate, which, when covered with a cover-glass and examined with the microscope, will be seen to consist of numerous minute brown crystals, often arranged in groups, somewhat resembling the so-called hæmin or blood crystals. If the stain is upon a piece of unstarched cotton or linen cloth, the same result is obtained if a minute fibre of the cloth is cut out, treated with water in the same manner as above described, and brought in contact with a small drop of the Florence reagent.

Dr. Florence, in his original article ("Du Sperme et des Taches de Sperme en Médecine Légale," Lyons, 1897), states that he has been unable to obtain this reaction with anything but human seminal fluid. He has not obtained it with the seminal fluid of any animal, nor with any other human secretion except seminal fluid, but the writer has obtained the same crystals by the action of this reagent upon a little extract of partly decomposed suprarenal capsule, and also with a minute quantity of lecithin treated with water. It does not give the reaction with any of the ordinary human secretions, so that this reagent is of exceptional value as a preliminary chemical test for seminal stains.

A seminal stain can, however, be detected with absolutely certainty only by the recognition of the characteristic formed elements of seminal fluid, called spermatozoa, by microscopic examination, and generally it is necessary to use the higher powers of the microscope. These are usually found associated with various cellular elements coming from the seminal passages and prostatic ducts. Spermatozoa are usually recognized by their peculiar tadpole shape, having a peculiar conical-shaped head, and a long tail several times longer than the head. The spermatozoa of different animals vary somewhat in their size, and in the proportion of the head and tail. Human spermatozoa when fresh are about $\frac{1}{500}$ to $\frac{1}{550}$ inch in length, the length of the head being about $\frac{1}{3000}$ inch. If seen upon its side, the head of a spermatozoon appears pear-shaped, the anterior one-third of the head being less dense than the posterior two-thirds, so that if a stained spermatozoon be examined it will be seen that the anterior one-third of the head is colored less deeply than the posterior two-thirds. Spermatozoa may be detected in dried seminal stains for many years after the stain was made. The writer has been able to detect them in a dried stain more than four years old. Roussin has detected them after eighteen years (*Annales d'Hygiène*, 1867, i., 152). Unfortunately, however, after spermatozoa become dried, they are very brittle, and the tail is very liable to be broken off from the head by ordinary manipulation of the cloth or by the manipulation necessary in preparing the stain for microscopic examination. It is for this reason that so few perfect spermatozoa are found in the examination of a dried seminal stain.

For the certain recognition of a seminal stain it is, in the opinion of the writer, necessary to find absolutely perfect spermatozoa with head and tail complete, since many other substances, such as certain spores, might be mistaken for the heads of spermatozoa, and many other substances, such as delicate fibrils from the cloth fibres, might be mistaken for the detached tails. Care should always be taken, therefore, not unnecessarily to handle or rub the stain suspected to be a dried seminal stain before submitting it to the expert for microscopic examination.

The recognition of the spermatozoa is comparatively easy in cases in which the stain is a scaly one upon a non-absorbent surface. In that case it is necessary only to scrape off a little of the scaly stain and transfer to a microscopic slide, treat it with a drop of water or some fluid which does not dry readily, such as dilute glycerin, or a solution of potassium acetate, and allow it to soak for several hours. It can then be gently broken up and stained, if desired, by some of the ordinary stains used in pathological work, covered with a cover-glass, and examined with the microscope. Dr. Florence recommends a concentrated aqueous solution of crocein, but the writer has had very satisfactory results by staining with methyl green or eosin. Usually, however, the spermatozoa can be recognized very satisfactorily if they have not been stained. A microscopic power of seven hundred or seven hundred and fifty diameters should be employed for the microscopic examination, and in some cases it will be found advisable to use an oil-immersion lens for the examination.

If the stain is upon unstarched cotton or linen cloth, the recognition of the spermatozoa is much more difficult, because they are much more liable to become broken by preliminary handling, and also because the spermatozoa apparently cling very tightly to the fibres of the cloth when fresh, and are very liable to become broken when the fibrils of any individual fibre are separated. In order to prepare such a stain for examination, care should be taken to select a point near the centre of the stain, because the spermatozoa are more apt to be present in the centre of the stain than near the edges. Then a few threads may be cut from this portion of the stain, so that the individual fibres do not exceed in length one-sixteenth or one-eighth of an inch. Each thread should then be treated separately upon a glass slide or cover-glass with a small drop of water for at least two hours, care being taken to prevent the evaporation of the water. It would perhaps be better if they could be soaked for from twelve to twenty-four hours without being allowed to become dry. These individual threads, after having been digested for several hours, should be very carefully separated into their individual elements or fibrils by means of very sharp-pointed needles. The preparation can then be stained or not, according to the desire of the examiner, be covered with a cover-glass, sealed with paraffin so as to prevent evaporation, and examined with the microscope.

Moist material, such as scrapings from the mucous membrane of the vagina, for instance, can be treated with a drop of water and examined immediately with the microscope with or without being stained.

Edward S. Wood.

SENEGA, U. S. P. (*Senegæ Radix* B. P.).—The dried root of *Polygala Senega* L. (fam. *Polygalaceæ*). The senega plant is a smooth, perennial herb, its habit well displayed in the accompanying illustration. Flowers small, pinkish-white, in terminal spikes; calyx irregular, of three small green, and two (lateral) large, petaloid sepals, the latter concave and enclosing the corolla; corolla consisting of three partly united petals, of which the lower is concave and ornamented with a crest of papillæ; stamens eight, diadelphous (4 + 4); ovary transversely two-celled; style single. Senega has a wide range in the United States, from Western New England and the Middle and Western States southward. It is now mostly collected in Minnesota and Manitoba. The variety *latifolia* is a larger form with broader leaves.

The plant takes its common name, "Seneca snakeroot," from the Seneca Indians, by whom it is reported to have been used as a remedy for snake bites.

The root is mostly 7 to 15 cm. (3 to 6 in.) long and 4 to 8 mm. ($\frac{1}{6}$ to $\frac{1}{3}$ in.) thick, exclusive of the large, knotty, many-headed crown, occasionally reaching several times this size; tortuous, tapering, and bearing several similar horizontal branches, and few rootlets, and for a variable distance below the crown a more or less sharp keel, vary-

FIG. 4184.—Senega, Root and Stem. One-half natural size. (Baillon.)

ing greatly in prominence, and usually taking a spiral direction, often nearly absent; externally yellow-brown to dark-gray-brown, longitudinally wrinkled; fracture rather tough, but short and sharp, the bark thick, yellow or brownish, of a waxy or resinous, faintly fine-radiate appearance, enclosing a yellowish-white wood, from which a larger or smaller radial segment is usually wanting; odor slight, disagreeable; taste sweetish, then acrid.

Various adulterants of senega have been reported, consisting chiefly of the roots of other species of *Polygala* of the Southern United States, but any other than the genuine root is now scarcely seen in commerce.

CONSTITUENTS.—The important constituents of senega are the two saponin like glucosides *senegin* and *polygalic acid*, from one to two per cent. of the former and about five per cent. of the latter. There are also present from six to nine per cent. of fixed oil, some glucose, resin, gum, and very variable amounts of methyl salicylate and methyl valerianate, which latter give to the drug its characteristic odor. Starch is wanting. Senegin resembles in properties and action the saponin of soap-bark, while polygalic acid resembles quillajic acid, but they are weaker, respectively, than these substances.

ACTION AND USE.—Senega possesses in medium degree the characteristic physiological properties of the saponin-containing group of drugs. In the nares it is sternutatory, in the mouth acrid and somewhat sialagogue. In small doses it is stomachic and laxative; in larger ones emetic or purgative. It is a nauseating yet stimulant expectorant, and this constitutes the basis of its principal use. It has been extensively employed in chronic bronchitis and other diseases accompanied by cough. As an ingredient of cough preparations it has probably its most extensive use, but is much less valued than formerly. As an emmenagogue and diuretic it is obsolete.

The dose of senega is about 1 gm. (gr. xv.). The official preparations are the fluid extract and from it the twenty-per-cent. syrup, which also contains one-half per cent. of ammonia water. The compound syrup of squill contains eight per cent. of fluid extract of senega.

Henry H. Rusby.

SENILITY.—(Latin *senilis*, from *senex*, an old man.) Senility is the condition of body and mind resulting from the sum total of degenerative changes characteristic of old age.

The period of old age has its beginning, from the biological point of view, at the time of cessation or decline of the reproductive function. This occurs suddenly in women at the time of the menopause, while in men there is a gradual decline from about the fortieth year. Some animals have no old age, as is the case with those insects that die from exhaustion or shock immediately after completing their reproductive functions. Other animals, notably man, have a considerable period of old age in their lives, unless they are cut short earlier by accident or disease.

During this period, which has been studied chiefly in man, the body undergoes certain degenerative changes which result in the gradual loss of function in the various organs until, if no other cause intervenes, the individual dies, as we say, of old age.

One of the most characteristic features of senility, as was pointed out by Canstatt (1839), is the fact that it does not appear in all the organs of the body at the same time, but it begins sometimes in one organ, sometimes in another, while the remaining organs of the body continue in a normal condition.

Of the various pathological conditions met with in the aged, it is not easy to determine always which should be regarded as strictly senile and which are more characteristic of the period of maturity. But it seems to be the general opinion that the most important and characteristic of the senile changes are those that occur in the walls of the blood-vessels, especially the arteries; and, according to Demange (1886), the impairment of nutrition thus brought about is responsible for all the other strictly senile conditions. In five hundred carefully made autopsies on old people Demange found in every case evidence of endarteritis. The importance of arteriosclerosis as a cause of lesions of the tissues appears to have been recognized first by Gull and Sutton in 1871. In regard to this disease Osler says: "Longevity is a vascular question, and has been well expressed in the axiom that 'a man is only as old as his arteries.' To a majority of men death comes primarily or secondarily through this portal. The onset of what may be called physiological arteriosclerosis depends, in the first place, upon the quality of arterial tissue (vital rubber) which the individual has inherited, and secondarily upon the amount of wear and tear to which he has subjected it. That the former plays the most important rôle is shown in the cases in which arteriosclerosis sets in early in life in individuals in whom none of the recognized etiological factors can be found. Entire families sometimes show this tendency to early arteriosclerosis, a tendency which cannot be explained in any other way than that in the make-up of the machine bad material was used for the tubing."

As causes of wear and tear of the arteries Osler enumerates: (1) Chronic intoxications, as from alcohol, lead, gout, and syphilis; (2) overeating; (3) overwork of the muscles; and (4) renal disease.

It may be too much to say that senility is always associated with or caused by a diseased condition of the arteries, for, according to Schrötter, the literature contains a number of cases of persons who have lived over a hundred years and whose arteries were found to be normal. Unfortunately, these cases have never been gathered together and discussed collectively. So we know practically nothing of senility from which arteriosclerosis is absent. It is interesting to note that according to the statistics of Eppinger, quoted by Schrötter, the period of maximum frequency of this disease is for men between the ages of sixty and seventy years and for women between seventy and eighty years, thus corresponding fairly well with the period of maximum death rate for aged men and women, respectively. (See *Longevity*.)

Councilman (1891) distinguishes three forms of arteriosclerosis: (1) Nodular arteriosclerosis, (2) senile endarteritis; and (3) diffuse arteriosclerosis. While these forms grade into one another more or less, the third form is regarded by Councilman as a definite disease arising during middle life, and is of little interest in connection with the subject of this article. But the other forms are so characteristic of old age and appear to play so important a part in fixing the natural limit to man's life, that they possess a unique biological as well as medical interest. The histological picture of these conditions is described elsewhere (see article *Blood-Vessels, Pathological Anatomy of*), and we will refer here only very briefly to their causation.

The most generally accepted theory is that of Thoma, set forth in a long series of papers, the last of which appeared in 1898. According to this view, the beginning of the process is a "compensatory endarteritis." Thoma's law, as quoted by Peabody (1891), is that "every slowing of the blood current in the arteries and veins of man which is not completely and at once remedied by a proportionate contraction of the media, leads to a new growth of connective tissue in the intima, which narrows the lumen of the affected vessel and thus restores the normal swiftness of the blood current more or less completely." The first cause, according to Thoma, appears to be the slowing of the blood current, which may be due to a stoppage of the flow beyond or to a decrease of pressure. If the muscular coat is not able to contract sufficiently to restore the normal rapidity of current, the slowing of it in some way stimulates the nerve endings, Pacinian bodies, in the arterial wall, and this sets up a reflex hyperæmia of the vasa vasorum, which in turn results in proliferation of connective tissue and an accompanying proliferation of the vasa vasorum themselves into the media, which normally lacks these vessels. According to Councilman, this explanation is extremely hypothetical and without analogy in pathology.

Henri Martin and Huchard have developed an attractive theory of the etiology of arteriosclerosis, starting with a primary lesion in the vasa vasorum. But, then, the lesion in the vasa vasorum is left to be accounted for, and there is the further difficulty, as pointed out by Schrötter, that arteriosclerosis occurs in arteries that have no vasa vasorum.

Sokoloff (1892) has shown experimentally that it is not a lessening but an increase of blood pressure that causes new formation of connective tissue. And this harmonizes with most of Thoma's results, as, for example, thickening of the intima of the aorta between the ductus arteriosus Botalli and the umbilical arteries of children after birth, and the similar process in the arteries of amputated limbs, in both of which cases there is a sudden rise of blood pressure due to the stoppage of the peripheral circulation. It would simplify Thoma's law if we might make it read somewhat as follows: Whenever the intima is unduly stretched the connective tissue tends to increase, giving rise to a compensatory endarteritis. The stretching may be due to increase of blood pressure or to failure of the media under normal pressure. Such a proliferation of connective tissue under strain has its analogy in the reactions of bony tissue to stresses and strains, and might result from the direct stimulation of the cells without the establishment of a reflex arc.

We are indebted to Seidel (1890) and to Councilman (1891) for convenient reviews of the senile changes in the various organs of the body. It will suffice for the present article to give little more than a list of these phases of senility, and the reader is referred for details to the articles on the special topics indicated.

The nodular form of arteriosclerosis, which is found frequently in autopsies on old persons, is confined to the aorta and large arteries. "We find along the course of the vessel, which is otherwise smooth and of normal calibre, elevated plaques, sometimes translucent and cartilaginous in appearance, sometimes calcified or softened. The growth is entirely within the intima, and the media at the point affected is thin and degenerated" (Councilman). This condition frequently involves the orifices into lateral branches and may descend to the valves of the heart, thus giving rise to serious functional disturbances.

In typical cases of senile endarteritis the aorta and all the larger arteries are converted into almost rigid calcareous tubes with walls thinner than normal. Similar conditions may be found less commonly in the veins and even in the capillaries.

The heart is one of the organs most frequently impaired in old people. In cases of senile endarteritis it is frequently small, the condition of brown atrophy being common. On the other hand, in seven out of fourteen autopsies on such cases Councilman found a small degree of hypertrophy. The coronary arteries may become sclerotic, and this is a potent cause of disease of the heart, the walls of which, according to Seidel, may undergo changes analogous to the atheroma of the larger arteries.

All of the organs concerned in respiration are subject to senile changes. The segments of the sternum become ankylosed, the costal cartilages become ossified, the ribs change somewhat in shape, with the result that there is a loss of mobility and capacity of the chest. The chest muscles also atrophy, adhesions form in the pleuræ, and, owing to atrophy of the alveolar walls, the respiratory surface is decreased, producing senile emphysema.

The digestive tract is also subject to important alterations, especially characterized by the atrophy and degeneration of the glands. The muscular fibres of the stomach and intestine lose their tone and allow of dilatation. In connection with disturbances of the circulation, the liver frequently suffers the lesions resulting from engorgement, atheromatous changes, sclerosis of the connective tissue, and reduction in size of the gland cells.

The kidneys are subject to atrophy and sclerosis, and the renal arteries become atheromatous. The result is a diminution in the secretion, and the consequent retardation in the removal of waste products from the body adds another factor to the unfavorable environment of the component cells of the organism in old age.

In the urogenital system the cessation of the reproductive function is accompanied by loss of weight and volume of the ovaries and testicles, with atrophy of the germinal cells and increase in the connective tissue. According to Seidel, the arteries are atheromatous, but Metchnikov calls attention to the fact that degeneration of the ovarian ova and their replacement by connective tissue begins early in life and is completed before arteriosclerosis sets in. Hypertrophy of the prostate occurs in a large number of old men (according to Seidel, in sixteen to twenty-two per cent.), and atrophy of that organ is also common. The muscular coat of the bladder becomes atonous, due to fatty degeneration of the wall with passive distention. The ureters may also become distended, and their muscular coat may undergo fibrous degeneration. The connection of all these troubles with arteriosclerosis was first demonstrated, according to

Seidel, by the Guyon School in Paris (Lannois, 1885; Arthaud, 1885).

The first change in the skin is the appearance of gray hair. The subcutaneous tissue atrophies, producing wrinkles, and the atrophy extends to the cutis. These changes are accompanied by atheromatous arteries and varicose veins.

Even the apparently stable skeleton suffers extensive alterations in old age. There is in general a tendency toward calcification of the cartilages and ankylosis of the joints and sutures, while the spaces within the bones become enlarged and the compact bone becomes more spongy. But arthritis deformans does not belong in the category of senile alterations, as it appears commonly at an earlier period.

Accompanying these changes, there is more or less atrophy of the muscles, sometimes with fatty infiltration. In the central nervous system there is some loss of weight and volume, often with local areas of degeneration; while the meninges become thickened and adherent. The brain is one of the organs in which the connection between the senile changes and an atheromatous condition of the vessels is most evident.

With the changes in the brain substance there appears a decline of its functions. The reflexes become slower and less intense. The organs of special sense become impaired, and there is a decadence of the intellectual and moral attributes.

Recently Mühlmann (1901) has described a deposition of fatty pigmented granules in nerve cells. This begins in the third or fourth year of life, the granules being at first scattered and later collected in a definite place in the cell. With age the number of cells showing this phenomenon gradually increases, and the amount of the inert, pigmented, fatty material becomes larger in each cell until in old age there is but little protoplasm left, for the cells do not increase in size. Mühlmann regards this as a normal process of senile degeneration, finally ending in death.

There are three principal theories as to the biological significance of senility: (1) Senility is the result of the inherent properties of protoplasm; (2) it is not due to the inherent properties of protoplasm, but has been acquired as a normal process by the multicellular animals and plants for the good of the species; (3) it is a pathological condition resulting from the imperfect adaptation of the organism to its surroundings.

Maupas in France and Minot in this country are among the chief advocates of the first theory. They imagine the organism to receive a store of vital energy at the time of fertilization, and this energy is supposed to be dissipated gradually until, if no accident occurs, the organism dies of old age. As evidence Minot cites the results of his investigations on the growth of guinea-pigs, in which it was shown that the rate of growth diminishes from the time of birth. (See *Growth.*) But it would seem that the facts could be accounted for equally well by the familiar physiological principle that with growth the surface for the absorption of food increases in proportion to the square of the stature, while the tissues to be fed increase as the cube. Thus, other things being equal, the larger the organism the slower would be the rate of growth.

The second theory is Weismann's. According to his view, the protozoa never die of old age. But the higher organisms have been endowed with senility and natural death through natural selection, those species which are composed of the greatest proportion of young uninjured individuals being the best fitted to survive the struggle for existence with other species. This involves the idea that senility is a normal condition like growth or hunger, which is denied by the advocates of the third theory.

Metchnikov (1899) has appeared recently among the latter with a remarkable hypothesis of phagocytosis as a cause of senile degeneration. He calls attention to the fact that the loss of the power of cell multiplication is not universal in old age, as one would expect it to be on the theory of senility being a normal process. On the contrary, the connective-tissue elements show a remarkable capacity for growth. He supposes a struggle for existence to be going on continually in the body, in which the megaphagocytes are on one side and all the remaining cells on the other side. These megaphagocytes attempt to attack and devour everything they touch, whether living or dead. Healthy living cells can resist them, but when a cell is weakened by any cause, for example, bacterial poison, the phagocytes are successful, and, after destroying the weakened cells, they take their place and change into connective-tissue corpuscles. Unfortunately for this hypothesis, however, there is very little observational evidence to support it.

On the other hand, there is abundant evidence of the close relation between senility and a diseased condition of the walls of the blood-vessels, and Thoma's main thesis that this condition arises primarily as an adaptive modification to meet unfavorable conditions of life harmonizes well with the facts. The pathologists are agreed that with the beginning of arteriosclerosis a vicious circle is soon established, resulting in the progressive increase of the various troubles associated with that disease. If this group of pathological conditions does not form the sole feature of senility, it certainly forms the most conspicuous one. And in the absence of any knowledge of the unknown conditions, if there be any, we should expect, on the theory of chances, that these unknown conditions would be of the same general character as the known conditions. Spencer has defined life as "the continuous adjustment of internal relations to external relations," and we may define senility as the progressive result of imperfect adjustment of internal relations to external relations. *Robert Payne Bigelow.*

REFERENCES.

Canstatt: Die Krankheiten des höh. Alters und ihre Heilung. Erlangen, 1839.
Charcot, J. M.: Clinical Lectures on Senile and Chronic Diseases. Trans. by W. S. Tuke, London, 1881.
Councilman, W. T.: On the Relations between Arterial Disease and Tissue Changes. Trans. Assn. Amer. Phys., vol. 6, 1891, pp. 179-192.
Demange: Étude clinique et anatomo-pathologique sur la vieillese, Paris, 1886.
Martin, H.: Pathogenie des lésions athéromateuses des artères. Rev. d. méd., 1881.
Metchnikov, E.: Revue de quelques travaux sur la dégénérescence sénile. Année biol., vol. 3, 1899, pp. 249-267.
Minot, C. S.: Senescence and Rejuvenation. Jour. of Physiol., vol. xii., 1891.
Mühlmann, M.: Ueber die Ursachen des Alters, Wiesbaden, 1900.
Peabody, G. L.: Relations between Arterial Disease and Visceral Changes. Trans. Assn. Amer. Phys., vol. 6, 1891, pp. 154-178.
Schrötter, L. v.: Erkrankungen der Gefässe, Wien, 1901.
Seidel, A.: Diseases of Old Age. Wood's Med. and Surg. Monog., vol. v., 1890, pp. 629-635.

SENNA, U. S. P., B. P. (*Folia Sennæ*, P. G.).—The dried leaflets of *Cassia acutifolia* Delile (*Alexandria Senna*), or of *Cassia angustifolia* Vahl (*India Senna*); fam. *Leguminosæ*.

In the United States, German, and French pharmacopœias, the general title covers both the principal varieties; in the British, the Alexandrian (*Senna Alexandrina*) and Tinnivelly (*Senna Indica*) sennas are distinguished by name; they are always entirely distinct in the market.

1. *C. acutifolia* Delile is a small shrub about a meter (a yard) high. Its pod is broad, flat, coriaceous, slightly curved, rounded, and oblique at the ends, containing about half a dozen seeds. This species has a wide and unknown range in Central Africa, is abundant in Nubia, Kordofan, Sennaar, etc., and is said to be found in Timbuctoo. The leaflets are gathered twice a year by native tribes and carried to Alexandria, where they are very carefully freed from sticks, stems, stones, and other impurities, and the broken and defective leaves separated, the different portions of leaf, even to the siftings, being marketed separately.

2. *C. angustifolia* Vahl, is also a small shrub, a good deal like the preceding, but it has larger flowers and larger, more numerously paired leaflets. Its pod is narrower and straighter than that of *C. acutifolia*, and contains about eight seeds. It is a native of Arabia, and in the wild state supplies an inferior, carelessly collected variety of senna (Arabian). It is also said to be found

in Somaliland. This is the species cultivated in the south of India (where it is not indigenous) as the source of Tinnivelly senna. The leaves, under cultivation, are increased in size and improved in quality.

Although the Alexandrian variety brings a higher price and is generally held in higher esteem, there seem no good grounds for the idea that it is essentially different in its action from the other.

DESCRIPTION.—*Alexandria senna* consists of leaflets with extremely short, stout petioles, about 2.5 cm. (1 in.) long and 1 cm. (⅖ in.) broad, inequilaterally lanceolate or lance-ovate, acutely cuspidate, entire, subcoriaceous, brittle, pale-green or slightly yellowish- or grayish-green, sparsely and obscurely hairy, more so underneath, the hairs appressed; odor peculiar, tea-like; taste mucilaginous, tea-like, bitterish.

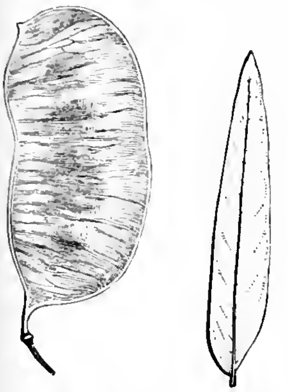

FIG. 4185.—Leaf and Pod of Cassia Angustifolia; about natural size. The leaf is Tinnivelly senna. (Baillon.)

It is frequently contaminated with the one-nerved, thick, wrinkled, glaucous, equilateral Argel leaves.

India senna leaves average nearly twice as long, though but little broader, are more abruptly pointed, usually more yellowish, and the hairiness is even more obscure.

CONSTITUENTS.—As to its active constituents, senna is closely related to rhubarb, cascara sagrada, and some other laxative and cathartic drugs. Like them, its active principles appear to be the anthraquinones emodin, iso-emodin, and chrysophanic acid, all of which have been considered elsewhere, with which exist rhamnetin, a large amount of gum, a little tannin, and ordinary leaf constituents. Cathartic acid, formerly regarded as the active constituent, is apparently a mixed body, and fairly represents the properties of the drug. However, the administration of anything else than the entire drug, or a preparation of it, appears inadvisable.

ACTION AND USE.—This is one of the most satisfactory and generally useful of simple cathartics, usually emptying the bowels thoroughly in ten or twelve hours, with but little depression or other untoward effects, excepting a variable amount of griping; it acts principally upon the small intestine, and the amount of effect produced can generally be pretty accurately regulated, by the dose, from the mildest laxative to a brisk cathartic. It is in universal domestic use, and is the foundation of numerous proprietary laxatives. By combination with salines its activity is considerably augmented; in small doses it does not readily lose its efficiency. It appears to be partially excreted in the milk, when taken by nursing women.

ADMINISTRATION.—A few senna leaves chewed every day are a favorite habitual laxative with many people, who find them to act efficiently, without griping and without producing after-sluggishness of the bowels. One or two dozen leaves usually display some effect. In large doses (6 or 8 gm. [ℨ iss.] or more), as required for thorough action, it is apt to produce colic, unless modified by aromatics or salines. A strong alcoholic extract is inert; a watery extract, made from the residue after exhausting by alcohol, is active and much pleasanter than one made without this previous treatment. Infusion with hot water extracts the active principles and makes a good form for administration, but prolonged boiling destroys it, as do also mineral acids and alkalies. Bitters are said to increase its action.

The official preparations are numerous and good. The Fluid Extract (*Extractum Sennæ Fluidum*, U. S. P.), made with weak alcohol, represents the leaves weight for weight. It is not often given alone, but is eligible for mixture with other medicines. The Compound Infusion, Black Draught (*Infusum Sennæ Compositum*, U. S. P.), consists of: Senna, 6 gm.; manna, 12 gm.; sulphate of magnesium, 12 gm.; fennel, bruised, 2 gm.; boiling water, 800 c.c.

Pour the boiling water upon the senna and fennel, macerate until cold, strain with expression, dissolve in the Epsom salt and manna, again strain, and add enough cold water to make the infusion measure 1,000 c.c. The syrup has a strength of twenty-five per cent. of senna, and contains a little oil of coriander to flavor. The confection contains ten per cent. each of senna and tamarind, sixteen per cent. of cassia fistula, seven per cent. of prune, twelve per cent. of fig, and a little oil of coriander to flavor. It is a blackish extract-like mass of a sweetish taste, and is an appropriate remedy for chronic constipation, being especially useful for children, who take it readily. The compound syrup of sarsaparilla contains 1.5 per cent. of the fluid extract of senna. The compound liquorice powder has already been considered under *Liquorice*.

ALLIED PRODUCTS.—The leaves of a number of other species of the section of *Cassia* to which the official species belong, possess similar properties, though much weaker, and have been at one time or another proposed as substitutes, especially those of *C. obovata* Collad., widely diffused through the tropics of both hemispheres. No others, however, appear in commerce at the present day.

Henry H. Rusby.

SENSATION, DISORDERS OF.—The scope of the present article is the discussion in brief of those abnormalities of sense perception not described under separate headings. General sensibility is the name given to the power of perception possessed by the various body tissues other than those of special sense. It is not, however, homogeneous in kind nor equal in degree, but varies in acuteness, in localizing power, and in other ways. Sensitiveness of the skin and mucous membranes is divided into that to tactile, that to painful, and that to temperature impressions. Muscular sense is an indefinite feeling, by which the weight and size of objects are appreciated or approximated; it is probably composite, the feeling of tension in the muscles being supplemented by tactile impressions from the skin and other tissues. Visceral sensibility has a varying but comparatively slight localizing value. Its appeal is largely to the subconscious psychic stratum; when visceral sensations rise to the level of consciousness, they may consist of visceral pain, local or referred, or be felt as hunger, thirst, fright, nervousness, psychic pain, anger, and so forth. These feelings are more or less indefinite, often not referred to an organ or part of the body, although at times they may be somewhat localized,—as, for instance, hunger and depression as epigastric sensations, thirst as dryness in the mouth and throat.

The general sense of well being on which happiness depends is a form of general sensation known to us mainly by its occasional loss, or rather by a feeling of definite depression, not usually localized, though sometimes felt as a cardiac or epigastric sinking or feeling of heaviness. An allied and in some ways opposite state is nervousness, a much abused term, but one of sufficient importance to deserve careful definition and description.

General sensibility, then, is a function of widely different tissues, much varied in kind, definiteness, and degree. The impact on consciousness due to sensory stimuli may give rise to intellectual or to emotional processes, the first being concepts relating to location, form, size, weight; the latter consisting of either pleasurable or painful feelings.

Disturbances of sensation are classed as anaesthesia,—that is, diminution or loss of sensitiveness, which has been described elsewhere in these volumes; hyperaesthesia,—that is, increased sensitiveness; paraesthesia,—that is, perverted sensitiveness; the different varieties of the latter are usually spoken of as paraesthesiae. Variations in sensitiveness are spoken of as hyperæsthesia or as paræsthesia only when they reach a marked degree and are the result of distinct morbid processes. Normal people vary widely in the acuteness of their perceptive power, both to tactile and to painful impressions; different parts of the body vary widely in sensitiveness, and acuteness of sensibility varies much in any given individual at different times of the day and even more with changing vascularity and varying degrees of heat and cold. Sensation present in consciousness varies almost directly in amount with expectant attention. Even the strongest stimuli may be disregarded and pass unnoticed under excitement or hypnotism.

Although sensation in its restricted sense is a mental impression received from a part of the bodily organism by way of the afferent nerves, and is thus necessarily conscious, the disorders resulting from sensation in the broad sense cannot be so limited. Sensibility is not originally conscious; the earliest and lowest sensory elements subserve the purposes of reflex action; they are evolved from cells capable of motion and possessed of digestive power, and develop their more acute sensory functions gradually. On about the same level are the sensory elements in vaso-motor action. Both these activities are carried on as well without the aid of consciousness, in fact often better, and they are not initiated either volitionally or consciously. Automatic action, as a higher and later manifestation of nerve force than either of the above, is nearer to consciousness. While some automatic acts, especially in the lower animals, are organic and inborn, many of them in man originate in conscious volitional acts and are the result of education.

In order to appreciate the importance of reflex and vaso-motor disturbances from derangement of the sensory mechanism, it is necessary to consider in brief the distribution of the sensory elements in the body. Sensory filaments of some kind are distributed to almost every organ and almost every tissue. Nerve filaments conveying impressions of pain are most abundant and active in the skin and the mucous membranes near the surface. The mucous membranes of the rectum, the tonsils, the stomach, and the intestines may be cut without causing much discomfort to the patient. The same is true of the muscular tissue and the brain. The arteries, on the other hand, are quite sensitive; the peritoneum and other serous surfaces, especially when inflamed, are exquisitely tender.

Tactile sensibility is also much more acute and finely differentiated in the skin and superficial mucous membranes. Touching and wounding the internal organs, the stomach, the bladder, and so on, give only a general idea of the seat of injury. Irritants at the neck of the bladder and in the rectum give the same feelings; pains are not distinguished as between the stomach and pancreas, the liver and gall-bladder, often not even between the appendix and the right kidney. The obvious reason for this fact is to be found in the rarity of opportunities for observing and learning to distinguish between pains in these different organs. How much might be learned if such opportunity existed we do not know. The frequency of referred feelings from visceral irritation, as compared with the rare occurrence of the same phenomena from the skin, points to the low tactile value of visceral sense impressions. Such impressions may be referred from one part of the abdomen to the other, from the teeth to the scalp, and even from the intestinal organs to remote regions of the skin. These referred pains will be described more fully later.

The main use of the sensory elements in the deeper structures is in the determining and controlling of vaso-motor and glandular action and the activity of the unstriped muscles; in other words, in carrying on the vegetative functions of the organism. These may be carried on very well without being brought to consciousness, and often when diseased they may be better performed if removed from consciousness. For instance, the reflex and automatic activity of the bladder is unimpaired in many cases of transverse and other spinal cord lesions, cerebral control alone being lost. The peptic glands probably act largely though not entirely on direct stimulation, but the peristaltic movements of the stomach and automatic control of the pylorus require the intervention of the sensory apparatus, normally apart from consciousness.

The digestive and other visceral functions result in another set of changes which impinge on consciousness only incidentally, but are carried on by the intervention of the sensory system; vaso-motor changes occur in the viscera themselves, and circulatory disturbances often follow in distant organs. It is necessary only to mention as examples the flushing of the face that accompanies the same change in the mucous lining of the stomach on the ingestion of food, the profound vaso-motor changes that often occur at the menstrual period, the faintness amounting to collapse that occurs with many severe abdominal diseases.

In addition to, often in connection with, its activity in reflex, vaso-motor, and automatic acts, the sensory system contributes two elements to consciousness—the one emotional, the other intellectual: the skin and serous membranes furnish almost exclusively intellectual percepts and the single emotion of pain; the viscera and deep mucous membranes furnish almost no intellectual percepts, some pain, and probably all of the emotions.

The emotional results of visceral action are common and familiar. Anger from hunger, irritability from distention of the bladder, depression from constipation, nervousness and motor unrest from thirst are visceral reactions scarcely beyond the bounds of the physiologic.

The emotions are, normally, visceral reactions to psychic stimuli. The psychologic side of the subject has been carefully worked out by William James in his "Psychology." His theory is, in brief, that the psychic cause sets up a physical change in the viscera, and the sensations from these in turn, perceived by the brain, constitute the emotions. For instance, a financial loss or death of a friend causes a change in the heart and vascular system, the stomach, and other viscera. The feeble heart action, loss of appetite, and sense of unrest in the epigastrium are the direct results, not of an emotion following the bad news, but of the news itself. The emotion is the perception of the changed visceral action, and without this the loss would be perceived intellectually but not emotionally. The jaundice of anger, the excitement and accelerated heart action of joy, and the nausea of disgust are similarly explained as the direct result of psychic stimuli, and the emotions are the perception of the altered visceral conditions.

That the physical reaction follows directly on the psychic stimulus is often observed. A man who had never heard a rattlesnake, when walking on the prairie quite quietly, suddenly bounded out of the path, and only a moment after was aware of the rattling noise. In this case the reflex jump and accelerated heart action could have been dependent on no conscious emotion. Similarly men who have run away from battle assert that their legs carry them away before they realize what they are doing. The faster they run the more frightened they become. The contrary attitude of calmness is well known to restore confidence.

James says that when a boy he examined curiously a bucketful of blood at a butchering. He had never heard of fainting at the sight of blood, had no fear or other emotion, and was much surprised when he found himself growing dizzy and fell to the ground. The sight of blood on the next occasion might cause nausea and repugnance from the renewing of the previous experience in memory.

This brief statement of what may be called the visceral theory of the emotions must suffice. To be convincing it should be read *in extenso*. It is necessary to an understanding of the part played in the human economy by the sensory apparatus of both the viscera and the skin.

Increased sensitiveness to stimuli, called hyperæsthesia, is common and is even more important than anæsthesia as an indication of disease. Hyperæsthesia which consists of a heightened power to distinguish variations in temperature or other qualities of objects is rare. Such increase of capability may be regarded as supernormal.

It occurs in some sensitive and gifted individuals, but is usually not the result of disease. On the other hand, a painful reaction to what should be normally felt as touch, pressure, heat, or cold is common as either deep or superficial tenderness. It is one of the most important signs of disease, local or central.

It is important to distinguish between deep and superficial tenderness, as that to deep pressure usually indicates local disease, while tenderness to a light touch with a blunt object like a pinhead, or to pinching up the skin, usually if not invariably in the absence of a superficial and obvious lesion, is tenderness referred from a diseased viscus.

The headache due to brain tumor when associated with scalp soreness, elicited by gently pulling the hair or touching the scalp, is sometimes on the side opposite to the lesion; it has no localizing value, but indicates increased intracranial pressure.

Headaches from visceral disease have been confused with attacks of megrim. The tenderness of megrim, associated with scotomata, hemiopia, and fortification lines,* and sometimes with aphasia, is always to deep pressure. Visceral headaches are not associated with these symptoms; tenderness in them is superficial and confined to areas which depend on the viscera involved and on the tender areas set up by the same disease in other parts of the body.

The headache of hypermetropia comes on at the time of awaking in the morning; it is due to strain from overaction of the ciliary muscle, and is a true visceral pain. It is associated with a superficial area of tenderness over and just above the eyes. The same area, the midorbital, may, however, be tender as the result of disease of the nasal mucous membrane, the stomach, the heart, or the apices of the lungs. Other eye diseases cause pain and tenderness of other regions; glaucoma sets up pain in the temple, which is associated with nausea and vomiting, as are temporal pains from other causes; temporal headache is often associated with gastralgia, and may be due to gastric or thoracic lesions or disease of the bicuspid teeth.

Iritis causes tenderness in the fronto-temporal and maxillary areas. Liver disease causes vertical headache, and ovarian lesions are associated with pain and tenderness in the occipital region, often together with pain over the lower dorsal region of the spine.

The skin of the neck, trunk, and limbs may show hyperæsthetic patches from visceral disease, and there may or may not be with them like patches over the scalp, with headache. They are readily distinguished from the deep tenderness found in affections of the serous membranes, which is always local; for instance, the tenderness due to rheumatic inflammation of the joints, to peritonitis, to meningitis, is found on pressure over the affected structures; the pain of lumbago is similarly elicited; appendicitis sets up local tenderness as well as referred pains in the left side of the abdomen and left lumbar region. Disease of the uterus causes pain referred to the lower part of the back but does not cause headache. Ovarian and rectal diseases may cause pain down the thighs and in the feet, as well as hyperæsthetic areas over the body and head.

The hyperæsthesia of the trunk sometimes seen in tabes dorsalis has the characteristics of the referred variety of pain. The patient, over a greater or less and sometimes a varying area of skin, cannot bear the weight of clothing or the slightest rubbing with a towel. This symptom may persist for years. The lightning pains in the legs are associated with a like soreness, which is, however, much shorter-lived than the trunk anæsthesia, but which corresponds closely in its main features with the headaches referred from disease of the brain, the teeth, and other viscera.

* Gowers (p. 840, second edition) says: "When a luminous spot is the first change and this expands, it may become dim in the centre. Very commonly the outer edge assumes a zigzag shape with prominent and re-entrant angles, like the ground plan of a fortification, and hence called 'fortification spectrum.'" Mills also uses the expression "fortification lines."

The mode of production of referred pains is not known. To suppose them signals from the viscus and apprehended by the receiving stations in the brain as coming from the skin leaves out of account the tenderness, a local phenomenon, as are herpes and sympathetic inflammation. The setting up of such tender spots must be conceived of as a phenomenon analogous to the jaundice, indigestion, suppressed menstrual flow, and local flushings and pallors consequent on psychic shocks and associated with strong emotion. Whatever the explanation, they are important from the therapeutic as well as the diagnostic point of view. The frequency with which so-called osteopathic practitioners find tender spots in the back, and the fact that their removal by treatment usually gives the patient relief in spite of the persistence of organic visceral lesions make the treatment of tender spots, either local or referred, a matter worthy of attention.

The distinguishing marks of local and of referred pains and hyperæsthesia have been given above. A third variety of tenderness is important, viz., that due to inflammation of nerve trunks; such inflammation causes pain along the course of the nerve, with tenderness to deep pressure. This tenderness is due to involvement of the *nervi nervorum* in the nerve sheaths. When the skin supplied by the affected nerve is tender, it is so because the inflammation extends to and involves the terminal filaments and end bulbs. Thus both varieties of tenderness are local, not referred. The pain, however, caused by pressure on sensory nerve fibres anywhere in their course is referred to their terminations in the skin.

Paræsthesiæ are of two kinds: perverted spontaneous feelings other than pain, and perverted transmissions of stimuli to the sensory centres. Of the first of these, itching, ticklings, prickling and burning feelings, numbness, formication, and feelings of heat and cold are common. They may be due to disease in the peripheral nerves, in the cord, in the receiving centres in the brain, or they may be psychic. Of these, the immediate cause will usually be found in the periphery, and any other theory should be accepted with caution and only after careful exclusion of possible change in the nerve endings or small blood-vessels. Vaso-motor changes are prolific sources of paræsthesiæ of various kinds, and are a common accompaniment of central disease. Again, the scleroses, cerebral and spinal, are accompanied not only by vaso-motor and trophic changes, but also by lesions in the peripheral nerve tissues, so that in a large proportion of cases paræsthesiæ occurring in the course of central disease are found due to accompanying peripheral change.

Most of the paræsthesiæ will be found described among the vaso-motor, trophic, and cutaneous disorders. A curious form is the so-called allochiria, or reference of a stimulus to a corresponding spot of skin on the other side of the body. This symptom has been found in some cases of brain tumor, in sclerotic cord lesions, and in hysteria.

Muscular sensibility is the power of feeling in relation with muscular acts. It enables one to appreciate the strength of action of the muscles, the position of the limbs, the extent of objects, and, in the case of the eye muscles, it helps to maintain the equilibrium of the body, and gives information in regard to the size and distance of objects.

Muscular sense is not limited to sensitiveness possessed by the muscles. That the amount of force sent along the motor nerves is directly appreciated or estimated by the sending apparatus is probable, but hardly susceptible of proof. The amount of common sensibility possessed by the muscles themselves is much less than that of the ligaments, tendons, and connective tissues. The impressions conveyed to the brain are the sum of all the sensations set up by strain and pressure in all of these tissues, as well as in the skin, and even in the blood-vessels, their rich sensory nerve supply being affected by pressure of the surrounding parts and the amount of contained blood varied by pressure and change of position.

When an act or series of acts is once carried out as the result of a stimulus, it follows that stimulus the next time with greater ease. Such an impression stored up is a muscle memory. All muscular action not directly reflex is the product of such memories; automatic action is connected with memories which impinge little if at all on consciousness; in fact, much of it is so rapid as to run before consciousness. Volitional acts are dependent on muscle memories combined with or added to memories of sense perception.

The way in which the muscle sense contributes to voluntary acts has been well illustrated by Meynert. A finger is approached to the eye of a new-born child. A memory is stored up of the visual impression on the retina, of the tactile and painful impression when the finger touches the cornea, of the muscular movement which results by reflex. After this has been repeated a number of times, the sight of the approaching finger awakens the memory of the pain and the eye is voluntarily closed by the intervention of muscle memory.

The weight of an object is estimated by comparison of the muscle percept consequent on lifting it, with the muscle memories of other objects similarly lifted. The actions in so testing an object are characteristic.

The position of the limbs is partly gauged by the exertion put forth in maintaining them in that position. The size of objects may be estimated by the position of the grasping hand and fingers, this being made possible by the muscular sense. The amount of eye strain in accommodating and converging for near objects affects one's estimate of their distance and size. As small near objects may subtend the same projection angle on the retina as do large distant ones, it would be impossible to estimate their comparative distance and size if it were not for memories of similar things seen before, with the memories of the effort of the eye muscles in accommodating and converging for them. As distant objects require practically no accommodation and convergence, one's estimate of their size is governed by any opinion which may be formed in regard to the distance and *vice versa*. Very distant objects, like the moon, are apt to be judged in relation with the objects seen at a small angular distance from them—for instance, the objects on the horizon. When the head is moved the eye muscles by their action tend to keep the eyes directed toward the same object. The muscle percepts are in this case changed, and give the impression not of movement of the eyeballs, but of the shifting positions of the head. When body movements are violent, as on a ship or in a swing, muscular sensations may be so acute as to cause nausea and vomiting.

Muscular sensibility is too complex to admit of close localization in the brain. The motor centres and parietal centres for common sensibility are probably the ones chiefly concerned.

Isolated disturbances of muscular sensibility are not so common as would seem likely from the importance of the muscular sense. This is probably due to the fact, just pointed out, that it is complex in action and scattered in various parts of the nervous system. A severe and widespread lesion causes paralysis or general anaesthesia or both, either of which masks the loss of muscular sensibility. Isolated loss of muscle sense usually shows itself in one of two ways: as loss of power to appreciate the position of the limbs, and as astereognosis, or failure to estimate the size, shape, and weight of objects. The former is more marked in the legs and is seen in some cases of locomotor ataxia and multiple sclerosis; the latter is more often found in the arms and is a rare accompaniment of organic brain disease. A curious and rare muscular anaesthesia occurs in the so-called megalopsia and micropsia. These are usually transient symptoms, occurring suddenly in the early stages of tabes dorsalis and other scleroses and in hysteria. Objects seem unusually large or unusually small from a failure of muscular sense in the ocular muscles.

To test the integrity of the muscle sense the limbs should be given various positions, the patient's eyes being closed, and he should be made to guess the degree of their flexion or extension. He should be made to estimate the weight of objects held in the hand; he should name and describe the shape and size of objects held with the eyes closed.

Disorders of visceral sensibility have been less studied and less importance has been attached to them than to those of the skin, probably because of their vagueness and often their slight localizing value. They are, however, from the psychologic and still more from the medical point of view, of much greater importance.

Visceral sensations may be classed, so far as our present knowledge goes, under the heads of local pain; referred pains (already described); more general visceral sensations on the border between pain and emotion, including hunger, thirst, fatigue, sexual desire, nausea, dizziness, and nervousness; emotions, either as direct visceral sensations, or as perceptions of visceral change from psychic causes, including fear, shame, anger, joy, exaltation, and depression or psychic pain.

Local pain in visceral disease is usually dull even when very severe; it is, unlike referred pain, not associated with psychic or emotional change. Tenderness is elicited by deep pressure and may be masked by the referred tenderness of superjacent skin. It may take on varying characters according to its location; when it is abdominal, the patient has a tendency to draw up the knees, with the apparent purpose of diminishing tension in the abdominal cavity.

Hunger is the desire for food, which increases with abstention, but not indefinitely. It is born in large part from the physical state of the stomach, as indicated by the fact of its existence as a dyspeptic symptom. Too free secretion of hydrochloric acid or the presence of an excess of organic acids, either ingested or formed in the stomach by fermentation, may cause craving hunger with consequent over-eating. Spices and alcoholic stimulants have the same effect. The need of the body tissues in general for nourishment causes a feeling of weariness, not of hunger; the appetite is sated before an appreciable amount of ingested food has reached the more distant tissues.

Thirst is a sensation caused by the drying of the tissues. The mucous membranes of the mouth, tongue, and throat are the parts most affected. The feeling may be excited by other irritants.

Hunger and thirst are occasional symptoms of organic brain disease. This fact does not prove the existence of a hunger centre or a thirst centre in the brain any more than running from danger proves the existence of a fear centre. The various mucous membranes have a cortical representation, and excitation of these sensory centres by disease has the same psychic result as that which follows the application of a stimulus to the membranes themselves.

Extreme hunger and, still more, extreme thirst may have an overwhelming effect on the nervous system. Sufferers from thirst in the dry hot air of the desert are maddened by the agony of the drying tissues, and die in delirium within a few hours, practically the victims of shock. Long-continued hunger commonly evokes dreams and hallucinations of banquets.

Fatigue is a toxic symptom. Tired muscles are overcharged with sarcolactic acid, and brain work and other expenditure of nervous energy result in the accumulation of oxidized waste products; in either case the result is a set of sensory signals, consisting of heavy aching pains in the muscles, soreness in the eyeballs, and, in the case of brain fatigue, a tired feeling, not in the brain itself but in the cerebral or cranial blood-vessels, possibly also in the meninges.

Of more interest is the pseudo-fatigue of neurasthenia and of visceral disease. The same tissues are affected by the poisons formed as the result of fatigue and by stomach indigestion and intestinal putrefaction, by defective liver action, and by poisons retained on account of imperfect elimination by diseased kidneys. The result is the same, viz., heaviness in the limbs, aching of the eyes, throbbing and dulness in the head. These may be spontaneous or may ensue on an amount of exertion too slight appreciably to affect a normal person. Such fatigue is spurious and may sometimes be overcome by exercise if the underlying disease is benefited by it.

Great fatigue is the apparent cause of many of the functional and even some organic nervous diseases. Such disorders arise from fatigue in three ways: as the result of the acuteness of the feeling; by the overwhelming of the nervous structures by poisons produced from the overworked tissues; but mainly by the exhaustion of the nerve cells by severe and long-continued action. Of diseases produced in the two last-named ways we are not speaking, but only of those set up by fatigue as a sensation. In the latter sense fatigue is on the same footing with the emotions, and, being ordinarily a weak sensation, it is of not great importance in causing disease.

Of much more import as sensation is sexual desire. It is, even apart from performance, accompanied by vaso-motor changes which, when excessive or perverted, give rise to widespread disturbances of the vascular system. The sexual organs proper are not alone concerned in the sexual act. Desire is influenced by complex considerations in which beauty and even intellectual attractions play a part; the phenomena of blushing, erethism of the lips and breasts, and the mysterious part played by the thyroid gland in sexual life all contribute to involve widely different functions in sensory sexual disorders.

Sexual excitement, especially when accompanied by masturbation about the age of puberty, is likely to be attended with disastrous results. It is not always easy to trace the relationship of cause and effect between sexual excitement and the psychoses. Either may be the cause, or they may intensify each other. They usually coexist with degenerative stigmata. *Dementia præcox*, chorea, habit spasms, exophthalmic goitre, and even epileptiform attacks may follow in the train of sexual excitement in the young apparently as the result of the effect on the sensorium and of the accompanying vasomotor derangement.

Nausea and dizziness are symptoms often associated with each other and with temporal pain. Nausea is not a stomach sensation, but is the sensation or the sensory and motor memory of the act of vomiting, together with that of the flow of saliva and trembling of the lips which precede it. With this there is often the sensation known as dizziness, coming from the semicircular canals, with possibly fulness of the cranial blood-vessels and throbbing in the temples. Some of these phenomena may be absent, according to the cause of the nausea or of the dizziness. Pain in the temples, which so often accompanies nausea, is usually the referred pain of liver or stomach disease, of disease of the cerebrum or cerebellum, or of disease of the eyes or teeth.

One of the most important feelings on the border line between emotion and sensation is nervousness. This term should be dissociated from hysteric and neurasthenic symptoms in general and limited to the pathologic feeling of unrest consequent on physical or psychic stimuli, and leading, or tending to lead, to either purposive or spasmodic movements of the voluntary muscles. The predisposition to nervousness varies much in different people. When not produced by psychic causes it is present in consciousness usually as a distinct feeling from the arms or legs, although it may be occasionally referred to the head, back, or other parts of the body. The lesion may be a local irritant, a suppurating wound, a felon, or compression of a nerve trunk among other alterations, or the abnormal feeling may be referred from a viscus to the limbs or trunk as ordinary pains are referred. This referred nervousness is common and is remarkable at times for its intensity. Patients suffering from an overloaded sigmoid flexure and rectum may suffer torments from nervousness in the legs and feet as do patients suffering from uterine or ovarian disease; intestinal putrefaction sometimes causes a generalized nervous feeling that keeps the patient walking the floor day and night in agony.

Of the causes of nervousness, aside from the predisposition which is always to be reckoned with, it makes little difference whether they are psychic, irritative, or toxic, so far as the symptoms are concerned. Any one of these causes is more effective in the presence of either of the other two, and, as with ordinary pains from whatever cause, the amount of nervousness felt is much modified by diversion and increased by attention. Nervousness is no more under the direct control of the will than is ordinary pain, but like the latter it may be more or less controlled by suggestion or affirmation. While the motor effects of nervousness are in some ways like those of exaltation of acute mania, the underlying emotional content is entirely different, being in the one case disagreeable, in the other pleasant. Nervousness is, in fact, often associated with profound depression, especially when both states of feeling arise from visceral disease.

The sensations which have just been described have an obvious emotional content; they hold a position about midway between feeling and what has been considered pure emotion; they may be set up by purely physical or by purely psychic causes, and there is no peculiarity in the resulting feeling to mark its origin. The fact that impressions of touch and pain may have a purely psychic, and true emotion a purely physical cause, justifies the inclusion of the three kinds of sensation in the one category. The emotions of depression, of exaltation, fear, joy and the like, have the peculiarity in common that they are projected into the psychic environment. The tendency to find an object for a feeling of anger, and to attribute depression to a misfortune great or small, connects these emotions definitely with the realm of thought. That they really consist of the normal individual sensations which come from the viscera but which are not recognized as such, has already been pointed out. This fact puts them among the most important sensory manifestations from the medical point of view.

The study of emotion from visceral disease is attended with certain difficulties. Chief among these is the fact that disease of any one viscus, and even the same disease of a particular organ, so far from always causing the same feeling, may give rise to the most varied play of emotions. Much, however, may be learned by observations of such cases, and reasoning back from psychic symptoms to the disease is often possible even in the absence of definite physical indications.

The lighter grades of emotional change may be called moods. These moods are of frequent occurrence in otherwise normal people, and apparently depend on either autotoxic or meteorologic influences, or both. The referred pains of organic visceral disease are associated with well-defined changes of mood which are coincident in time with a sudden increase in the amount or intensity of the pain. These moods are depression, exaltation, suspicion, irritability, and with them there may be hallucinations of sight, hearing, and smell. The patient assigns no cause for his depression; he has no delusions with his hallucinations; although his suspicions attach themselves to his friends and those about him, they are readily removed by simple denial of their truth. The moods have practically only an emotional content; they come as suddenly as the pains, last for a few minutes or a few hours, and leave equally suddenly. They are, according to Head, singularly little affected by outside circumstances, by cheerful society, music, and so on. Pains below the mid-dorsal segment are likely to be associated with depression; above this, with exaltation.

A more profound and lasting change in the emotional life is wrought by toxins of various kinds. An instance of this kind is the well-known irritability of a masked attack of gout. Depression from auto-intoxication may be so intense as to overshadow all other symptoms. Typical instances are furnished by patients who, following an indiscretion in diet, have a mass of sour material retained in the stomach. They may have with this marked but not intolerable depression, which is promptly relieved on emptying the stomach with a tube or by vomiting. Much more serious is the depression associated with intestinal putrefaction, following acute diarrhœa in patients in whom the poisons have been allowed to accumulate in the intestinal canal, and in putrefaction from other causes. In these patients depression is extreme, often not associated with delusions except possibly the pardonable idea that they are going insane; there may be with the depression a nervousness so great that the patient presents a typical picture of *melancholia agitata*, walking the floor in agony. Such cases are acute. A deficiency of the hydrochloric acid of the gastric juice may cause a mild chronic depression, simple, and easily improved or cured by appropriate treatment.

In all of these cases it is not known where or how the poisons generated in the alimentary tract have their effect. As the emotions are sensations from the viscera, and as the sensory nerve endings of the affected viscera are bathed in the poisons, it is not a remote possibility that their action may be a local one and not due to their being absorbed and in this manner producing an effect on the sensory centre. The prompt action of local remedies, stomach washings, purgation and enemas, favors this view.

The prevailing emotion in consumption is moderate exaltation. This may be heightened by the stimulus of an attack of referred pain, especially that due to disease of the upper pulmonary lobe; disease of the lower lobes is likely to cause referred pain with attacks of depression.

Uterine and ovarian disease is especially prolific of emotions, either simple depression, to which in extreme cases delusions may be added, or exaltation amounting in some cases to mania. The most deceptive forms of these affections are those in which there are no accompanying symptoms, sensory or otherwise, calling the patient's attention to the affected organs. The difficulty is further increased by the fact that digestive disturbances may make their appearance and mask the other symptoms. The difficulty of distinguishing between these cases and cases of insanity with coincident visceral lesions may be considerable, as these patients possess many or all of the symptoms of insanity, and yet it is not very important to make the distinction between the two classes of cases. Organic defects should be remedied, if possible, even in the insane, and in addition it may be fairly doubted whether even in cases of hopeless insanity, organic visceral disease may not often be the determining cause of the mental breakdown.

The pelvic organs sag and pull on their attachments and as a result there are sent out to other parts of the nervous system signals of distress which take not only the form of moods, but of pains in the back and head, vasomotor disturbances, flushing, fainting, palpitation and the like. In the same way sagging abdominal organs set up all these classes of symptoms. In especial a prolapsed kidney is often responsible for attacks of dizziness, headaches, flushings, and faintness which are often attributed to anything but their real cause.

One of the most striking emotional changes from visceral disease is the fear suffered by patients afflicted with angina pectoris. A good deal of anxiety is felt by many patients who suffer from palpitation, over and above what would be warranted by the nature of their complaint. The fear in angina pectoris is inherent and does not proceed from a knowledge of the danger incident to the disease. It is a signal to the brain direct.

Little more has been attempted in the present article than an outline of the subject of sensory disorders, with the idea, especially, of tracing the complex relations which exist between the sensory system of the skin and that of the viscera. Consciousness is not, in this connection, of prime importance. It is a mysterious light that shimmers on a few of the actions and reactions of the nervous system; in considering the part played in disease by the sensory system, it is of especial importance to recognize the fact that sensory phenomena may and often do take place without its intervention.

Henry S. Upson.

SEPTICÆMIA AND PYÆMIA. Historical Memoranda.—A constitutional disturbance accompanying putrefaction in wounds, particularly fractures and injuries of the skull, was described by Hippocrates. In the Middle Ages Ambrose Paré and Paracelsus, both noted metastases following certain injuries in which suppuration occurred. In 1720 Boerhaave first enunciated the doctrine that the condition was due to pus in the blood. His contemporaries, Morgagni and Petit, also tried to prove that metastatic abscesses were brought about by penetration of pus into the blood. In 1774 John Hunter recognized phlebitis as an intermediate factor in producing metastatic abscess, but the exact relation of the two was not clearly defined. In the early part of the nineteenth century (1808–22) Gaspard initiated the experimental method of studying septicæmia by injecting putrefying materials into the veins of animals. Later, the investigations of Virchow, Billroth, O. Weber, Koch, and others formed the basis upon which Gussenbauer built the following definitions: "By *putrid infection or septicæmia* we mean that general disease of the body which results from the introduction into the circulation of the products of decomposition, and which is characterized by definite changes in the blood, a typical succession of inflammatory processes, and a continuous fever together with peculiar nervous symptoms and critical discharges." *Pyæmia* is defined by him as "a general infective disease which arises from the entrance into the blood of the constituents of infected pus, and is distinguished from other septic infective diseases by the development of multiple pus foci in different organs, and an intermittent fever."

Since Gussenbaur formulated these definitions, extensive investigations have been made from both a bacteriological and a pathological standpoint. From the studies of Ogston, Rosenbach, Doyen, von Eiselsberg, and others the conclusion is drawn that the general systemic disease known as septicæmia depends upon the *introduction of pathogenic, especially pyogenic micro-organisms into the general circulation.* Marmorek further limits the definition of septic intoxications, infections (mycoses), and pyæmia to those general systemic diseases caused by the activity of the streptococcus pyogenes and staphylococcus aureus, for, he claims, that these are the only two micro-organisms which can cause all the various phases of septicæmia, from a carbuncle to the most severe pyæmia. He excludes as etiological factors such agents as bacterium coli, pneumococci, etc., which he claims cannot cause furunculosis, lymphangitis, and lymphadenitis. However, this cannot be accepted by the clinician, for not only are his premises and therefore his conclusions incorrect, but in addition there are so many forms of septic intoxication and infection presented to the observer, in which the etiological factor is other than the streptococcus pyogenes and staphylococcus aureus, that it is impossible to limit the disease to those agents alone.

Classification.—Konrad Brunner ("Erfahrungen und Studien über Wundinfektion und Wundbehandlung, III. Theil. Die Begriffe Pyämie und Septhämie im Lichte der bakteriologischen Forschungsergebnisse") classifies the disease from an etiological and symptomatological standpoint. Slightly modified by the present writer, it is as follows:

I. *Septicæmia Not due to Bacterial Activity.*—A general disease brought about through necrotic or putrefactive processes.

II. *Systemic Diseases due to Pyogenic Microbes; Pyæmia, Acute or Chronic.*—General infections in which metastases make their clinical appearance, due generally to staphylo-, strepto-, pneumo-, and gonococci, or to proteus, pyocyaneus, coli, or typhoid bacilli; the fundamental principle being that the signs and symptoms of metastases break in upon the general symptoms.

2. *Ptotoxinæmia, Toxinæmia, Toxæmia.*—A general disease without the clinical signs of metastases, but with the symptoms of a constitutional intoxication, brought about by all kinds of bacteria.

III. *Pyosepticæmia or Septicæmia.*—A general disease in which the products of pyogenic bacterial activity combine with those of decomposition to cause the symptoms. For a fuller discussion of the subject of classification the reader is referred to the above work by Brunner.

Etiology.—So far as the classification is concerned, the bacteria, in all but the first form of the disease, play the chief rôle. There is *no specific micro-organism*, but a whole series of them as etiological factors. The same micro-organism acts differently under different conditions. There are many factors which tend to change or govern the result of their activity. The point of infection, the character of the media into which they penetrate, the personal factor, the microbic association, the varying virulence of the micro-organisms themselves, the lowered vitality of the parts—all these influence the course of the infection.

The *mode of entrance of bacteria* into the system has been the subject of much investigation. In some cases they are, through the medium of a seemingly slight wound, introduced rapidly into the circulation, presumably being taken up by the capillaries. In the great majority of the cases, however, the bacteria first gain access to the lymph spaces and are carried through the lymph channels to the blood. Starting from a localized pus focus the bacterium first has to pass the barrier of *granulation tissue*, which has been thrown up by the tissue as a bulwark against the bacterial invasion. That healthy granulation tissue does act as a successful barrier has been conclusively demonstrated by Noetzel in his experiments on sheep. When these granulations, however, are not sufficiently developed, the micro-organisms pass through them and enter the lymph spaces. By the lymph they are carried to the lymph nodes, which present the next barrier against their invasion. In their course to the nodes varying degrees of *lymphangitis* may be set up. The nodes increase in size and in some way, as yet not definitely known, they retard the growth of the bacteria and in many cases limit their further growth. Dr. Mallory, of the Harvard Medical School, has lately demonstrated that in the periphery of the node there sometimes occurs a proliferation of the endothelial cells lining the trabeculæ which traverse the lymph spaces. These take upon themselves phagocytic properties and enclose not only the bacteria but also leucocytes themselves, which may already have ingested some bacteria and in addition large numbers of red blood cells. In the nodes the pyogenic bacteria often bring about suppurative processes and, destroying these organs, pass on and are emptied into the blood stream. More often the resistance of the nodes is overcome without producing suppuration. Upon reaching the blood the bacteria are again attacked. Through the production of so-called *sozins* and *alexins* (the mode of origin of which is unknown) the growth of the bacteria is again hindered; in fact, these sozins and alexins, aided by the leucocytes acting as phagocytes (Metschnikoff), may destroy the bacteria. Canon believes that the chief difference between septicæmia (pyotoxinæmia) and pyæmia depends upon the phenomena, that in septicæmia the bacteria increase and produce their toxins in the blood, whereas in pyæmia the bacteria are introduced into the blood but do not increase there. Brunner holds that there never occurs any marked growth of bacteria in human blood, and he thinks that this is one reason why bacterial blood tests sometimes fail. An acute mycosis is met with in no human infection. He further holds that the micro-organisms are especially prone to collect in the parenchymatous organs, and in the acute cases they set up metastatic processes, which, however, remain microscopically small, the duration of the disease being too short to develop macroscopic foci or to be clinically evident.

The bacteria carried by the blood may be deposited in the various tissues and organs of the body and there continue their activity and bring about local inflammatory or suppurative processes. They may, on the other hand, be destroyed in the tissues and be excreted. The relation of thrombophlebitis to the blood will be discussed later.

All authors hold that *in the majority of the cases the ordinary pyogenic cocci, i.e., the pyogenic staphylococci and streptococci, alone or associated together, constitute the cause of the disease.*

The streptococci have long been looked upon as liable to bring about more virulent infections than the staphylococci. But no absolute line can be drawn. We may have an acute or a chronic streptococcus infection with or without metastases. The same is true of the staphylococci. However, many other bacteria play an important part, etiologically, in this disease. The *pneumococcus* may cause a metastatic-pyæmia, or a pneumococcus-toxæmia, in which the bacteria are found in the blood. Metastatic foci occur most frequently in the meninges and the joints. The *B. coli communis* generally invades the system from the intestinal tract. Cholecystitis, abscess of the liver, peritonitis are often sequelæ. Cystitis is set up, the bacillus being carried by the lymph vessels or the blood. Meningitis, pneumonia, strumitis, etc., have followed its escape into the blood. It has also been isolated in local phlegmon and lymphangitis. The *gonococcus* is frequently met with in pyæmic conditions. *B. typhosus, B. pyocyaneus, B. Friedländer, Proteus vulgaris, Micrococcus tetragenus*, and many others are capable of bringing about the disease.

The infection may be a mixed one, a *double infection* taking place at the same time, or a *secondary infection* taking place in a focus alr ady the seat of microbic activity. It often happens that only one of the bacteria can be demonstrated in the blood, and when streptococci and staphylococci are associated, the streptococcus is generally the one to bring about the general infection.

Pathology.—In the mildest form of the disease, *septicæmia without bacterial activity*, or, as it is more commonly termed, "*sapræmia*," the pathological changes are limited to the site of the necrosing or putrefying focus. In the *pyosepticæmic* form of the disease we have locally the combined phenomena of pus formation and putrefying, decomposing, or necrosing tissue. It may exist in the form of a moist gangrene. Often, in the case of wounds which seem at first insignificant, but in which cases there ensues a malignant and rapidly fatal toxæmia, the pathological findings are very slight. More often we have the local changes of a pyogenic disturbance, presenting all of the characteristics of local inflammation and abscess formation. The primary focus may be a carbuncle, an infected wound, an otitis media, an osteomyelitis, a gastro-enteritis, a pneumonia, etc. From the seat of infection the inflammation spreads, the *lymphangitis* is set up, the nodes are attacked, and *lymphadenitis* follows. The bacteria reach the blood and here many changes occur. *Sozins* and *alexins* are produced, and *antitoxins* are elaborated. Ewing holds that the bacteria are present in the circulating blood only for short periods and at infrequent intervals, and that a few hours before death various bacteria, some of which may not be active in the original process, make their way into the circulation. There is a rapid development of severe anæmia. The red blood cells are diminished in number, and in the more severe cases a slight poikilocytosis and degeneration of the cells occur. Sometimes normoblasts appear. Grawitz reports a case of acute septic infection, in which after two days the red blood cells were reduced to 300,000 per cubic millimetre. The blood plaques are increased. Leucocytosis is marked, except in the very mild and very severe cases. Changes in the blood vessels occur mostly in relation to the local pus foci, but often by means of mural inplantation the endocardium is attacked and ulcerative or malignant endocarditis ensues. When a vein in the neighborhood of an abscess is attacked the adventitia is the first to be affected. The ordinary phenomena of inflammation follow, and the other coats of the vein become involved. The intima becomes swollen and inflamed and fibrin is deposited on it, which becomes the nucleus of a coagulum. This increases until the lumen of the vein is occluded and a thrombophlebitis established. Sometimes the thrombus extends for a considerable distance along the vein. As the infective process advances from the primary focus, the microbes invade the thrombus and there bring about purulent softening of the mass. Before this occurs small particles of the thrombus may be broken off, and, entering the general circulation as emboli, find lodgment in the various organs. In this way infarcts are produced, and these in turn may become infected by the bacteria in the circulating blood, thus giving rise to metastatic pus foci. In the original thrombus the process of purulent softening goes on, and if not checked by local forces or by treatment the whole mass breaks down and the particles laden with micro-organisms follow the course of the embolus and lodge in the portion of the vascular system where the size of the vessel retards its progress.

Post-Mortem Findings.—In *pyotoxinæmia* and *pyosepticæmia* putrefaction develops rapidly. In the subacute and chronic cases the original wound is found to be foul and unhealthy in appearance. The lungs may show congestion and œdema; small pleural and pericardial effusions are frequently seen. There is a marked degree of gastro enteritis, the inflammation affecting especially the lower bowel; generally cloudy swelling of the spleen, liver, and kidneys is present; the nervous system is not much affected; bacteria may be demonstrated in the connective tissues; the lymph nodes are enlarged. In the rapidly fatal *peritoneal pyotoxinæmias* the gut is found greatly distended with gas; the peritoneum is grayish and lustreless, and shows a fine network of congested vessels.

In *pyæmia* the wound looks gangrenous. The adjacent veins are thrombosed. Metastatic abscesses are seen, most often in the lungs, liver, spleen, and kidney. The intestinal tract is not so often affected. The brain may show a passive hyperæmia but metastatic foci are rare. In the joints there may be either serous or purulent effusions. Heart lesions are not frequent, but they do occur.

When recovery takes place, there is a gradual regeneration, the bacteria disappearing from the blood and the local conditions subsiding.

Signs and Symptoms.—The complex of objective signs and subjective symptoms of the disease in its various forms vary to such an extent that no hard-and-fast lines can be drawn. And still there are groups of symptoms which are most frequently observed in certain manifestations of the disease.

Under the division of *septicæmia without bacterial activity* are included all those conditions in which from a specific focus of necrosis or putrefaction or decomposition the toxic elements elaborated by these processes are absorbed into the general circulation and thereby bring about a general poisoning of the system. The primary focus may become infected, and so, through the addition of the bacterial element, we have a pyosepticæmia, to be described later. Septicæmia without bacterial activity—or, as it is more commonly termed, "sapræmia"—is most strikingly exemplified in the so-called ptomaïn poisoning, which originates in the gastro-intestinal tract, and in the cases of retained secundines, in which the putrefactive changes take place in the placental tissues and without bacterial activity bring about a general poisoning. The tyrotoxicon discovered by Vaughan, of the University of Michigan, is accepted as the etiological factor in the poisoning from cheese, and is supposed to be the active principle in some of the other forms of ptomaïn poisoning.

Large masses of gangrenous or sloughing tissues which are confined within the body may bring about the disease. The symptoms which develop are those of a poison which is gradually progressive, acting as a depressant on the nervous system, and bringing about a considerable febrile movement. The disease affects more especially the gastro-intestinal tract. There is no chill to mark its onset. The patient has a persistent headache, general malaise, anorexia. At first there is only a slight rise of temperature; the pulse frequency is increased; there is some nausea. If the cause is not removed the headache becomes more intense, the temperature rises, vomiting takes place, and diarrhœa is the rule. The blood shows degenerative changes, diminution in the number of the red blood cells, decrease in the hæmoglobin index, and some leucocytosis. These changes vary with the intensity of the poison. In the fatal cases the temperature is continuously high, the pulse rapid and feeble, delirium follows restlessness, coma develops, and death occurs. In the cases which originate in the intestines the most marked symptom is the violent vomiting and purging, which may even simulate cholera. Most of this class of cases of septicæmia react well to treatment, and when the cause is removed there is a rapid return to normal conditions.

In *pyotoxinæmia* attention is first called to the local conditions. It may be a suppurating wound which is draining poorly, an unopened abscess, or some deeply seated inflammation. In the *cryptogenic form* (*i.e.*, that form in which the original focus of infection cannot be found) there may be a history of some old trouble which is supposed to have subsided. A gastro-enteritis, a pneumonia, a cystitis, or a perityphlitis may be the starting-point. The patient at first does not appear to be very ill; there is some prostration; he complains of a slight headache which does not yield to treatment; the appetite is poor; no interest is taken in surroundings; the symptoms of lymphangitis and lymphadenitis may be present; the temperature shoots up, especially in the evening, with only slight morning remissions; the pulse becomes rapid; the patient feels "feverish"; there may be some pain in the wound. Often an examination of the local condition will demonstrate the cause of the symptoms, and prompt surgical treatment may cut short the further course of the disease, the condition returning rapidly to normal upon removal of the local cause. If the disease goes on, gastro-enteritis appears, with vomiting and diarrhœa. The tongue, at first thickly coated, becomes dry and hard. The heart's action becomes weaker and increasingly rapid, often out of proportion to the temperature; the arterial tension is lowered, and in the severe cases cyanosis appears. The liver and spleen are often enlarged. The urine shows albumin and casts. The skin may show a slight yellow tinge, but icterus is not so marked here as in pyæmia, and is probably due to destructive processes in the blood rather than to hepatic disease. At first dry and hot, the surface of the body later is bathed in perspiration, the skin feeling cold and cadaveric. The prostration increases, the expression is listless, the face being drawn and colorless, the eyes are sunken, and the alæ nasi dilated; no complaints are heard. If the disease reacts to treatment, a general improvement of the sensorium is first noted; the pulse becomes a little stronger although still rapid; the temperature gradually subsides, often showing at first marked morning remissions, until finally the evening rise disappears; the desire for food gradually returns; the heart is the last entirely to recover its normal condition. The disease may run a chronic course, lasting for from three to twelve weeks. The temperature in these cases is not generally high, but is often quite irregular. The spleen is frequently palpably enlarged, this being simply a phase of the general lymphatic enlargement. If, however, recovery does not occur, the condition may rapidly become worse, the temperature continuing high and the heart rapidly failing. Finally, violent purging, anuria, delirium and coma, are likely to precede the patient's death. In the malignant cases the course may be very rapid, presenting possibly only a slight lymphangitis, an increasingly high temperature, rapid cardiac failure, rapid overwhelming of the nervous system, and death. This last form is occasionally seen in cases of wounds received at the post-mortem table, cases in which, from a seemingly slight wound, the most intense and rapidly fatal toxæmia develops.

In typical cases of *pyæmia*, in which multiple abscesses are produced as a result of infected emboli, the clinical picture is somewhat different. The conditions at the primary focus may be the same as in pyotoxæmia. Severe local injuries, wounds of the joints, compound fractures, injuries of the veins, fracture of the skull, associated with pyogenic processes, are the most frequent among the primary lesions in pyæmia. The local condition may not appear to be especially active, but is markedly persistent. The wound looks bad and exudes a semi-serous, foul-smelling pus; and the surrounding tissues become œdematous and deeply inflamed. The temperature is not very high, with moderate morning remissions, and the pulse is rapid. This may continue for about a week, during which time the induration does not lessen, but extends more deeply into the tissues. Suddenly, on the tenth or twelfth day, the patient has a severe chill, following which there are a burning fever and then a profuse perspiration. Again, the wound may have been doing very nicely, and the evidence of infection may have been slight, when suddenly a chill appears and pyæmia is ushered in. Such chills are generally a reliable index of the lodgment of an embolus in some portion of the vascular system. The chill may, however, be very slight, and in those forms of pyæmia in which the secondary foci are caused through direct infection by the bacteria circulating in the blood, and not by infected emboli, often no chill at all appears. In *pyotoxinæmia* and *pyosepticæmia* a chill rarely is noted. Chilly sensations sometimes occur, but a sudden, violent chill is the exception. Following the sweating there is marked exhaustion. The temperature immediately preceding or during the chill is likely to shoot up to the highest point of the curve only to drop in a few hours, but not to normal. The chill may be repeated the same day or on the next day. The temperature runs apace, and describes a very irregular tracing, varying from hour to hour. The sensorium is perfectly clear, and the patient exhibits none of those somnolescent features which are seen in an acute toxæmia or pyosepticæmia, but he is keenly sensible to his suffering. The local symptoms of the new foci soon make their appearance. Pain is felt in the chest or under the border of the ribs, and upon examination an abscess of the liver, a pleurisy, or a pneumonia is found. The joints may be swollen and tender. Icterus is generally seen, slight at first but often marked in the later stages of the disease when the emaciation is far advanced. There is not so much gastro-enteritis as in toxæmia, and, in fact, in the earlier stages the constitutional symptoms are very little in evidence. The temperature continues as before, possibly not so high, exhibiting, however, the same marked irregularity. The tongue, at first thickly coated, becomes later dry and hard and looks dirty. The patients are often hyperæsthetic and suffer much from local pain. They often complain of pain first in one place and then in another, and sometimes there is a general sensitiveness all over the body. The cause may possibly be referred to localization of bacteria in the tissues, where they set up inflammatory processes and, in many cases, purulent collections. Later, the patients lose all sensation of discomfort. Erythematous and sometimes pustular eruptions appear on the skin. The pulse, which at first was fairly strong but rapid, later becomes weak and rapid. At any time the local symptom of some new metastatic focus may be ushered in. Prostration is very marked, the emaciation is severe. Gradually the patient becomes unconscious and dies in a comatose condition.

In *puerperal pyæmia* the course is very similar. In the chronic form of pyæmia chills are much less frequent and recovery may occur.

Von Leube ("Specielle Diagnose der inneren Krankheiten") states that from a scientific standpoint it is not always possible at the bedside to differentiate between the two conditions septicæmia (meaning toxæmia, pyosepticæmia, etc.) and pyæmia, or, better, strictly to draw the lines between these forms. The one leads into the other, and many cases of pyotoxinæmia would develop into pyæmia were it not for the short duration of the disease. Therefore he holds that in most cases it is proper to speak of a *septicopyæmia*. This is the form, he maintains, which is most likely to occur in the cryptogenic type of the disease. The patient, sometimes in fine health, sometimes suffering from a slight illness, begins to have pain in the legs, loss of appetite, eventually headache, vomiting, then a severe fever, and is very ill. The fever, often like a fluctuating typhoid, may be, however, continuously high, with slight remissions. The tendency is markedly to an up-and down course, with irregularly intercurrent chills. The pulse in the severe cases is very rapid, varying from 120 to 150, soft, dicrotic, and sometimes irregular, especially so in cases in which, on post-mortem examination, the heart walls are found to be the seat of metastatic abscesses. The heart is dilated, and endocarditis very frequently occurs. At times the endocarditis is the only objective sign of the disease at first (a loud systolic or systolic-diastolic murmur, increased second pulmonic sound, etc.). This cardiac condition governs very markedly the course of the disease. Embolic processes in the spleen and kidney follow, and abscesses form. This is the condition commonly termed "malignant endocarditis," but von Leube believes that the so-called malignant endocarditis is really a cryptogenic septicopyæmia, in which the septic poisons become localized in their action on the endocardium and remain circumscribed for a long time here. In the majority of cases, however, the endocarditis is only a link in the great chain of multiple inflammatory foci.

Next in diagnostic importance comes the inflammation of the joints, which may occur as an involvement of a single joint, or many joints may be affected at the same time. In such cases the disease will very closely resemble acute articular rheumatism. The process concentrates itself most often in one joint, which becomes greatly swollen. In connection with this we often have bone involvement, which, however, may take place independently of the joint inflammation. The long bones are especially susceptible. The foci may be circumscribed or be extensive in their involvement of the bone tissues, and they may present the ordinary symptoms of osteomyelitis. Changes in the skin are almost constant. Roseola, erythema-like urticaria, purpuric spots, hemorrhagic pemphigus, blisters, pustules, herpes, etc., are among the most frequent of its manifestations. As the disease advances these cutaneous inflammations may extend into the underlying tissues and large areas of inflammation and œdema, or hæmato-purulent infiltrations, may be found.

These affections, especially the hemorrhagic forms, are met with in three-fourths of the cases of "cryptogenic septicopyæmia," and are therefore important signs from the standpoint of differential diagnosis. Symptoms referable to the nervous system are quite constant: headache, vertigo, sleeplessness, delirium, convulsions, and temporary paralysis are chief among these. When metastases develop, purulent meningitis, abscesses of the brain with their various symptoms, are among the possibilities. Retinal hemorrhages are occasionally seen. Through localization of the septic processes on the pericardium, pleura, and peritoneum there ensue at times small areas of inflammation, or serous or purulent exudations, with their symptoms. In the lungs miliary abscesses are found, or in other cases large infarcts, abscesses, lobular pneumonia; especially frequent is a diffuse bronchitis. Cyanosis and increased respiratory movements are brought about by the heart weakness and pulmonary complications.

The spleen is no more enlarged in this form than in the others. But metastatic abscesses in the spleen and liver may increase the size of these organs very markedly. The symptoms referable to the digestive tract are neither constant nor characteristic. Icterus is only occasionally seen. The kidney functions are almost always affected. Albumin in the urine is the rule, and is caused by the septic irritation of the renal parenchyma. Acute nephritis, with its characteristic symptoms, often follows. Large abscesses may be formed, but as a rule there exist multiple miliary, sanguino-purulent collections in the kidney tissue.

Résumé.—Here we have, then, a form of the disease, put down by von Leube under the name of "cryptogenic septicopyæmia," characterized by the following symptoms: A very pronounced, irregular fever with a disproportionately high pulse frequence, great emaciation, more or less marked nervous disorders, enlargement of spleen, and special symptoms referable to the various organs in which the septic poisons become localized. In brief, then, the disease is one in which a peculiar form of exanthema develops, and in which the inflammation of the joints, the muscle and bone tenderness, the endocarditis, the embolic processes in the spleen, liver, lungs, and brain, the nephritis, the inflammation of the serous membranes, the petechial hemorrhages, all play a part in making up the complex of symptoms.

Grawitz ("Klinische Pathologie des Blutes," 1902), in discussing this form of septic poisoning, states that in most cases of "cryptogenic septicopyaemia" pyogenic bacteria are present in the blood, and that in many uncertain cases a positive diagnosis may be established by a blood examination. A negative result, however, does not exclude the disease. He further maintains that in cases of ulcerative or malignant endocarditis repeated failure to isolate the micro-organisms from the blood speaks most strongly against the disease being present, and *vice versa*.

In the cases of *pyosepticæmia* the symptoms vary somewhat, and are very largely governed by the pathological conditions which give rise to the disease. In gangrene of the lung, in tuberculous coxitis which has become secondarily infected, in chronic myelitis and myelitis transversa, in which decubitus, necroses, etc., are associated with poly-infections, we have striking examples of a pyosepticæmia. These processes, when examined bacteriologically, are found most often to harbor many different varieties of micro-organisms acting together. The streptococci, bacillus coli communis, proteus vulgaris, and bacillus pyocyaneus are frequently found associated in such a process. The symptoms then are those of the local condition and the general poisoning of the system. The fever is marked and the pulse rate is high and, as in the other forms of septic poisoning, the spleen is enlarged. The temperature is very irregular and of the remittent type. The nervous system is markedly involved, more so than in the pyotoxinæmic forms. The blood itself does not show such marked changes, and frequently micro-organisms cannot be demonstrated in the general circulation. We have then in these cases to deal with a condition of poisoning, due chiefly to the absorption of the toxic products from a localized process, rather than with disease resulting from a bacterial invasion of the whole system.

The symptoms in cases of septic intoxications and infections, as given above, are only composite pictures of the various forms of the disease. In many of the actual cases the disease manifests itself differently, and the course of these cases can be best demonstrated by giving examples of actual cases. The following cases, unless otherwise designated, have been taken from the records of the Methodist Episcopal Hospital of Brooklyn, New York.

Case I. Pyotoxinæmia Following Infection of Knee-Joint.—On June 20th, 1888, an operation was done on the knee-joint to remove a foreign body. The next day there were considerable pain in the joint and tenderness. Temperature rose to 100.6° F., pulse 110, respirations 25. Second day after operation pain continued, the temperature jumped to 104° F., pulse 118, and patient felt listless. Third day: Patient began to vomit, at first at intervals of two or three hours and later in the day almost continuously, temperature remaining high and pulse becoming irregular and rapid. Some diarrhœa. Fourth day: Vomiting not so marked; bowels moving involuntarily; patient very restless. Temperature continuously above 102° F., pulse averaged 138, respirations 28. Fifth day: Joint re-opened and small amount of sero-sanguineous fluid was evacuated. Irrigated with antiseptic solutions and thoroughly drained; no change in general condition. Sixth day: Patient delirious, the bowels still moving frequently, temperature and pulse continuously high. Eighth day: Still delirious; much diarrhœa. Patient lies in a sort of stupor, twitching of muscles of the left shoulder and fingers of right hand; marked flushing of left side of face. Slight paralysis of the left facial muscles. Picking at bedclothes. Temperature had fallen to 100° F., pulse 120. Perspired freely. Under treatment, by thorough drainage and irrigation with antiseptic solutions, these symptoms gradually abated with the exception that the temperature remained continuously above 100° F., and the pulse about 100. On the thirtieth day the joint was again opened and some dead bone removed, after which the wound healed, the temperature becoming normal and the pulse dropping to 90. The patient had entirely recovered after an illness lasting over two and one-half months. In the accompanying chart are shown the temperature and pulse curves for the first sixteen days of the disease.

CLINICAL CHART.

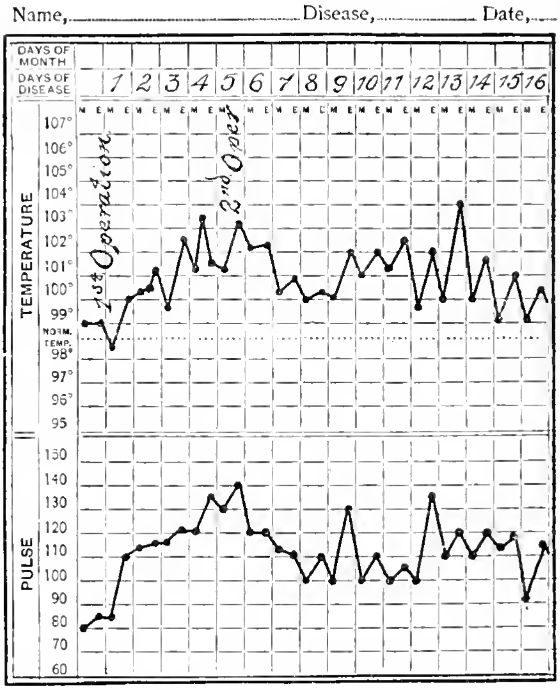

FIG. 4186.

This is an example of a case of pyotoxinæmia arising from an infection in the knee-joint. Infection of this joint is an event always to be dreaded by the surgeon, for in almost all such cases a rapid and often fatal toxæmia, and frequently a pyæmia, occurs. The synovial membranes of the joints offer very little resistance to the inroads of bacteria, and when once affected are easily destroyed and the process attacks the underlying tissues. It has been shown that streptococci may be introduced under the skin of an animal and there set up only a localized abscess, but the same organism when injected into the synovia of the knee-joint will bring about a virulent and rapidly fatal intoxication. In the present case, no bacterial examination was made. The infection evidently took place during the operation, and although the condition was soon discovered and thorough drainage established, still the process persisted for over two months. During the course of the disease the temperature and pulse were continuously high, with intercurrent remissions. The point of special interest in this case is the peculiar involvement of the nervous system, which showed itself in the unilateral paralysis of the facial muscles, the twitching of certain sets of muscles, and the flushing of one side of the face.

Case II. Cryptogenic Pyotoxinæmia.—Patient had been in poor health for about a year. Two weeks previous to admission had a severe chill, followed by fever and sweating. Chills occurred on successive days thereafter. In a few days patient began to complain of great pain in gluteal region, and then in knee and ankle. At end of eight days there were marked swelling, pain, and tenderness of the left knee and ankle. This continued, and on admission to hospital the temperature was 103° F., pulse 120. Under local treatment inflamed condition of ankle subsided, but knee remained swollen and tender. May 19th: Knee-joint was opened and considerable pus evacuated. Drained. During the ten days following the operation the temperature abated somewhat, but the pulse remained continuously high. Patient in a semi-stupor. June 1st: Patient passed into a "typhoid state," temperature becoming irregular again. June 3d: A necrotic spot appeared on left buttock. Wound looks more healthy. June 6th: Severe chill, following which temperature reached 103° F. and pulse 140. Necrotic spot on buttock broken down and surface granulating slowly. During next six days temperature at no time high, but irregular. Pulse vacillating between 120 and 170, very weak and irregular. Frequent diarrhœal movements. June 12th: Death.

Autopsy showed only inflammatory condition in and around knee-joint; cloudy swelling of kidneys; fatty degeneration of liver. Spleen was soft and normal in size.

The question arises in this case as to how the bacteria gained entrance to the joints. The autopsy does not help us in deciding this. There were no other foci of inflammation and no history of any wound as a starting-point. It therefore comes under the head of cryptogenic pyotoxinæmia, the main point of suppuration being, as in the previous case, in the knee-joint. There evidently was also an inflammatory process in the gluteal region and in the ankle, but these were controlled. There had been no pneumonitis, otitis media, enteritis, or urethritis to attract our attention. The initial symptoms, repeated chills, and high temperature, followed later by pain in the gluteal region, knee, and ankle, would suggest embolic pyæmia. But this we cannot have without some initial lesion. The origin then remains a mystery, cryptogenic. In this case there was no enlargement of the spleen.

Case III. Staphylococcus Pyotoxinæmia with Transition to Pyæmia.—February 19th, 1888: Patient fell downstairs, sustaining an injury to left ankle. No external wound. February 28th entered hospital complaining of pain in and around ankle-joint, which was somewhat swollen, tender, and red over a circumscribed area. No fracture could be demonstrated under chloroform. Pain increased in spite of local applications, and on March 2d patient had a temperature of 103° F. There were slight remissions of the continuously high temperature. Patient's general condition poor, pulse 110 to 120 per minute. March 5th: Very restless and during night slightly delirious. Area of redness extended slowly. March 6th: Fluctuation appeared at ankle. Incision was made and considerable pus was evacuated. Bone not involved. Following the operation there was a slight fall in the temperature, which, however, rose again the next day to above 103° F. March 7th: Temperature still high, respirations very rapid and superficial, but examination of the lungs was negative. Over the cardiac region, most distinctly over the aortic area, were heard a distinct friction sound and a blowing murmur, where previously there had been none. In the evening this friction sound disappeared. During the night the patient became very restless, and toward morning began to vomit at long intervals. Temperature reached 104.5° F., pulse increasingly rapid, 130 to 160. There was marked emaciation. Vomiting became more frequent, bowels moving involuntarily. Gradually the patient became comatose, pulse imperceptible. Death.

Autopsy: Pericardium injected and the sac distended with pale, greenish-yellow fluid and flocculi of fibrin. No fluid in either pleural cavity. Lungs in places adherent. Heart is covered with a layer of fibrin, thicker in some places than in others; fibrin also seen on the pericardium. Left lung: Scattered through the lung are areas of congestion surrounding infiltrated patches with whitish centres; none of these areas is larger than a pea. Right lung: On surface, especially on anterior border, are a number of small circumscribed white spots, cone-shaped upon section. On posterior surface are a number of small punctate spots of hemorrhage. The lung is somewhat œdematous and congested; bronchi are normal. Heart muscle is very pale. Spleen enlarged and soft. Right kidney: Just beneath the capsule is a single small abscess.

Microscopical examination: The nodules described in the lungs and kidney proved to be small infarcts, the blood-vessels leading to them being occluded by firm thrombi. They consist of masses of inflammatory tissue with small pus collections.

Bacteriological Examination: Original wound, infarctions of kidney and lungs, showed pure culture of staphylococcus pyogenes aureus.

Diagnosis: Acute pericarditis, multiple infarctions of both lungs, abscess of kidney. Staphylococcus pyotoxinæmia passing into pyæmia.

Remarks: We have here the history of an injury to the ankle-joint without any external wound being present. The staphylococci may have gained entrance through the skin which was evidently bruised, although no actual open wound occurred. Again, the micro-organisms may have been conveyed to the joint by the blood from some other undiscovered focus. The only clinical evidence of pyæmia was noticed on March 7th, when a pericardial friction sound was heard. There were no chills, but there were marked gastro-intestinal symptoms, a continuous remittent fever, and a weak but rapid heart's action—in fact, all the clinical symptoms of a pyotoxinæmia, which at autopsy proved to be an embolic pyæmia.

Case IV. Pyosepticæmia.—November 8th: Patient on admission to hospital presented an area, over right eye, about three inches in diameter, bright red in color, with a well-defined margin, slightly œdematous and gangrenous in places. It was covered with small suppurating points. Upper eyelid enormously swollen. Temperature 106° F., pulse 120, respirations 35. Operation: Curetting of necrotic tissue, free incisions. November 9th: Temperature dropped to 95.6° F., pulse 75, respirations 25. Patient delirious, tinnitus aurium. Extensive reddish, papular eruption on chest. Skin cold and clammy. Later in day, temperature rose to 104° F., pulse 110; vomiting. November 10th: Diseased area shows the characteristics of a sloughing phagedæna. November 11th: Restlessness and delirium alternating with stupor. Great prostration. Temperature continuously high. The phagedæna spread rapidly and involved a large portion of the head. Patient died in coma.

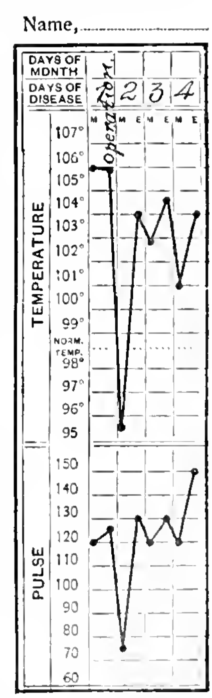

FIG. 4187.

A glance at the accompanying chart (Fig. 4187) will show the remarkable deviation in the temperature and pulse curves. The disease, originating in an inflammatory condition of the face, developed into a virulent phagedæna, combining a suppurative and a putrefactive process, which resulted in a rapidly fatal intoxication and infection of the entire system. It therefore falls into the class of *pyosepticæmia*. However, most cases which may be classified as pyosepticæmia run a more subacute or chronic course. The following case reported by Brunner (*loc. cit.*, p. 101) is an excellent example of this, and his analysis of the same is of interest:

Diagnosis: Chronic myelitis; decubitus sacralis. Putrid abscess of thigh. Polyinfection by streptococci, bacillus pyocyaneus, bacterium coli, proteus vulgaris. Death. Pyosepticæmia.

History: Patient well until three years ago. First signs of disease appeared as feeling of fatigue in the feet, chilly sensations and formication. The symptoms were steadily progressive. Disturbance in the function of the bladder and rectum appeared, and finally loss of control of same. In December complete loss of use of the legs; later, decubitus sacralis. Admitted to hospital January 25th, 1898.

Status præsens (at time of admission): Both legs useless. Hardly any sensation in them. Beginning involvement of upper extremities. Involuntary micturition and defecation. Decubitus spots, about size of silver quarter of a dollar, on each heel. Over the sacrum a deep decubitus about the size of the palm of the hand; sacrum exposed, a further defect over the lumbar vertebræ and over the trochanters. High temperature. Urine cloudy, strongly ammoniacal.

Course: February 13th: The decubitus slowly enlarging. Application of vinum camphoratum. In the region of the left trochanter a collection of foul-smelling pus, undermining the skin. February 19th: Always high temperature with morning remissions (see accompanying chart, Fig. 4188). On right thigh a large fluctuating abscess has formed. Incision and drainage. A large amount of filthy, bad-smelling material and gas evacuated. During the night *exitus lethalis.*

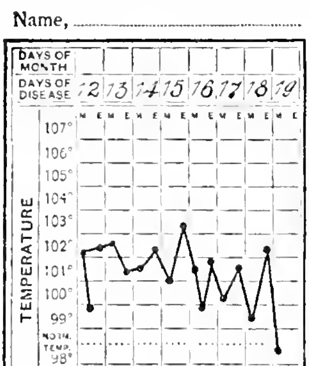

FIG. 4188.

Autopsy: Ten hours after death. Extract from the protocol. On back, over the sacrum and over the trochanters, the above-described decubitus defects. The abscess cavity on the right thigh reaches from the patella to the middle of thigh; its periphery presents masses of bad-smelling necrotic tissue, with threads of fascia running through it. A sound can be passed from this abscess cavity up to gluteal region. Spleen very much enlarged and soft. Both kidneys contain small abscesses, the size of a pea.

Bacteriological Examination.—I. During life: 1. Examination of urine: bacterium coli. 2 Examination of blood. February 19th: Blood aspirated from vein of arm, under aseptic conditions. Cultures made on glycerin-agar and in gelatin. *Result negative.* 3. Examination of pus evacuated from abscess cavity at time of incision. Smear examination; streptococci in short chains, numerous small rod shaped bacteria. In the glycerin agar and gelatin cultures, copious growth of pure culture of proteus vulgaris. Pathogenesis: Injection of 1 c.c. of original culture into ear vein of rabbit, evening of February 24th, caused death during night of February 25th. Guinea-pig: Injection of 1 c.c. of the same culture subcutaneously into wall of abdomen on February 24th, 4 P.M. February 27th, local infection. February 28th, fluctuation. March 1st, incision and thick yellow pus evacuated! Culture on agar showed proteus in pure culture. Injection of 1 c.c. of the same growth into abdominal cavity of guinea-pig. Animal lived.

II. At the autopsy: 1. From the deepest portion of the decubitus; proteus vulgaris greatly predominating; Bacterium coli and bacillus pyocyaneus also present. 2. Thigh abscess: proteus vulgaris. 3. Heart blood: pure culture of proteus vulgaris. 4. Liver: proteus vulgaris. 5. Spleen: negative. 6. Kidney abscess—could not be properly examined owing to use of non-sterilized knife in making the section.

Analysis of the case by Dr. Brunner. Avenue of the infection. On account of the myelitis the trophic changes and anæsthesia of the skin took place, and owing to pressure the mortification of the tissues occurred and pressure-necrosis resulted. Owing to incontinence of urine and fæces the area became easily infected with the proteus vulgaris and bacterium coli, to which later was added the bacillus pyocyaneus. The B. coli caused early a cystitis. Subcutaneously the tissue surrounding the sacral decubitus broke down under the attack of the pyogenic micro-organisms. The process worked down along the thigh and manifested itself there in the formation of a putrid, gas-containing abscess. In this abscess the proteus vulgaris was the most active agent, and was found in pure culture in the remotest portions of the cavity. Streptococci were found only in smear preparations and could not be demonstrated in the cultures. It is probable that they were active during the abscess formation up to the time when the incision was made, but were no longer able to develop or were killed by the proteus in the culture media. From this extensive area of putrefaction with destruction of much tissue, the poisons which were elaborated were doubtless absorbed into the blood. It is also very probable that from time to time various streptococci and proteus rods wandered into the blood stream; they, however, did not develop in the blood; a bacteriæmia—bacterial septicæmia, in the sense of Koch's definition—was not present. That such a condition did not exist at the height of the disease is proven by the negative result in the examination of a relatively large amount (5 c.c.) of the blood. The bacteriæmia post mortem was in itself not proof positive.

Characteristics of the Clinical Picture. If one may ever speak of a "rotten infection" and "putrid intoxication," this case certainly falls into such a class. Putrefaction and malodorous decomposition were brought about through the activity of four dangerous micro-organisms: streptococcus, bacterium coli, proteus vulgaris, and the bacillus pyocyaneus. Together with this disintegration occur the pyogenic phenomena due to these germs. A large gas abscess developed, and this, together with the decubitus, was the chief source of the poison which brought about the general intoxication. High fever, high pulse frequence, dry tongue, enlargement of the spleen, changes referable to the nervous system—these are the symptoms of the intoxication. The temperature curve again shows the zigzag remittent type without special diagnostic significance. An intense invasion of the circulation by the causative agents, or any growth of the same in the blood, did not occur. Bacteriæmia is excluded, and a toxæmia remains. Since we have in this case a combination of pus formation and putrefaction, it falls into the class of pyosepticæmia. The small abscesses in the kidneys are explained as an extension of the B. coli infection from the bladder. In the absence of a bacteriological examination a definite conclusion cannot be arrived at.

The gonococcus starting from an initial lesion in the urethra may act alone or in combination with other micro-organisms to bring about a general infection or pyæmia. Bujwid, in his article, "Gonococcus als die Ursache pyämischer Abscesse" (*Centralblatt für Bakteriologie*, 1895, Bd. xviii., S. 435), presents the following case: Young man, thirty-two years of age, suffering from chronic gonorrhœal urethritis, after passage of a sound had a severe chill which lasted some time. This was repeated the next day and the two or three days following. Later, four abscesses appeared: one in the region of the left shoulder, one in the right popliteal space, one on the inner side of the left leg, and one over the external malleolus of the right leg. These abscesses were all confined to the muscular tissues and did not involve the connective tissue or the joints. Upon incision they contained a small amount of odorless, brownish-red pus, in which the gonococcus in pure culture was found.

Ohmann reports a case in which the complications were multiple arthritis and tendo-vaginitis, epididymitis, and nephritis, and in which case he was able to demonstrate the gonococcus in the blood. Brunner states that in these cases the course may be very acute with all kinds of complications, but that there is very little tendency to destruction of tissue. Finger, from his observations in gonococcus pyæmia, holds that in such inflammations there is always a tendency toward the early formation of granulation tissue and later an increased connective-tissue formation. There occur in the urethra strictures; in the prostate a destruction of the glandular structure; in the epididymis, thickening of its walls; in the joints, ankylosis etc. The micro-organism is less energetic and less destructive in its action than are the other pyogenic agents.

In the cases of puerperal infection, owing to the richness of the blood and lymph supply incident to pregnancy, the disease is often very rapid and fatal. It may follow the type of a pyotoxinæmia, a pyosepticæmia, or lastly a pyæmia. In the rapidly fatal cases pyotoxinæmia is most frequent, while pyæmia is often a complication. In the subacute cases pyosepticæmia is often the form of the disease which is present, the uterus and adnexa being found in a necrotic or gangrenous state associated with pus formation.

Otitis media frequently is the starting-point of a general septic infection, the sigmoid sinus becoming involved and thrombo-phlebitis resulting. Purulent meningitis and abscess of the brain with their characteristic symptoms may cause death, or a typical embolic pyæmia with metastatic foci in the lungs, heart, kidneys, etc., may develop. The course is generally long.

Prognosis.—In septicæmia without bacterial activity the prognosis depends mostly upon the etiological factors and the ability to remove the cause. When the condition is due to retained secundines, the removal of the same is followed by rapid recovery. In the various forms of ptomaïn poisoning, from the ingestion of putrid foods, some prove rapidly fatal, while others recover upon removing the offending material from the intestinal tract. But, in general, the adoption of prompt treatment, as soon as the cause is discovered, is followed by recovery.

In the milder forms of *pyotoxinæmia* and *pyosepticæmia* the disease often is amenable to treatment, but all forms depend upon many factors. The age of the patient, the ability of the tissues to check the inroads of the bacteria, the virulence of the micro-organism, the site of the infection have all been referred to above. Even in the severe cases, the establishment of thorough antiseptic treatment may bring about recovery. In general the prognosis is poor. In the majority of cases of pyosepticæmia the prognosis is bad.

The prognosis in pyæmia is always grave. When metastases develop rapidly and involve important organs the result is usually death. In gonorrhœal pyæmia the prognosis is better. Warren ("Surgical Pathology," p. 378) claims that there is a relatively high percentage of cures in puerperal pyæmia.

Diagnosis.—To distinguish between the different forms of the disease from a clinical standpoint is often impossible. It must be remembered too that one form may merge into an advanced form without any marked symptoms to designate the period of transition. In septicæmia without bacterial activity surgical interference with disappearance of the symptoms will establish the diagnosis. In the cryptogenic or spontaneous forms of the disease a careful examination of the entire body must be made and all of the secretions be carefully tested. The presence of a suppurating focus, lymphangitis, enlarged regional lymph nodes, with a continuously high temperature, very rapid pulse, absence of chills, indifference of the patient, gastro-enteritis, presence of albumin and bacteria in the urine, and bacteriæmia would point most strongly to pyotoxinæmia. Such conditions as a gangrene of the lungs, moist gangrene of the extremities or other portions of the body, extensive decubitus and other necrotic and putrefactive processes in which pyogenic bacteria are present, and accompanied by a markedly irregular temperature, rapid and feeble pulse, pronounced nervous disorders, no marked blood changes, and negative bacterial blood tests, together with the other phenomena of septic intoxication, may be safely diagnosed as pyosepticæmia. If, in the presence of an imperfectly draining wound, cellulitis, lymphangitis, thrombo-phlebitis, ulcerative endocarditis, pyosepticæmia, pyotoxinæmia, or any of the conditions above mentioned, there occurs a sudden sharp chill, accompanied by a marked rise in temperature, and followed by sweating and pain referred to some distant point, pyæmia must be suspected. If, in the subsequent course of the disease, the chills are repeated, the mental faculties remain clear, marked emaciation, hyperæsthesia, diaphoresis, and great prostration are present, and the symptoms of metastatic abscesses make their appearance, the diagnosis of pyæmia is definitely established.

Among the diseases which resemble the various forms of toxæmia, septic intoxications, and septic infections, may be noted acute articular rheumatism, malaria, typhoid fever, acute miliary tuberculosis, severe anæmias, and uræmia. But in each case a careful inspection of the history and a thorough consideration of the signs and symptoms which each disease presents will result in a correct differential diagnosis.

Treatment.—*Prophylactic.*—The state of our knowledge at the present day enables us to operate almost without fear of infection, and a thorough understanding of the aseptic treatment of wounds is presupposed by the writer. It is, however, to be especially emphasized in the preparations for any operation on the knee-joint. Chronic tuberculous processes, wherever they may be, especially those of the joints and bones, are most frequently confined to the points of their primary activity and do not generally give rise to a systemic intoxication; but if, during the course of an operation upon such a process, it becomes secondarily infected the condition becomes much more serious, and any of the forms of intoxication or infection may develop. This must also be borne in mind in the treatment of any infected wound, for a polyinfection is generally more difficult to handle than a monoinfection. In the various nervous diseases in which trophic disturbances are present, much care must be exercised to prevent bedsores. If a decubitus should appear despite the frequent change of position, rubbing with alcohol, etc., they should be treated antiseptically, to prevent if possible any infection. The prophylactic measures in the treatment of compound fractures, extensive lacerated and contused wounds, and burns, should always be carried out most carefully.

Local Treatment.—In the cases of septicæmia without bacterial activity the results of removing the cause are very marked and satisfactory. If the offending substance be contained within the intestines, a course of calomel in divided doses, followed later by a saline purge, may be all that is needed to bring about recovery. In the puerperal cases the removal of the secundines, the fingers being used as a curette and the scraping being followed by a hot saline irrigation, is indicated. The same principle is to be followed in all of its forms, *i.e.*, the cause must be removed under all possible aseptic precautions.

In the other forms of the disease the care of a pus focus must first be considered. If the case presents itself with an abscess already formed, the indication is to evacuate the pus. *Ubi pus, ibi evacua.* If a putrefying area is associated with a purulent focus, as much as possible of the putrid material should be cut away, the surgeon being careful not to expose healthy surfaces. In such a condition it may be proper to swab out the cavity with pure carbolic acid and then immediately after to cleanse it with alcohol. All such abscess cavities should be irrigated with some antiseptic solution and thoroughly drained, at first with iodoform gauze and later by means of rubber-tube drains. In cases in which, following an operation, there develop the symptoms of toxæmia, an early inspection of the wound should be made, and if infection has taken place the sutures should be removed, the wound irrigated with some antiseptic solution, drainage established, and dressings wet with some non-irritating solution, as Thiersch's solution of boracic and salicylic acids, be applied. The wound should be dressed daily or, in the virulent cases, more often. In some cases constant irrigation is indicated. In pyæmia, where possible, the secondary foci should be opened and treated as above.

General Treatment.—The routine treatment always includes as a preliminary procedure the stimulation of all of the excretory organs. The bowels should be freely moved, the kidneys stimulated, and diaphoresis increased. The proper nourishment of the patient should be carefully looked after, easily digested food being given in small amounts, and, when the stomach is unable to retain food, rectal enemata of peptonized milk, peptonized egg, and whiskey should be given every four hours, in amounts not exceeding from four to six ounces. The hygiene of the sick-room is also of importance; every opportunity for fresh air, sunlight, and cheerful surroundings is to be favored. In no condition is careful nursing more necessary. The use of drugs is not very satisfactory. Antipyretics are contraindicated, for they often act as powerful cardiac depressants and mask the symptoms. Alcohol in the form of egg-nogs, whiskey, and brandy, is considered by many to have very beneficial effects. In fact, these patients bear large amounts of alcohol very well, and it should be given freely. The heart's action can be stimulated best by using relatively large doses of the tincture of digitalis. If the diarrhœa is troublesome, it may be controlled by opium, or by bismuth and salicylic acid in their various forms. Paresis of the gastro-intestinal tract may be treated by an hypodermic injection of atropine sulphate gr. $\frac{1}{80}$, and bisulphate of quinine gr. v., to be repeated in five hours if necessary.

The use of intravenous and subcutaneous infusions of normal salt solution acts very beneficially in these cases. It helps to maintain the circulation, protects the nervous centres, dilutes the poisons, and assists very materially in the elimination of both the micro-organisms and their toxins. The infusions may be given daily in relatively large amounts, 1,000–1,800 c.c. being given intravenously. An objection has been raised to this, the statement being made that such a regular dilution of the blood would cease, after the first day or two, to have any beneficial effect; but this is not true, for in the course of twenty-four hours the excess of the solution may be entirely excreted from the body and a new infusion be called for. With this as a basis, many experiments have been made by adding antiseptics to the solution with the hope of bringing about a direct antiseptic influence upon the micro-organisms in the circulation and tissues.

Intravascular Antisepsis.—Experiments were carried out by Maguire, of London, to ascertain the effects of introducing a solution of formaldehyde gas directly into the circulation. His experiments were carried out upon animals and upon himself, and he concluded that 50 c.c. of a 1 to 2,000 solution of formaldehyde gas, or 50 c.c. of a 1 to 800 solution of formalin, could be safely introduced into the circulation without bringing about any serious blood changes. After injecting 100 c.c. of a 1 to 2,000 solution of formaldehyde into his own circulation, the only change that was noted was the appearance of albumin in the urine. Later, he injected 263 c.c. of a 1 to 2,000 formaldehyde solution. There followed considerable cramp-like pain in the arm, where the solution was injected, and peculiar cardiac distress. Many red blood corpuscles and blood-coloring matter were noted in the urine. This disappeared the next day. A solution of 1 to 1,000 formaldehyde, of which 63 c.c. was injected, caused severe pain in the arm and faintness. Maguire's conclusions were that 50 c.c. of a 1 to 2,000 solution of formaldehyde (1 to 800 solution of formalin) was the maximum dose to be safely injected in man. That is to say, if the total quantity of blood in an adult be estimated at 5,000 c.c., the solution of formaldehyde in the blood would be 1 to 200,000, which is a very efficient germicide. Barrows, of New York, applied this principle in the successful treatment of an advanced case of puerperal sepsis, as reported in the New York *Medical Journal*, January 31st, 1903. In his case he gave an intravenous infusion of 500 c.c. of a 1 to 5,000 aqueous solution of formalin, and on the third day following a second infusion of 750 c.c. of the same solution was given. There followed a rapid, marked, and permanent improvement which resulted in recovery. As a result of his experiments and those of others he concludes that the procedure depends on its being correctly and scientifically applied. He warns the profession against its indiscriminate use where proper blood cultures have not been made. It is also suggested that normal salt solution be used in making the formalin solution, as it has been found that no change takes place in the formaldehyde in this solution. Although no harm has been done to the blood cells by the infusion of formalin in distilled water, theoretically the normal salt solution is to be preferred.

Fortesque-Brickdale, as a result of his experiments upon rabbits, published in the *Lancet*, January 10th, 1903, does not favor the use of intravascular antisepsis. He states: "That rabbits injected daily with non-toxic doses of oxycyanide of mercury, formic aldehyde, chinosol, protargol, or taurocholate of sodium are not thereby protected from the usual effects of a previous inoculation of virulent anthrax; and that chinosol and formic aldehyde in large doses (toxic) so depress rabbits infected with the pneumococcus that they die sooner than an untreated animal."

Credé has applied the theory of intravascular antisepsis in the use of colloidal silver or collargol. This he claims to be a non-irritating, strongly bactericidal agent which may be employed as an inunction or as an intravenous infusion without any detrimental effects, and which is followed by marked improvement and often by recovery from the most severe forms of septic infection. He recommends it especially in cases of general sepsis, puerperal fever, pyæmia, and septic osteomyelitis. In the less severe cases, especially where the infection is localized, he uses a fifteen-per-cent. ointment of colloidal silver, rubbing two or three grams into the skin, after mildly irritating the same and causing local hyperæmia. In the more severe cases he recommends an intravenous injection of from 5 to 20 c.c. of a one-half to one-per-cent. solution, repeated daily or every week as required. Of his more recently perfected collargol solution he uses from 2 to 10 c.c. of a two-per-cent. solution. His technique is as follows: The syringe should be cleansed, the silver solution, and no other chemical, being used for this purpose. The syringe is then partially filled with collargol solution, and the detached needle is inserted, either through the skin or, if necessary, but only after a carefully made preliminary dissection, into the vein. The syringe having been attached to the needle, some blood is withdrawn into the syringe in order to remove from it any bubbles that may be present. Finally, the fluid is slowly injected. Subcutaneous injections are not effective. Viett used the intravenous method in a series of twenty cases of sepsis, and recommends it strongly.

The experiments of Grindes and Balardzsheff, however, do not bear out the conclusions of Credé, for they reported that a one-per-cent. solution of collargol had no effect on anthrax, staphylococcus, and streptococcus infections. They report that unless the injection is given at the point of the inoculation of the micro-organisms, no effect followed. They claim that the simple injection of collargol intravenously causes death sometimes. Baginski, Naltenius, and Kunzl-Krause report no beneficial results. However, other experimenters have met with decided success in its use, and the failures of others may be due to faulty technique.

Unguentum Credé, an ointment of metallic silver, has been used by some in the treatment of these cases. Forty-five grains are rubbed into the skin very gradually.

Antistreptococcus serum of Marmorek is limited in its usefulness to certain kinds of cases, but in these it has met with marked success. The favorable cases are those which are caused by streptococci alone, and when the infection is a mixed one, the serum acts upon the streptococcus infection alone. In many of the cases reported the disease was already far advanced, and consequently they can scarcely be considered satisfactory test cases of the usefulness of the procedure. Packard and Wilson (*American Journal of the Medical Sciences*, December, 1902, p. 1033) have collected 117 cases treated during the past two years with antistreptococcus serum, and in 114 of these cases there followed either temporary improvement or prompt recovery. After citing many other cases they make the following statement: "All of these reports tend to convince us of the fact that antistreptococcus serum will at least do no harm, and that in cases in which the streptococcus is alone involved it will eliminate that micro-organism and control the symptoms caused by its toxin unless used too late for any remedy to be of avail. When the streptococcus infection is found in combination with those of other micro-organisms we have learned that the serum has no influence except in so far as it controls the streptococcus symptomatology. Undoubtedly the attempt to obtain a polyvalent serum is one in the right direction, and, as in typhoid fever, it presents a key to new accomplishments in the line of special serum therapy."

Special forms of treatment are indicated in infections of different regions of the body. In extensive processes involving the extremities amputation may save life, but even after such a drastic measure it may be found that the infected thrombus has extended too far to be checked, or the systemic disease may be developed to such an extent that amputation is contraindicated. Klebs first suggested the idea of ligating and removing the veins in which thrombi had formed before the infected emboli should become broken off and pyæmia set up. This procedure is especially considered in involvement of the lateral and sigmoid sinuses following suppuration in the middle ear. Here thrombo-phlebitis is very likely to occur, and the internal jugular vein is also frequently involved. The first step of the operation should be in most cases the ligation of the internal jugular below the point of involvement. Then the sinus may be exposed and the purulent material scooped out or gently washed out. Sometimes an excision of a portion of the vein is indicated.

In cases in which the pyogenic focus is in the pelvis, or in which a general suppurative peritonitis exists, the entire abdominal cavity may be flushed out with hot salt solution. The head of the patient's bed may be raised, which, as Fowler suggested, will favor gravitation of the purulent material into the pelvis, from which it may be aspirated every few hours.

The question of the treatment of puerperal sepsis occupied the attention of the Fourth International Congress of Obstetrics and Gynæcology in Rome, September, 1902, and formed one of its chief topics for discussion. The following extracts are taken from the report by Dr. H. N. Vineberg ("American Gynæcology," January, 1903). The conclusions of H. Treub (Amsterdam) were as follows: The usual methods of treatment (curettage, intra-uterine irrigations, ice bags, cold baths, turpentine injections, antistreptococcus serum, alcohol) for puerperal sepsis localized in the uterus are in most cases followed by cure. In a few exceptional cases hysterectomy will be indicated. Tuffier (Paris) said that in a given case of *septicæmia*, post partum, or post abortum, when there is no cause for the fever to be found either in the external genitals or in other organs, when the usual methods of treatment are of no avail and when the peritoneum and adnexa are intact, and the uterus is large, flabby, and is discharging fetid lochia, and if the patient's general condition warrants it, total extirpation of the uterus should be done, whether there be placental retention, a sloughing myoma, or the so-called "metritis desiccans." A. Pinard (Paris) recognized only the following indications for hysterectomy: retained putrid placental remains, sloughing myoma, and perforation of the uterus.

The *convalescent stage* calls more for careful nursing and attention to general hygienic principles than for drugs. Nourishing food, fresh air, and cheerful surroundings are the essentials. *Paul Monroe Pilcher.*

SERUM DIAGNOSIS AND SERUM THERAPY.—I. SERUM DIAGNOSIS.—Serum diagnosis and serum treatment rest upon the same fundamental principles. When a group of foreign cells enters an animal body, whether in the form of disease or of experimental infection, there results a group of changes both in the foreign cells and in one or more cell groups of the body which they invade. These changes are peculiar and specific in relation both to the invader and to the territory invaded. The blood, as the representative of all organs, undergoes specific changes which are at the basis both of serum diagnosis and of serum therapy. A few examples will make this clearer. When a human body is invaded by a group of cells of that peculiar species known as typhoid bacilli, the blood acquires a number of new and specific properties, specific in the sense of manifesting their action only in relation to the typhoid bacillus. Upon one of these new properties serum diagnosis is based. The ability to agglutinate any specimen of the race typhoid bacilli is possessed to a feeble degree by the blood of many healthy human beings. But when a person is or lately has been suffering from typhoid fever, the agglutinating power of the blood over typhoid bacilli becomes greatly increased, and the resulting reaction, first brought into clinical use by Widal in 1896, is that ordinarily known as the "Widal reaction." This reaction, like all the agglutinative reactions, is specific in a double sense. The bacilli are thus agglutinated only by the serum of patients recently or formerly infected with typhoid. On the other hand, no bacillus, except the typhoid bacillus, is clumped in high dilutions by typhoid serum. The reaction has therefore a double use. Given a group of bacilli clearly identified as typhoid, we can use them for testing the serum for diagnosis in doubtful febrile cases. Or, given some serum or blood from a case known to be typhoid, we can use this liquid either fresh or dried on blotting-paper as a means of identifying doubtful cultures of bacteria.

The agglutinative reaction has now been shown to be of use, in both the ways just exemplified, as a means of identifying a considerable variety of diseases on the one hand, and of bacterial species on the other. The diseases in which it has been found of value thus far are, first and foremost, typhoid in which its use has been firmly established since 1898. Probably the number of tests performed in this disease exceeds those performed in all of the diseases put together. Next to typhoid, Malta fever and epidemic dysentery of the type due to Shiga's bacillus are the diseases in which the agglutinative reaction between the patient's blood and the specific bacillus of the disease is most frequently performed. The reaction has also been found to be of value in the diagnosis of the bubonic plague, and it is apparently our only reliable means of diagnosis in cases of infection by the so called paratyphoid bacillus, an organism closely allied to, but not identical with, the bacillus of Eberth.

A certain amount of agglutination has also been demonstrated in infections due to the tubercle bacillus, the pneumococcus, the pathogenic streptococci, and various others, but the reaction is not distinct enough to be clinically available. An agglutinative reaction may also be obtained with the serum of cases of glanders, whether in animals or in human beings, but the usefulness of mallein has thus far prevented any widespread application of the agglutination test in glanders.

Technique of Serum Diagnosis in Typhoid Fever.—First of all we must have a culture of the typhoid bacillus identified as such by all known tests. Bacilli that have recently been obtained from a human body are usually preferable. From such a well-identified stock culture, which is best grown on agar-agar, a loopful is transferred to a test tube containing about an inch of sterile bouillon. At the end of twelve hours at room temperature the bouillon will be slightly cloudy owing to the presence of very actively motile bacilli. Such a culture remains fit for use for from twenty-four to thirty-six hours, at the end of which time a loopful of the bouillon culture should be transferred to another tube of sterile bouillon and so on, a new culture being started every twenty-four hours and all being kept at room temperature, not in the thermostat. In order to be fit for use the bacteria must be very actively motile and show no tendency to spontaneous agglutination, such as often occurs in cultures more than thirty-six hours old. Since such spontaneous clumping occasionally occurs even in cultures frequently transplanted, it should be an invariable rule to examine, between slide and cover glass, a drop of the culture to be used, before adding any of the suspected blood. Spontaneous clumping is the most frequent source of error in performing the Widal test, for if we have added the blood of a suspected case without previously examining the culture, and if agglutination is then found, we have no means of knowing whether it was produced by the action of the blood or had previously taken place in the culture.

It should never be forgotten that the reaction is a quantitative one and not a qualitative one. If enough *normal* serum is added to a culture of typhoid bacilli and they be left in contact an hour or two, some agglutination often occurs. The Widal reaction is the occurrence of agglutination in a particular dilution and within a specified time. The dilution recommended by Professor Welch of Johns Hopkins is one part of blood to fifty parts of bouillon culture of typhoid bacilli. Any agglutination which takes place in such a mixture, if accompanied by a cessation of motion within one hour, is considered a positive reaction. In my own work I prefer a dilution of 1 to 10 with a time limit of fifteen minutes. With a longer time limit this dilution often gives rise to mistakes, but among many thousands tests I have known not more than one per cent. of mistakes, provided the short time limit (fifteen minutes) is rigidly enforced.

Either the whole blood or the serum may be used, in fluid condition or dried on glass or glazed paper. The chief obstacle to using dried blood is the difficulty of securing accurate dilution. A full drop of blood should be allowed to fall upon a glass slide and dried. (In this condition it may be preserved for weeks without losing any of its properties, or may be sent by mail in case no laboratory is at hand.) To make the test the dried blood is simply scraped off into a test tube containing ten drops of a bouillon culture of typhoid bacilli. It is difficult to measure the size of the drops accurately, but in a vast majority of cases this degree of accuracy is unnecessary.

The reaction is present in about ninety eight per cent. of all cases of typhoid fever, but in a small proportion of these the reaction does not appear until so late a period of the disease that we cannot use it for diagnosis. In about two-thirds of all cases the reaction is present by the time the patient feels sick enough to consult a physician, that is, somewhere about the end of the first week of the disease. After defervescence the reaction persists in many cases for three or four months, occasionally for years. In a case of this latter type, if the patient is seen for the first time with some febrile affection and without knowledge of his previous history, the agglutinative reaction to typhoid still persisting in the blood may give rise to an error in diagnosis. As a matter of fact, however, I have very rarely known this difficulty to arise.

Technique of Serum Diagnosis on Other Diseases.—*Plague.* Since the bacillus pestis clumps spontaneously in bouillon it has been found necessary (Klein, *Lancet*, June 8th, 1901) to make an emulsion of a small fragment of solid culture in 0.75-per-cent. solution. Cairns (*Lancet*, June 22d, 1901) has made three hundred tests in twenty-four cases by this method, and finds that in all but the mildest and the most rapidly fatal cases an agglutinative reaction appears by the end of the first week in dilution of 1 to 10. This increases until by the eighth week a dilution of 1 to 75 is often insufficient to prevent agglutination. The time limit is fifteen minutes. In hanging-drop preparations agglutination within two hours often occurs in dilutions as high as 1 to 200.

Malta Fever. The test is performed exactly as in typhoid. Agglutination is often found in dilutions of 1 to 100 or more with a one-hour time limit.

Dysentery. The serum of cases studied by Vedder and Duval (*Jour. of Exp. Med.*, February 5th, 1902) agglutinated several strains of dysentery bacillus in dilution varying from 1 to 30 up to 1 to 500 within one hour. Controls with B. coli and B. typhosus were always negative. The reaction does not always appear simultaneously with the symptoms and may disappear in convalescence with great rapidity. The clumps are usually like those in the Widal reaction. Rarely, long loose skeins of bacteria are formed.

II. Serum Therapy.—As already intimated, serum therapy depends upon the fundamental fact that a group of body cells—for example, those of the central nervous system—have a way of rising to the emergency when compelled to defend themselves against a group of foreign cells (*e.g.*, tetanus bacilli) and of producing in excess substances antagonistic to such foreign cells or to their products. Such an antagonism is known as immunity. To be immune against a given cell is to possess the power of poisoning or dissolving that cell. This is known as antibacterial immunity. When the body is attacked, not by cell groups but by cellular products, such as toxins, another type of immunity is produced by virtue of which the blood of the immunized individual is able to neutralize and render inert the toxin molecules.

Either of these forms of immunity may be "natural" or "acquired," that is to say, the blood of many individuals contains substances similar in their action to antibacterial or antitoxic substances, even when the individual has never, so far as we know, been obliged to repel the attack of foreign cells, or, in simpler language, has never had the disease against which he is thus immune. Thus negroes seem to be, for the most part, congenitally immune to malaria, in much the same way as many species of animals are immune to the typhoid bacillus.

Acquired immunity is the result (*a*) of the disease, (*b*) of inoculation with the bacterial cells or the non-cellular toxins which cause the disease, or (*c*) of the inoculation of the body with the serum of persons convalescent from the disease in question or of some animal which has previously been rendered immune to the disease. Immunity acquired as the result of infection, whether accidental or experimental, is known as "*active immunity*." That acquired as a result of the injection of serum from a convalescent or immune animal is called "*passive immunity*."

In the great majority of instances practical serum therapy consists in causing a patient to acquire a *passive immunity* by the means just described, but there are a few examples of serum therapy by which we endeavor to give the individual's blood antibacterial rather than antitoxic power.

The diseases in which serum therapy has been used may be divided for convenience into those in which its utility has been definitely established, those still in the experimental stage, and those in which experiment seems to have demonstrated that by our present methods immunity cannot be conferred. In the first class we may group the following diseases in which it may be considered that serum therapy has come to stay: 1. Diphtheria. 2. Tetanus. 3. Snake-bite. 4. Rabies.

I will subdivide the next class into those diseases in which the outlook for serum therapy is very promising, and those in which it is distinctly less hopeful. Very promising have been the experiments with serum therapy in: (1) Bubonic plague; (2) acute epidemic dysentery; (3) typhoid.

Less promising, but still hopeful, is the outlook in: (1) Cholera; (2) anthrax; (3) scarlet fever.

Unpromising has been the result of our work so far in: (1) Tuberculosis; (2) pneumococcus infections; (3) streptococcus infections.

A few experiments have also been made with sera in Graves' disease (milk of thyroidless goats), epilepsy (serum of epileptics between paroxysms), syphilis, and various other diseases with results thus far inconclusive.

Diphtheria. Antidiphtheritic serum (into the details of its production I cannot here enter) is the serum of horses rendered immune to diphtheria toxin by increasing doses of the toxin administered subcutaneously. Its uses are two: (1) Prophylactic and (2) curative.

Its *prophylactic* value in communities exposed to infection (schools, hospitals, etc.) is very great. The immunity begins about twenty-four hours after the injection and lasts for from three to four weeks. For a young child two hundred and fifty units is a proper dose. For adults a proportionately larger dose is required.

Its curative properties are now established beyond reasonable doubt. By its use the mortality in large contagious hospitals has been reduced from an average of forty-five per cent. to an average of sixteen per cent. (this last figure is based on an analysis of over 200,000 cases by Bayeaux). The mortality is less the earlier the serum is given in the course of the disease. In mild cases 4,000–6,000 units are sufficient. In severe cases 80,000–100,000 units may be needed to save life. The single dose for adults is 4,000–8,000; for children 2,000–4,000, and the dose is to be repeated every four to six hours unless marked improvement shows itself after the first dose.

Urticaria occasionally results from the use of antitoxin in diphtheria and may be very troublesome, but there is no evidence that nephritis, neuritis, or any other severe complication is ever produced by the serum.

Tetanus. Less brilliant than those of antidiphtheritic serum, the results of antitetanic serum are still such as place it far ahead of all other known remedies for tetanus. The great difficulty is to get it into the system sufficiently early in the disease.

Two sera are used: (*a*) that of Behring and Roux; (*b*) that of Tizzoni. The latter has been the more successful, but there is reason to believe that the type of disease is milder in Italy. Pfeiffer* has recently collected the cases treated with Behring's serum and finds a mortality of 52.7 per cent.; in 88 cases treated with Tizzoni serum the mortality was 36.3 per cent.

The Behring serum is used in doses of 20 c.c. every five to ten hours. Of Tizzoni's product (solid) 2.25 gm. are used for the first dose and 0.6 gm. for subsequent doses.

Recently cases have been treated by subarachnoid injections of the antitoxin by means of lumbar puncture, and there is some evidence that this method is preferable. Intracerebral injections have also been employed, but without any evident advantage.

Preventive inoculations with tetanus antitoxin in cases of injury in a community in which tetanus has been prevalent, have resulted in a marked lessening of the number of tetanus cases developing.

Snake Poisoning. Calmette's antivenene, 10–20 c.c., frequently repeated, is a most useful remedy especially for the bites of cobras and colubrine serpents, less so for bites of vipers or rattlesnakes.

Antivenene appears in the serum of horses treated with increasing doses of cobra venom slightly modified by heat. Injected in patients suffering from a cobra bite it neutralizes one of the two poisons present in cobra venom —the nervous poison—and "enables the individual to devote all his vitality to overcoming the local injury" done by the other poison (the irritant) present in the venom. Since the nervous poison is the chief death dealing agent in venoms antivenene is of great value and should be carried by all travellers likely to be exposed to snake-bite.

Rabies. Although the specific poison is as yet unknown, much has been accomplished in the prevention of rabies by injections of what is probably a toxic serum (in all essentials) obtained from the spinal cord of mad dogs. Cords preserved in dry air gradually lose their virulence, and in the treatment of mad-dog bite in the human subject injections are begun as soon as possible after the bite, first with material from cords nearly devoid of virulence and later with material of gradually increasing virulence.

The figures of the Pasteur Institute from 1886 to 1894 include 13,817 persons supposed to have been bitten by rabid animals. The mortality is 0.5 per cent. Allowing for many mistakes in diagnosis we can hardly doubt that these inoculations have been effective, since the mortality of the disease is usually estimated at from sixty to eighty per cent.

Plague. Three sera are in use: 1. The Haffkine prophylactic vaccine. 2. The Yersin "antipest" serum. 3. The Lustig "antipest" serum.

1. According to Haffkine's own reports, the difference in mortality between those inoculated and those uninoculated is from eighty to ninety per cent. As sample results he reports (Proc. Roy. Soc., vol. lxv., No. 418) an epidemic in the Umerkadi Jail: 127 uninoculated; 10 cases, 6 deaths; 147 inoculated; 3 cases, *no* deaths.

The vaccine has no effect on cases in which the disease is incubating at the time of inoculation. The dose is 2.5 c.c. The duration of immunity is not well determined.

In a Russian village Tchistowitch (*Annales de l'Institut Pasteur*, March, 1900) succeeded in stamping out an alarming epidemic by the prophylactic use of Haffkine's vaccine. Its effects are very unpleasant, far more so than those of—

2. *Yersin's serum*, which is used as a curative in cases of plague actually under way. Daily injections of 20–40 c.c. subcutaneously or intravenously have reduced the mortality from thirty-three to thirteen per cent. in Calmette's hands. The serum also conveys a brief prophylactic immunity (twenty-five to thirty days).

Lignière has used 40–60 c.c. at a dose (*Annales de l'Institut Pasteur*, October, 1901) with ninety per cent. of recoveries in cases in which the serum was employed early.

Dysentery. Since Shiga's discovery of the bacillus of acute dysentery in the tropics, Flexner's identification of the same organism in the acute dysenteries of this country, and the discovery of the same organism in the summer diarrhœa of infancy by Vedder and Duval, work upon an antidysenteric serum has been pushed with eagerness. So far, the most definite results are those obtained in Japan and in Manila with Japanese serum from Kitasato's laboratory, but enough work has been done in this country to make it evident that the outlook is not at all unpromising.

Typhoid. The serum used in the vast majority of cases has been an antibacterial rather than an antitoxic serum, and has been administered as a prophylactic, not as a cure.

Wright (*Brit. Med. Jour.*, 1901, No. 2105) reports that among 2,669 uninoculated and 720 inoculated soldiers (Cyprus and Egypt, 1900) 68 of the former and only 1 of the latter contracted typhoid. Birt (*Brit. Med Jour.*, January 11th, 1902) noted at Harrismith (1900–01) the following data: Among 947 cases of typhoid in those not previously inoculated the mortality was 11.25 per cent. Among 203 cases of typhoid in men inoculated six to eighteen months before, the mortality was 6.8 per cent. and the type of disease milder.

Sterilized cultures of typhoid bacilli are the material used for inoculation.

Anthrax. Sclavo (*Berl. klin. Woch.*, 1901, pp. 480, 520) succeeded in obtaining from sheep, subjected to progressive inoculation of anthrax bacilli, a serum efficient

* Pfeiffer: Zeit. f. Heilkunde, xxiii., 2, 1902.

against the disease in sheep and apparently also in human beings. He refers to about twenty cases of human anthrax treated with this serum in various parts of Italy, and states that most of the patients recover.

Cholera. Working in the epidemic of 1891 at Calcutta, Haffkine inoculated with an emulsion of living cholera vibrios some 40,000 of the inhabitants. In one town, of 340 uninoculated, 45 got cholera and 39 died; of 181 inoculated, 4 got cholera and 4 died. Among 18 people living in one house, 11 were inoculated and no cholera occurred in any of them. Seven were not inoculated, 4 of them took the cholera, and 3 died. The inoculations cause a rise of 1° to 2° C., lasting with some constitutional symptoms for twenty-four hours.

Scarlet Fever. That the serum of patients convalescent from scarlet fever seems to exercise a favorable influence on the course of active cases has been noted by many observers (*e.g.*, Huber and Blumenthal, *Berl. klin. Woch.*, 1897, No. 31, and Leyden, *Munch. med. Woch.*, January 18th, 1902).

More recently sera prepared from streptococci isolated from the organs of scarlet fever cases have been used especially by Baginsky (using Aronson's serum) and by Moser, using a serum of his own manufacture. Each reports good results. *Richard C. Cabot.*

SEVEN SPRINGS.—Washington County, Virginia. These springs are located two miles from the Glade Springs. Depôt, on the Norfolk and Western Railroad. They have been known for many years, but no accommodations have as yet been provided for visitors. The waters are used commercially in the form of Seven Springs Iron and Alum Mass, an evaporated residue. An analysis of this mass by Prof. J. W. Mallet, of the University of Virginia, showed the presence of a large proportion of aluminum, sulphate and iron persulphate, besides a considerable quantity of magnesium and calcium sulphate, and numerous other ingredients in smaller proportion. This substance is highly recommended as a general tonic and reconstructive, and is said to possess special merits in such affections as cholera morbus and dysentery, and in various hepatic and intestinal disorders.
James K. Crook.

SEWERAGE AND SEWAGE DISPOSAL.—A system of sewerage is the network of pipes, conduits, etc., constructed for the purpose of collecting and carrying away from a city, town or village, the wastes of human life other than that portion of the wastes which are known collectively under the term garbage. The wastes entering the sewers may come from houses, stores, stables, factories, etc., and, if the sewerage system is constructed upon the so-called combined plan, the sewers will also carry street wash. If the system is constructed upon the so-called separate plan, street wash will be excluded, to be cared for by means of drains built for that purpose. The volume of sewage flowing in the sewers of a town or city of a given population depends mainly upon three things: (1) The consumption of water; (2) the tightness of the sewers, that is, their ability to prevent the entrance of ground water; and (3) whether the sewers are on the so-called separate or on the combined system. In England and upon the Continent, where the consumption of water does not average much more than thirty gallons per capita per day, the average volume of sewage produced by a given population must necessarily be less than in America, where the consumption of water in our largest cities and towns varies from seventy-five to two hundred and fifty gallons per capita per day. Upon the tightness of the joints of the pipes of the sewer system rests a great deal of responsibility in regard to the volume of liquid entering these sewers. By careful construction of the sewers and in some soils the ground water may be almost entirely excluded, but faulty construction in porous soils will often allow the entrance of a volume of ground water sometimes fully as great or greater than the volume of true sewage. In the combined system of sewage the volume of sewage flowing in the sewers is very much augmented at times of storm by the addition of street wash.

After collection in sewers some satisfactory method for the disposal of sewage is necessary. Formerly it was considered sufficient to empty this sewage into some body of water or flowing stream, which would either dilute it sufficiently to prevent visible nuisance, or carry it away from the vicinity of the town or city producing it. This method can still be carried out without offence by fortunately located cities and in sparsely settled countries with large rivers, lakes, and streams. As a country becomes more thickly settled, however, it is not sufficient simply to pass the sewage from its source to a point where it will not cause a nuisance to those producing it, but it must also be cared for in such a way as to prevent it from becoming a nuisance or a source of danger to other communities. On this account and coincidently with the great increase of urban life in civilized countries during the past twenty-five years, the question of sewage disposal has become a most pressing one. So general had the nuisance caused by sewage entering streams become in England as early as 1876, that the Rivers Pollution Prevention Act was passed—a law providing that no rivers or streams should be polluted because of the admission of crude sewage. In the twenty-seven years elapsing since that time there has been a constant agitation in England upon the subject, with an idea to bettering the condition of the rivers and streams, but even now the Act is very imperfectly carried out.

Practically the first agitation of this question in America was in the State of Massachusetts. The report of the State Board of Health for 1876 contained an article by the then secretary of the board, in regard to sewage disposal systems in England and on the Continent, and the same volume contained a report by an engineer of an examination in regard to the condition, on account of sewage pollution, of certain rivers and streams of Massachusetts. Since that date more important investigations upon sewage disposal and purification have been accomplished than during any previous period. An outline of this work, however, with descriptions of the most important methods, is all that can be given here. It is also well to state at this place that in this article little mention can be made of methods of dry disposal of wastes. These methods do not properly come under the head of sewage disposal, but they are methods in vogue in towns, dwellings, public buildings, etc., by means of which the wastes are collected in such manner as to render them more or less valuable for fertilizing purposes; that is, either without having been diluted or mixed with water, or only to a very slight extent. Besides the common middens, privies, etc., many patent processes for the accomplishment of the same result are in vogue in different places, and many processes by which by some means the solid matter of these wastes is, even when mixed with water, separated more or less efficiently from it before the main body of liquid enters the sewers.

The demands made upon modern engineering in complex and difficult sewerage construction are very great, and as a result methods of construction are constantly improving. Sewerage works are increasing enormously, in number, in the area covered by a single system, and in the volume of sewage collected at a single point. The volume of sewage thus collected for disposal by a single city or metropolitan district now often reaches into the hundreds of millions of gallons daily.

Direct Disposal into Bodies of Water, or Disposal by Dilution.—Fortunately located cities and towns can satisfactorily discharge their sewage unpurified into large bodies of water. Where such communities are in close proximity to the seacoast or upon a very large river, the discharge of unpurified sewage into tidal waters or swift currents is still resorted to successfully. The method is practically without expense after the sewerage system is once complete, other than that, in some instances, of pumping. It is efficient if the tidal or other currents are strong and the sewage is prevented in this manner from reaching adjoining shores, and if the volume of water into which the sewage is discharged is large compared with the volume of entering sewage. In some instances, however, even in such locations, some attempt at partial purification is made by collecting the sewage in basins and allowing sedimentation to occur before the discharge of the supernatant liquid; this sedimentation often being aided by the use of chemical precipitants.

Beginning in 1852 the straggling sewers of the city of London were given more definite form, and the sewage of this city was collected and carried by means of sewers to Barking Creek and Crossness, twelve miles below London Bridge. This enormous work was made necessary by the polluted condition of the Thames River. Before this date the sewage was discharged through many sewers directly into the Thames, as the river passed through the city. The greater part of the new works emptying at Barking Creek were completed in 1864, and in 1865 works on the opposite side of the river at Crossness were also completed. Ten years after the opening of these works it became necessary, on account of sewage carried up the river from these outfalls, to build large settling tanks in which the sewage was collected and chemicals were added for the purpose of precipitating the solid matter before discharging the clarified sewage into the tidal estuary. The solid matter resulting from this precipitation is taken out to sea in sludge boats, and the sewage is discharged between high and the middle of ebb tide. During 1901 and 1902 the average volume of sewage discharged daily amounted to 234,508,000 gallons and 47,673 tons of sludge were carried to sea each week. Twenty-two thousand tons of protosulphate of iron and five thousand tons of lime were used during the year.

Boston, Mass., together with the cities and towns surrounding it and composing a metropolitan district, with a population of 1,200,000 and having an area of 187 square miles, collects its sewage into three main systems, all of which discharge into strong tidal currents in the outer parts of Boston harbor. With two of these systems the discharge is continuous, while in the other the sewage is collected in large storage tanks and allowed to pass out on the ebb tide. Two of these points of discharge have been in operation for many years, and, notwithstanding the volume of the sewage, amounting at the present time to about 120,000,000 gallons daily, so efficient is the disposal because of dilution, sedimentation, and the rapid carrying away by swift tidal currents, that well-patronized summer resorts exist within short distances of the points of discharge.

The sewage of Greater New York all empties into New York harbor by means of many sewers, and is so diluted and dissipated by the swift and deep tidal currents that it is well cared for and practically unnoticeable. The sewage of Buffalo enters the Niagara River between Lakes Erie and Ontario. The sewage of St. Louis enters the Mississippi River, as does now the main portion of the sewage of Chicago through the Chicago drainage canal and the Illinois River, and in each instance, on account of the large volume of water flowing in the river, the disposal from some points of view is adequate.

Sewage Farms.—Berlin, Germany, passes its sewage to immense sewage farms, which have been in operation for many years, and are eleven thousand acres in extent; Paris, a portion of its sewage to farms at Gennevilliers and other places, where it is adequately cared for. Many other cities and towns, both in Great Britain and upon the Continent, follow the same method of disposal satisfactorily. This method can be carried out successfully, however, and at a profit to the farm only where the sewage is comparatively rich in organic matter, that is, where the volume of water is small compared with the population producing the sewage. It is with considerable difficulty even then that these farms can be made to return a profit above the cost of operation. It goes without saying that American sewage cannot be disposed of satisfactorily in this manner, being altogether too dilute; and any attempt so to utilize it means generally the use of only that portion valuable for irrigation, with the direct discharge of the remainder, unpurified by filtration through the soil, into the most convenient body of water. Sewage irrigation or farming, however, was the first attempt properly to purify sewage upon land, but having, sometimes at least, for its main object the utilization of the sewage rather than its purification; a profit from the farm being deemed of more importance than purification.

Continual agitation upon the subject of the prevention of the pollution of streams by sewage making a wide-felt demand for a thorough understanding of proper and efficient purification, scientific studies upon this subject were begun practically about eighteen years ago. It had been observed that the passage of sewage through soil not only caused the removal of the suspended matters, but that the matters in solution were also changed or destroyed, that is, they did not appear in the effluent unless in an unrecognized form. The knowledge of germ life and the science of bacteriology having practically its beginning at about this period, it was believed that these changes occurring in sewage were caused by bacterial life in the soil. These first investigations were made by Schloessing and Muntz in France, and Warrington and Frankland in England. Their experiments were upon a laboratory scale and, without attempting to show that bacterial life was present by means of observation, they did demonstrate that, if germicides were added to the filter or to the sewage, purification in the filter did not occur. They also observed that th ir small tube filters, containing the earth, marbles, and other media experimented with, not only purified the sewage, but the filters themselves remained fairly clean, and organic matter accumulated very slowly within them. These investigations were very meagre and not long continued.

Toward the end of 1887, however, the State Board of Health of Massachusetts established an experiment station for investigations upon the subject of sewage purification, and accomplished and published the results of the most important scientific studies that had ever been made upon this subject. This experiment station is still continued. During the past eight or ten years much work along the same lines, but upon a larger scale, has been done in England, practically all of this work being based upon the Lawrence data, with such additions in construction of filters and methods of application of sewage as local needs have suggested. Many of these English studies have been largely carried on by cities and towns with the intention of applying the results directly to their own problem of sewage disposal, and thus have a practical and in some cases limited bearing only, and are without such thorough investigation of the science of the subject as has been aimed at in the long-continued Massachusetts experiments.

Sewage farming having caused the recognition of the fact that it could not be successful except with comparatively small volumes of strong sewage and where land was plentiful and cheap, nearly all the scientific investigations at the Lawrence experiment station have centred upon evolving processes of sewage purification by means of which the largest possible volume of sewage can be efficiently purified upon the smallest possible area and at a minimum cost. These studies have nearly all been upon bacterial methods of purification, that is, the oxidation or purification of the organic matter in sewage by means of the bacteria which establish themselves sooner or later in sewage filters of all kinds. With these studies others have been made in regard to methods for the treatment of sewage preliminary to filtration, which would result in allowing larger volumes to be efficiently purified upon given areas than is possible with untreated sewage.

Theory of the Bacterial Purification of Sewage.—In the purification of sewage by the action of bacteria the process is about as follows: The bacteria in the sewage, in the presence of oxygen, first attack the carbonaceous matters, carbonic acid being formed, nitrogen and hydrogen are set free and unite to form ammonia, this in turn uniting with the carbonic acid, forming ammonium carbonate, which goes into solution. The next step is the oxidation of the nitrogen of the free ammonia, first to nitrous acid and then to nitric acid, by the nitrifying bacteria working in the presence of oxygen. The nitric acid then unites with a base, such as sodium or potassium, present in the sewage or the filter, and sodium or potassium nitrates are formed. These are, in the small amount present, innocuous mineral salts, and appear in solution in the effluent. In this work of the bacteria much of the organic matter is also changed to gaseous forms, and many gases are set free. If filtration through properly prepared filter beds is carried on slowly enough, all the organic matter in the sewage applied to these beds can be changed either to gaseous forms, such as carbonic acid, ammonia, free nitrogen and hydrogen, which escape into the air, or to mineralized bodies, which appear in solution in the effluents of the filters. Such thorough purification as this, however, is not generally necessary, nor is it practicable in many instances, except where the volumes of sewage to be dealt with are comparatively small and where land is cheap.

Intermittent Filtration.—Next to sewage irrigation or farming, in which mere driblets of sewage are generally applied to each acre under cultivation—at Berlin the volume is from five hundred to five thousand gallons—the best results and the best purification can be obtained by filtration through properly prepared filter beds of sand or similar material. In order that good work may be done in such beds they must be constructed of sand coarse enough to allow sewage to enter easily, and the sewage must be applied in such a manner, at such intervals and in such volumes, that it will pass through the entire area of the filter in a fairly uniform manner, and meet an abundance of oxygen within the filter.

Physical Characteristics of Sand Used for Filtration.—At the Lawrence experiment station a method for determining the efficiency of sands in sewage filtration was elaborated from practical experience. By this method the sand is sifted through sieves, these sieves being so calibrated that the approximate size of the sand grains passing through can be easily determined. It was found that the quantitative and qualitative efficiency of sands used in filtration depends to a considerable extent upon the finer particles present. Owing to this, a certain arbitrary standard was adopted, called the "effective size"; this being the diameter in millimetres of the finest ten per cent. by weight of the sand grains. Following this standard, if a sand is stated to have an effective size of 0.25 mm., the meaning is that ten per cent. by weight of the sand consists of grains with an average diameter less than this figure. The determination of the volume of water which a certain depth of sand of a known grade, well underdrained, will hold by capillarity is easily made. The knowledge of these two facts gives adequate data to enable one to foretell the volume of sewage which can be held by a well-underdrained sand filter of a given depth, or, in other words, its time of passage through such a filter when successive applications are made; this having a direct bearing upon the volume that can be purified satisfactorily and successfully upon a given area.

An average sand has about thirty-five per cent. of open space; that is, when this sand is dried and packed as closely as natural, the space between the grains filled with air amounts to about thirty-five per cent. of the total volume of the sand. This percentage of open space differs but little with coarse and fine sand. When a coarse sand, well underdrained, has water applied to it for a considerable period, it will hold but a small portion of this water by capillarity, while each finer grade will hold more and more, until a grade is reached that will hold itself practically saturated to within a few inches of its surface; that is, the open or air space present when the sand is dry will be filled with water.

Rate of Filtration Through Sand Filters.—A sand as fine as this last grade, which will in fact resemble clay, is practically useless in sand filtration of sewage. Any sand, ten per cent. by weight of the grains of which have a smaller diameter than 0.05 mm., is of small value for sand filtration, especially in a cold climate where freezing occurs in winter, although areas constructed of a grade of sand as fine as this can be used if trenched with coarse sand, and if the sewage is applied to these trenches. All grades of coarse sand are valuable for filtration purposes, none being too coarse to effect good results, if the underdrains of the area are placed at sufficient depths and a proper distance apart. A rate of filtration equal to 100,000 gallons per acre per day can easily be maintained upon coarse sand filters with sewage of average strength. On two filters of the same grade of coarse sand the rate that can be maintained depends very largely upon the strength of the sewage; that is, upon the amount of organic matter present in each unit volume of water going to make up the volume of sewage. Many weak sewages from towns having a considerable length of pipes laid but with comparatively few connections, or systems into which ground water enters in considerable volume, can be filtered through sand with satisfactory purification results at rates at least three times as high as the figure given above—that is, if the filters are properly cared for.

Care of Sand Filters.—The care of sand filters is, of course, one of the main points in maintaining permanency of operation. In order that the surface of the beds may not become clogged, much of the matter reaching them in suspension in the sewage either has to be raked up and removed from time to time, or else ploughed under. With a fresh sewage—that is, a sewage where the mixture of filth and organic matter of all kinds with the waste water of the town has just occurred and little time has been given for mechanical, chemical, and bacterial actions to take place in the sewers—we have a liquid containing organic matter in quite a different form from the same matter in the sewage when opportunity has been given for these various actions to take place. A fresh sewage generally contains free oxygen, nitrogen in the form of nitrates and nitrites, the proportion of organic matters in suspension to those in solution is comparatively large, and the matters in suspension are in comparatively coarse particles. When sewage reaches a filter area in this condition, the matters in suspension are easily strained or filtered out upon the surface of the bed and can be removed by raking. If then they are mixed with loam or sand—that is, composted—they cause little or no offense, and even when placed in a heap without mixture with soil or loam, the organic matter generally decomposes so slowly that little, if any, nuisance occurs. As fresh sewage flows along in the sewers and mechanical, chemical, and bacterial forces have a chance to act upon it, the organic matter present undergoes a decided change. The chemical and bacterial change is practically the breaking up of the organic matter into simpler forms, and the mechanical change is the disintegration of the matters in suspension into finer particles. Sewage in this condition—that is, with much of its suspended organic matter either changed to soluble forms or finely disintegrated—is designated as stale sewage, and, when it flows upon a filter bed, much more of the organic matter present in it is carried into the pores of the filter than when the sewage reaches the bed in a fresh state. Upon the surface of beds receiving such sewage, little matter accumulates that can be removed by raking, but the disappearance of this matter by bacterial oxidation can be very much aided if the surface of the bed is loosened from time to time by raking, harrowing, or ploughing.

Method of Operation of Sand Filters.—In order to purify sewage satisfactorily while passing it through sand filters, an abundance of air in the pores of the filter is a necessity. To assure the presence of this air, the application of sewage must be intermittent—that is, it must be applied from time to time and in limited volumes. If we should apply sewage continuously to a sand filter, keeping the surface of the sand covered with sewage, the entire open space in the filter would become filled with liquid, air would be excluded, and those organisms which oxidize the organic matter by working in the presence of air would be either destroyed or rendered unable to work successfully. This fact has often been proved, and is what occurs when attempts are made to purify sewage by passing it in any but very limited amounts through soil or clay—materials useless in sewage purification. Instead of oxidation in such beds, if they are overworked, we have reducing actions occurring, oxygen is taken from the oxides in the soil or clay or sand, and the base of these oxides passes into solution. Putrefaction of the organic matter of the sewage also occurs, with the production of odors, and an effluent often less pure than the applied sewage is the result. In order to prevent this the volume of sewage applied to any intermittent sand filter must be such that under no conditions will the sewage entering the filter exhaust the air present, or keep the surface of the filter covered for too long a period. The volume of sewage which can be applied to filters of coarse or fairly fine sand with good results varies comparatively little, but the method of application should vary considerably if good results are to be obtained. That is to say, with a filter of fine sand the sewage should be applied in large doses as it enters the filter slowly, and when once it has passed below the surface of the sand a considerable period should elapse before another application is made, in order that air may enter the upper portion of the filter. With a filter of coarse sand, into which the sewage enters readily, more frequent applications of a smaller volume of sewage is the preferable manner of operation, in order that the sewage may not pass through the filter too quickly. Much air may be made to enter the filter by this manner of flooding, as the sewage disappears quickly from the surface of the coarse sand. This difference of action of different sands can be modified very much, however, by different distribution of the underdrains. By such equalization as can be obtained in this way a filter of coarse sand may be worked practically in the same manner as a filter of finer sand, and vice versa.

The following table shows first the average results for one year obtained when filtering sewage through two different experimental filters that had been in operation for ten years at the Lawrence experiment station when these results were obtained. One of these filters (A) is constructed of coarse mortar sand and the other (B) of fine river silt trenched with a coarser sand, the coarse filter being operated at a rate three times as great as the fine filter, or approximately 60,000 and 20,000 gallons per acre daily respectively. In the same table are given the results from a third filter (C) of coarse sand, operated at a rate of 300,000 gallons per acre daily, the sewage applied to this filter being of such strength, however, that 300,000 gallons contained no more organic matter than the 60,000 gallons applied to Filter A:

TABLE I.—PARTS PER 100,000.

	Sewage (A and B).	Filter A.	Filter B.	Filter C.
Ammonia—				
Free	3.8200	0.5502	0.0660	0.0404
Albuminoid				
Total	.8000	.0697	.0166	.0306
In solution	.3800	....	....	....
In suspension	.4200	....	....	....
Chlorine	8.4800	8.3600	7.8900	2.8200
Nitrogen as—				
Nitrates	.0000	2.7100	2.9300	1.2500
Nitrites	.0000	.0118	.0009	.0014
Oxygen consumed	3.9000	.4500	.1100	.3400
Bacteria per cubic centimetre	4,760,000	28,800	58	15,800

In calculating the percentage of purification obtained by filtration the common method is to show the removal

PERCENTAGE PURIFICATION.

	Albuminoid ammonia.	Bacteria per cubic centimetre.
Filter A	91.3	99.4
Filter B	97.9	99.9
Filter C	96.2	99.7

or oxidation of organic matter as shown by the determinations of albuminoid ammonia in the sewage applied to and the effluents from the filters, and this is given in this instance in the table below. True purification in sand filtration is by nitrification, and it will be noticed that the nitrogen appearing as nitrates in the effluents of Filters A and B in the accompanying table, accounts for a large part of that present in the sewage as free and albuminoid ammonia.

Sand Filter Areas.—Massachusetts has more sand filter areas for the purification of the sewage of cities and towns than any other State in the country at the present time. These filters are in successful operation, and undoubtedly produce better results in the New England climate than could be obtained the year round by any other method of filtration yet known. At the end of the year 1902 there were fifteen cities and towns in the State, besides many large institutions, disposing of and purifying their sewage upon sand areas. It is well to describe one or two of these areas, with the results which are being obtained from them.

Sewage Disposal System of Brockton.—The city of Brockton has a population of approximately 40,000. The sewerage system was first put into operation in the year 1894, the sewage being conveyed through main sewers to a pumping station on the outskirts of the city. At this pumping station the sewage is received into a covered masonry reservoir, from which it is pumped to the filtration area. In designing this system it was planned to take house sewage only, and to exclude all surface water and as far as practicable all ground water from the sewers. There are several main lines of brick sewers, but the principal part of the system is constructed of pipe sewers. The main sewer, which is brick, is laid in the valley of a river and considerably below the level of the water in that river. On this account at times of high water in the river the surface of the ground in the vicinity of the sewer is flooded. When the main sewer was completed and before any connections had been made, the amount of leakage into this sewer was measured at a time when the water in the stream was low, and the results were as follows: In a section of the sewer about 2,000 feet long the leakage of ground water was found to be about 17,000 gallons per day, or about 45,000 gallons per day per mile of sewer. The entire amount of leakage in the main sewer amounted to about 61,000 gallons per day per mile of sewer, and this has increased, when the meadows along the river are flooded, to about 178,000 gallons per day per mile of sewer; these figures being given to illustrate the amount of ground water which may in some locations enter a well-constructed sewer. The measurements were made in a section of brick sewer of a maximum size, at the lower end, of 23 by 48 inches, underdrains were built beneath the sewers to take care of the ground water, if possible, and particular care was taken in construction to make the sewer tight.

From the masonry reservoir already mentioned, which has a capacity of 619,000 gallons, the sewage passes through screens consisting of iron slats with an open space between them of three-quarters of an inch, and then to the pumps. It is necessary to clean the screens several times each day while the pumps are being operated, and the material removed is burned beneath the boilers in the pumping station. The solid matter which accumulates in the reservoir is stirred up from time to time and pumped to the filter beds, this stirring being done by means of an agitator, consisting of perforated pipes laid on the bottom of the reservoir and connected with the force main through which sewage can be discharged under a head. The force main from the pumping station to the filtration area is a cast iron pipe 24 inches in diameter and 17,500 feet in length. The filtration area comprises approximately thirty-nine acres, on which twenty-three filter beds have been constructed, each having an area of about an acre. The beds were prepared for receiving sewage by the removal of the loam from the surface, and from twelve beds the subsoil was also removed. The sewage is distributed on the beds by means of wooden carriers which are laid across the bed from the centre of one side, so arranged as to discharge the sewage at several points. The grade of sand and soil in these beds differs very widely in different beds and in different portions of the same bed. The subsoil has an effective size of about 0.07 mm., and the effective size of the various grades of sand found varies from 0.07 to 0.75 mm. The underdrains in the filters are laid about sixty feet apart and discharge into two main underdrains. The heavy sewage which accumulates in the bottom of the reservoir is, when pumped to the beds, generally discharged upon a special sludge bed. The average volume of sewage reaching these beds amounts to about 900,000 gallons per day. The average analysis of the sewage and effluent during a certain period is shown in the following table:

TABLE II. PARTS PER 100,000.

	Sewage.	Effluent.
Residue on evaporation		
Total	72.0200	48.3000
Loss on ignition	34.9200	......
Ammonia		
Free	4.7383	.1633
Albuminoid		
Total	0.9058	.0163
In solution	.4983	......
In suspension	.4075	......
Chlorine	10.9100	10.4200
Nitrogen as		
Nitrates	.....	3.1667
Nitrites	.....	.0056
Oxygen consumed	13.0300	.1700

The percentage purification obtained by these beds is about ninety-eight per cent., as shown by the organic matter determined as albuminoid ammonia.

Sewerage and Sewage Filtration at Marlborough, Mass.—Marlborough is a Massachusetts city of about 17,000 people. The sewerage system was constructed in 1891, and was designed to take house sewage only. All the sewage is collected in a system of pipe sewers and conveyed by gravity through a main pipe sewer to settling tanks and filter beds about three and one-half miles away from the city. In constructing the sewers considerable ground water was encountered, and a large amount of this water leaks into these sewers. In this city, in distinction from Brockton, no underdrains were laid beneath the sewers to care for the ground water. The average amount of sewage reaching the beds daily is about 1,500,000 gallons, the amount varying very much at different times of the year. Accurate measurements have shown that the volume during wet months, such as in the early spring, is four or five times that flowing in the dry months of the late summer and early fall. The sewage at the filtration area enters settling tanks, two in number and with a combined capacity of 16,000 gallons. When the average volume of sewage is reaching these tanks, it is about twenty minutes in passing through them, this time being very much decreased as the volume of sewage increases, and of course increased when the volume of sewage decreases. The material which accumulates in these tanks is usually removed about once each fortnight and is discharged upon special sludge beds, where it is allowed to dry, and is then raked up and carried away, this material being used by the farmers in the vicinity as a fertilizer. The sewage in the tanks passes upward through horizontal screens having a one-inch mesh, before its discharge into the carriers leading to the filter beds. There are twenty-six of these beds having a combined area of about eleven acres. In preparing them nearly all the loam was removed, but the subsoil was allowed to remain in place. The beds were originally underdrained by lines of pipe about fifty feet apart, with a depth of from five to eight feet beneath the surface. On account of these drains receiving a large amount of ground water, it was found that their capacity was insufficient to remove both ground water and effluent, and additional underdrains were put into place.

The material in the beds is quite uniform in grade, and has an effective size of about 0.14 mm. The sewage is discharged upon these beds near the corners, and the

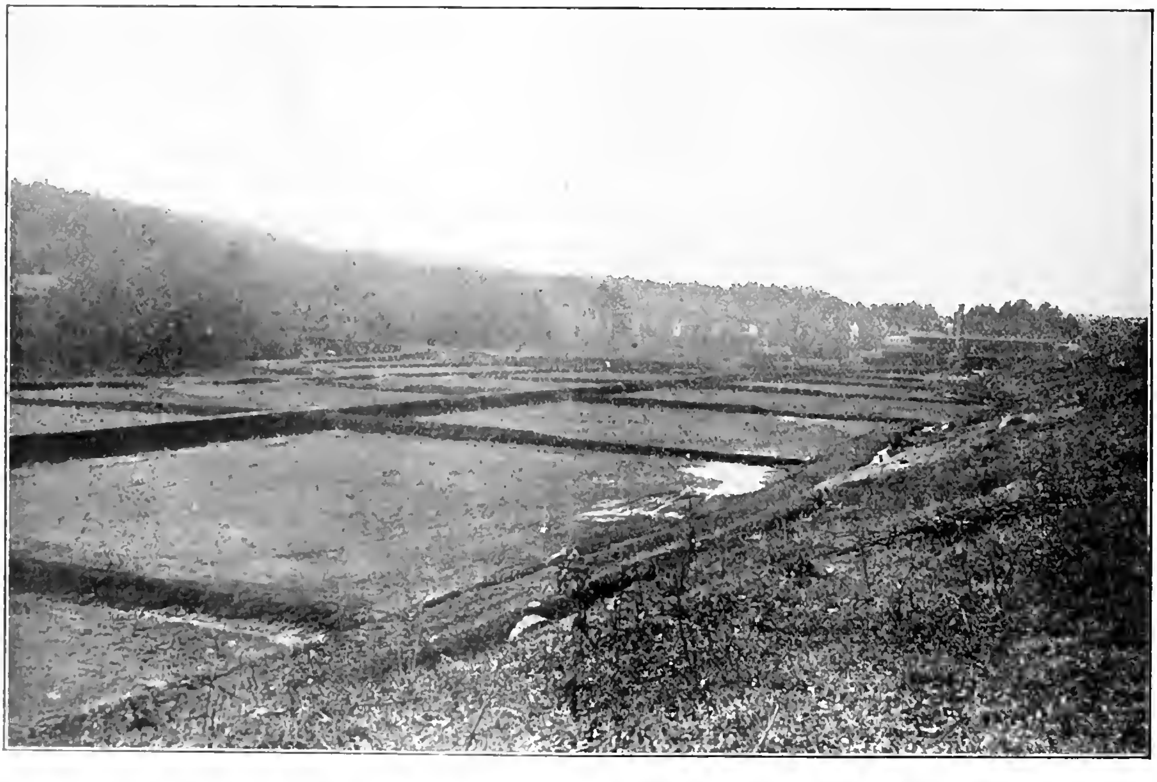

FIG. 4189.—A Massachusetts Filtration Area.

FIG. 4290.—A Massachusetts Filtration Area.

general method has been to turn all the sewage on to one, two, or three beds, according to the quantity flowing, and allowing it to flow upon these beds for twenty-four hours. In wet weather, of course, the flow has to be more widely distributed over the entire area. The sewage is applied to the beds in rotation, and once in about five weeks the surface of each of the beds is raked to remove the surface deposit, and then harrowed and allowed to remain out of operation for a short time; the solid matter which accumulates on the surface being removed before the surface is harrowed. In the fall the beds are ploughed and the surface is left in ridges and furrows, so that the ice forming upon the beds rests on the ridges and protects the sand from freezing, the sewage running in the furrows beneath this ice. The beds receive no attention in the winter in regard to surface management, but in the spring they are raked and then ploughed, harrowed, and graded, and remain level throughout the summer. The average rate of filtration at this area approximates 100,000 gallons per acre daily. The following table gives a fairly average analysis of the sewage applied to and the effluent from this area:

TABLE III.—PARTS PER 100,000.

	Sewage.	Effluent.
Residue on evaporation –		
Total	61.0000	24.8000
Loss on ignition	37.0000	......
Ammonia –		
Free	2.4000	.0203
Albuminoid –		
Total	.5800	.0328
In solution	.2000	......
In suspension	.3800	......
Chlorine	5.8000	5.0000
Nitrogen as –		
Nitrates	......	.5400
Nitrites	......	.0171
Oxygen consumed	3.9000	.3400

The average purification by these beds is about ninety-four per cent.; that is, ninety-four per cent. of the organic matter in the applied sewage does not appear in the effluent from the filters.

Chemical Precipitation.—In the early days of sewage disposal, when it was considered that in most instances the removal of the larger portion of the matters in suspension in sewage was efficient purification, the coagulation of these matters by means of chemical precipitants was a favorite process, and very many costly works were erected in England and on the Continent, to be used in purifying or clarifying sewage in this way. The chemicals most generally used in chemical precipitation are lime, sulphate of alumina, and salts of iron. These chemicals by decomposition form, with other elements present in the liquid, gelatinous bodies like aluminum hydrate, which entangle or coagulate a considerable percentage of the organic matters in suspension in the sewage, together with some of the matters in solution. The specific gravity of the precipitant and coagulated sludge causes more or less satisfactory sedimentation to occur. The supernatant liquid is then run off, and the accumulated sludge either passed to sludge beds or to filter presses, or both. The filter press is simply a machine in which the sludge is placed to undergo compression whereby it is freed from a considerable percentage of its water, while the solid matters are retained by the cloth bagging in which the sludge is placed. Sometimes this sludge, when sufficiently dry, will be carted away by farmers, to be used as a fertilizer, but generally only after having had a very large percentage of its water removed from it by pressing; and more frequently it cannot be disposed of in any way except by the expense (chargeable to the operation of the works) of carting it away to be composted, or used in filling in low ground. This method of sewage treatment is in use in many places in England and on the Continent, and in a few places in this country. Its successful use, however, is generally confined at the present day to such locations as London, England, or Providence, R. I., where all that is at present considered necessary in the treatment of the sewage is the removal of the suspended matters;

this being so at these places on account of their proximity to large bodies of salt water and the opportunity thus offered for the removal and dissipation of the sewage by dilution and tidal currents.

At Worcester, Mass., is a good representation in this country of a well-managed chemical precipitation plant. Worcester is a city of about 110,000 people, the natural drainage of which is into a river which flows through the city. The plant for chemical treatment of the city's sewage was constructed largely in 1891, although additions have been made to it since, as the growth of the city and the increase in the volume of sewage to be disposed of have required. At these works there are sixteen precipitation tanks, about 100 feet long, 66.7 feet wide, and 7 feet deep. When the works were first put into use, the volume of sewage treated was about 3.83 million gallons per day, and in 1901 it was 9.76 million gallons per day. The sewage on its way to the tanks passes through screens, and is there mixed with chemicals. From these screens it passes through a mixing channel to the first precipitation tank and then continuously through the series of tanks, at the end of which it is discharged over a weir. Lime and sulphate of alumina are generally used for precipitation. The sewage, however, is of a rather unusual character owing to the discharge into the sewers of much waste from iron and wire works, in which large quantities of acid are used. On account of this the sewage is sometimes acid and contains sulphate of iron. When in this condition no sulphate of alumina is used, lime alone being added in sufficient quantities to decompose the sulphate of iron and allow precipitation. In the addition of the chemicals they are powdered and then passed through hoppers into agitators, where they are well mixed with a small amount of sewage. From these agitators this sewage containing the chemicals is discharged into the main body at the head of the mixing channel. About one ton of chemicals per million gallons of sewage treated is used. During 1901 the purification effected by this plant was shown by the following table:

TABLE IV.—PARTS PER 100,000.

	Sewage.	Effluent.
Ammonia—		
Free	1.7500	1.6260
Albuminoid—		
Total	.6210	.3180
In solution	.2390	.2620
In suspension	.3820	.0560
Chlorine	9.1800	8.9500
Oxygen consumed	8.6700	4.1000

This table shows that approximately forty-nine per cent. of the organic matter determined as albuminoid ammonia was removed, and about fifty-three per cent. of the organic matter determined by the oxygen-consumed method. By operating the plant in the manner followed at Worcester the volume of wet sludge produced amounts to about 1.5 per cent. of the total volume of sewage treated.

A series of experiments upon the removal of organic matter from sewage by means of chemical precipitation was made at the Lawrence experiment station, continuing from 1890 until 1898, and the results showed that generally about fifty per cent. of the total organic matter could be removed from the Lawrence sewage by this treatment, and a considerably greater percentage of the matters in suspension only. As good results were obtained with the normal alkaline sewage of Lawrence when using one thousand pounds of chemicals per one million gallons as when using a greater amount, and, of the various precipitants tried, sulphate of alumina gave on the whole the best results. The chemicals used in precipitation are of low cost per pound, but when a large volume of sewage is to be treated, this expense amounts to a serious sum. At Worcester during 1901 the cost of operating the precipitation plant was $43,771 or $12.27 per one million gallons of sewage treated, a very large portion of this expense being for the chemicals used and for treatment of sludge.

By chemical precipitation the amount of organic matter present in sewage can be reduced very greatly before the main body of sewage is allowed to run to waste, as the figures already quoted show. The organic matter in solution, however, is affected but slightly by this treatment, and this is really the matter which is in the proper condition to putrefy first—that is, it is the most offensive matter in the sewage as the sewage undergoes decay. On this account clarification by chemical precipitation is but a partial purification at best, and in order really to purify the sewage, a further treatment of the effluent of the precipitation tanks must be resorted to. That is, this is necessary if a stable or non-putrefying effluent is to be obtained. Up to the present time this has usually been accomplished by filtration through sand. Almost with the inception of the work upon chemical precipitation at the Lawrence experiment station sand filters were put into operation to receive the sewage clarified in this way. For example, the supernatant liquid from treating Lawrence sewage with sulphate of alumina, at the rate of one thousand pounds per one million gallons and allowing four hours for sedimentation after the addition of the chemical, was applied for over four years to a sand filter containing five feet in depth of sand of an effective size of 0.17 mm., and at an average rate of 200,000 gallons per acre daily. This rate was from two to three times as great as could have been followed successfully upon the area used if untreated Lawrence sewage had been applied. A well purified, well nitrified, clear, and stable effluent was always obtained, and at the end of the experiment the filter used was in good condition. The upper few inches of sand were somewhat clogged with organic matter at the end of this period, but no more so than was to be expected when filtering sewage at this rate.

At Worcester it has been recognized that the effluent from the filtration plant would not have the desired effect in rendering the river into which the sewage formerly flowed very much less objectionable unless further treatment was given the sewage, especially as the volume of sewage is increasing steadily as the population of the city increases. On account of this, sand filters are being constructed there, upon which a portion of the sewage runs after chemical treatment. At the end of 1901 the city had 14.5 acres of filter beds. These filters received during the year 220,000 gallons per acre daily of partially purified sewage, and when the chemical effluent alone was being passed to them, they were at times operated at the rate of 300,000 gallons per acre daily. Owing to the fact that the Worcester sewage is often slightly acid, the results obtained by these beds have not, of course, been as good as would have been the case if the sewage was alkaline. Nevertheless, they add very materially to the efficiency of the plant.

Mechanical Straining of Sewage.—In the process just described a large body of sludge is formed, this sludge consisting of the precipitated matters, chemicals and water—that is, it consists of about five to ten per cent. of mineral and organic matter, mixed with ninety to ninety-five per cent. of liquid. By filter-pressing the sludge can be further freed from the liquid until the weight of water and that of solid matter are about equal—that is, fifty per cent. of each. This is expensive, however. This fact being recognized, experiments were early inaugurated at the Lawrence experiment station, looking toward some method of freeing sewage so thoroughly from the organic matter in suspension in it, that this matter would contain but a small percentage of water; that is, investigations were made looking toward producing high rates of filtration through sand filters by removing the matters in suspension in sewage as well as or better than by chemical precipitation, and at as low or lower cost per one million gallons of sewage treated. These experiments seemed to indicate that coke strainers could be constructed which would accomplish this result. Accordingly, in 1894 a coke strainer was put into operation, containing six inches in depth of coke "breeze." This breeze is the screenings from commercial coke. Strainers of this sort and of a varying depth were kept in operation for seven or eight years, and resulted in removing from the applied sewage nearly as much organic matter as is removed by chemical precipitation. The organic matter, moreover, removed in this way is left in a semi-solid mass upon the surface of the strainer or in the upper layers of coke, and can be easily removed, together with some of the coke, if necessary, when the strainer becomes clogged on account of its accumulation, and subsequently dried and burned. That is to say, instead of having the suspended matters in the sewage left in the bottom of a tank mixed with a large volume of water—so large, in fact, that it forms ninety-five per cent. by weight of this concentrated sewage—we have these matters practically freed from water.

Such strainers were operated at Lawrence at rates varying from 1,000,000 to 2,000,000 gallons per acre daily. A strainer constructed in 1895 was continued in operation for three years, and during this period the amount of coke removed from it amounted to one inch in depth for each 16,400,000 gallons of sewage strained. It was found later, however, that with a slightly coarser grade of coke as good a removal of organic matter from the sewage could be obtained and with an expenditure of not more than half as much coke as the figures given. As a result of straining through coke, about forty per cent. of the total organic matter in the sewage can be removed, and about sixty per cent. of the organic matters in suspension, varying, of course, with the different grades of sewage. The resulting effluent from a coke strainer can, of course, be purified at a rate of filtration much greater than can be attained with a sand filter receiving untreated sewage. At Lawrence a filter receiving strained sewage was continued in operation for a number of years at a rate approximating 300,000 gallons per acre per day, and the average effluent was about as follows, showing good nitrification and purification:

EFFLUENT OF SAND FILTER.

PARTS PER 100,000.

Color	0.1300	Nitrogen as—Nitrates	2.3800
Ammonia—		Nitrites	.0001
Free	.0145	Oxygen consumed	.2300
Albuminoid	.0207	Bacteria, per cubic centimetre	85.0000
Chlorine	7.0800		

A purification plant of this description has recently been constructed in the town of Gardner, Mass., where the sewage is first passed through a coke strainer with an area of one-half acre, and then to sand filter beds. Strainers of fine anthracite coal in operation at the experiment station have of late done better work upon an experimental scale than coke filters.

Filters of Coarse Material at Rapid Rates of Filtration.—Sedimentation, chemical precipitation, and straining are not, of course, in the true sense proper sewage purification. They are but preliminary methods taken to remove and concentrate a certain amount of the organic matter in sewage, and thus make it possible to filter the main volume at high rates upon sand or other filters. It is only in fortunate localities, however, that sand filters can be constructed at a low cost. In New England in most instances sandy areas are available. Throughout a large section of this country, however, areas of sand are not to be found, and sewage filters must be built on different lines. This is also the condition of affairs in England. Because of this, elaborate studies and experiments have been made of late years upon other means of purifying sewage than by sand filtration: all these methods having, of course, as their main feature the possibility of purifying large volumes of sewage upon relatively small areas. Sand filters are comparatively inexpensive of construction, costing in New England not more than from a few hundred to four or five thousand dollars per acre, according to the locality in which they are built and other conditions. All high-rate filters, however, are of necessity constructed of material, the expense of gathering which together or of preparing it for use varies greatly, and in some instances exceeds the cost of a like area of sand filter beds.

Of the first attempts upon filtering sewage at high rates, the passage of this sewage through aerated gravel or broken stone filters, with nitrification aided by a current of air forced into the filters, appeared to be the most interesting and practical. Such filters were operated at the Lawrence experiment station as early as 1892, and at experimental plants in other places soon after this date. At Lawrence average rates of 500,000 gallons per acre per day were obtained by this method, covering a period of five years, and good nitrification occurred in the filters, the sewage being applied to these filters in small doses at frequent intervals. The effluents of the filters, however, contained much organic matter in suspension and in solution, and the purification obtained was considered only preliminary to sand filtration, or, in other words, it was simply a method for increasing the rate at which sand filters could be satisfactorily operated, but with an idea of destroying, more effectively than could be done by chemical precipitation or coke straining, the organic matters in suspension in the sewage. The highest average rate obtained at the station by this combination of aerated gravel filters and sand filters was 250,000 gallons per acre daily. Owing to the grade of gravel used and the lack of proper underdrainage, these filters clogged badly from time to time, necessitating the removal of filtering material, washing, and replacing. The sand filter also became badly clogged from time to time, necessitating the removal of surface sand. The cost of aeration by means of a forced current of air was considerable. Later studies at Lawrence, moreover, have shown that the method of filtration and aeration followed in the gravel filters, although causing nitrification and thus partially purifying the sewage, undoubtedly rendered the organic matters coming through these filters in suspension in their effluents of a more stable, less easily decomposed nature than when applied in the sewage to the filters. For this reason, when these effluents were applied to sand filters, although the liquid passed below the sand readily and was well purified, these stable matters, instead of being readily passed into solution and nitrified by bacterial action, accumulated within the upper layers of the sand. Disposal plants based upon this method of procedure are, however, in operation in several places in this country with more or less success.

Contact Filters.—Contact filters are sewage filters constructed of any coarse material such as coke, cinders, slag, broken stone, gravel, broken bricks, etc. The method of operating these filters is to close the gate at the outlet of their underdrains, gradually fill the open space of the filter with sewage, allow a period of standing full, then drain, rest for a more or less prolonged period, and again fill. In this manner the entire depth of the filter is brought into contact with the sewage applied each day; that is to say, the entire open space of the filter is filled with sewage daily or even several times daily, and a high rate of filtration obtained. It is evident that filters constructed of these materials and operated in the way outlined cannot produce the results given by good sand filters; in other words, they are not good strainers, and the sewage passes through them too quickly for prolonged bacterial action to occur. Nevertheless, very satisfactory purification results can be obtained by their use, especially if the system of beds is so constructed that double contact of the sewage is given—that is, a system of beds in two sets, all sewage passing through two filters.

In operating these filters the method of filling may be continuous or intermittent; that is to say, the sewage may be allowed to pass into the filter continuously until the entire open space is filled from the underdrains to the surface, or the sewage may be run in at frequent intervals. When the latter plan is followed and the sewage is well distributed, the method introduces more air into the pores of the filter than the continuous method, and better purification ensues. When the effluent flows from the filter, air is drawn into the filter again and fills the open space. It is evident that, if the action of the bacteria upon the sewage in the filter is to be that of oxidation, the sewage should be withdrawn some time before the exhaustion of this oxygen occurs. When the filter is emptied, the oxygen drawn in causes a partial oxidation of the organic matter left within the filtering material, nitrification ensues, and we have a filter really working all the time, although flooded but a portion of the time. If the filter is constructed of rough material, such as cinders, coke, slag, etc., much organic matter is strained out from the applied sewage by being caught on this rough material, to remain in the filter and to become oxidized and nitrified when the filter is empty. Experiments with this class of filters were first made in England.

Long-continued investigations have been made at the Lawrence experiment station studying this class of filter. Filters of different materials have been in operation, different methods of flooding have been followed, and double contact has been compared with single contact. These studies have shown that the best results can be obtained with filters constructed of rough material, such as cinders and coke, that in such filters, when well operated, good nitrification occurs, and that fairly stable effluents are obtained. With filters of broken stone much poorer results are obtained. The rates of filtration followed have reached one million gallons per acre per day with filters of coke five feet in depth, and rates fully as great as this with filters of broken stone. In all these filters there is a tendency for the open space to become clogged more or less with the matters removed from the sewage, thus decreasing the rate of operation, and the prevention of this is the most serious problem presented in the satisfactory and permanent operation of contact filters. In fact, it is quite generally recognized at the present time that, if filters of rough material are to be used successfully in this way for any long period, a larger portion of the matters in suspension in the sewage must be removed as a preliminary to filtration. In the life of filters of this nature, but constructed of smooth material, this preliminary treatment is not so essential, as the material in the filter can be so graded and the underdrains left so open that much of this matter will pass from the top to the bottom of the filter and flow out from the underdrains. Such filters of smooth material, however, do not, as has been said, give as good results as the filters of rough material.

Contact filters are being adopted and constructed in many places, especially in England. At Manchester, England, a plant for the purification of 30,000,000 gallons of sewage per day upon contact filters is now being built, the sewage first being treated in septic tanks which will be spoken of later. To show the purification results obtained by this manner of filtration, the following figures are quoted, giving the average analyses of the effluents of two coke contact filters at Lawrence, operated during 1901 at rates of 910,000 and 850,000 gallons respectively. To the first filter sewage was applied which had first been passed through a coke strainer, and to the second filter sewage just as pumped from the sewer.

Table V. Parts per 100,000.

	Filter No. 1.	Filter No. 2.
Color	0.5200	0.5500
Ammonia		
Free	1.6400	1.7200
Albuminoid —		
Total	.1716	.1842
In solution	.1238	.1250
In suspension	.0478	.0592
Chlorine	11.4600	10.1300
Nitrogen as		
Nitrates	1.3400	.8900
Nitrites	0197	0096
Oxygen consumed	1.0700	1.0600
Bacteria per cubic centimetre	131,500	397,000

The effluents here averaged are somewhat better than can be obtained, generally speaking, by contact filtration. The purity of these effluents, however, does not compare favorably with those which can be obtained by sand filtration. The organic matter present in them is, nevertheless, often oxidized to a more or less stable condition, thus rendering them well enough purified to run to waste at many places.

Septic Tanks.—A septic tank is simply a brick or concrete tank, covered or uncovered, through which sewage passes slowly, allowing time for sedimentation and for the action of those bacteria which disintegrate, hydrolize, and by this means destroy or change organic matter by passing it into solution in the liquid or causing it to escape into the air in the form of gas. On a previous page a statement has been made regarding the difference between fresh and stale sewage. To carry on even further the bacterial action causing this change is the theory of the septic tank treatment. In many instances, however, of so-called septic tanks, the sewage when entering is so fresh and the period allowed in the tank so short that little more occurs toward changing the sewage than that which occurs when the sewage passes through a considerable length of sewer before reaching the filtration area. To explain the action of the tank in other words, we can say that, when oxygen is exhausted from sewage, bacterial life continues active and putrefaction ensues, following the process of decomposition, which occurs in the presence of oxygen. All of the organic matter in the effluent from a septic tank is supposed to be changed by the action of the bacteria to a condition in which it is more easily oxidized by the aerobic bacteria in sand or other filters.

While several claims to the first installation of a tank of this kind have appeared, it was in modern times and under modern studies probably first put into operation in Exeter, England, and soon adopted in other places in that country. Its success or failure as an addition to a sewage disposal or purification system appears to depend largely upon the nature of the sewage to be treated. It is evident from long-continued experiments in Lawrence and elsewhere, that with some sewages passage through the tank is of undoubted advantage in connection with the disposal of sludge, and that the sewage is as easily or more easily purified than without the tank action. Other experiments at Lawrence have shown that there is danger, in the treatment of some sewages in the tank, of so oversepticizing them, so to speak,—that is, of carrying the work of the anaërobic bacteria to such an extent—that the effluent of the tank can be filtered only with considerable difficulty and after good aeration. A small tank has been in operation for five years at the Lawrence experiment station, treating the sewage pumped there, and after these years of use the accumulated sludge within the tank amounts to about thirty per cent. of the tank capacity, the tank not having been cleaned out during the course of the experiment; and further than this, the effluent of this tank has contained only about one-half as much crude organic matter as the sewage entering. The time of passage of the sewage through the tank has averaged about sixteen hours. At a filtration area in Massachusetts a tank was continued in operation for several years, and the sewage reaching this area was really more difficult to filter after treatment in the tank than before. The reason was that the sewage was very rotten when entering the tank, and when issuing from it was of a character which seemed to retard nitrification within the filter, unless thoroughly aerated preliminary to filtration.

Table VI.—Parts per 100,000.

	Septic sewage.	Sand filter.	Coke filter.
Rate gallons per acre daily	......	300,000	800,000
Ammonia			
Free	4.5200	0.7867	1.4021
Albuminoid			
Total	.4300	.0807	.1480
In solution	.2700	......	.....
In suspension	.1600	.....	.....
Chlorine	11.2500	10.4800	11.1500
Nitrogen as —			
Nitrates	......	2.9200	1.1500
Nitrites	......	.0046	.0083
Oxygen consumed	2.8500	.6900	1.0500
Bacteria per cubic centimetre	1,020,000	69,000	221,000

The effluent from the septic tank at the Lawrence station has been applied for the past five years to two experimental filters, one of these being an intermittent sand filter and the other a coke contact filter. High rates of filtration have been maintained with each filter. During 1902 the rates and the average analysis of the septic sewage applied to and the effluents from these filters were as shown in the preceding table.

At Manchester, England, very extensive experiments were carried on for two or three years, investigating this process. Tanks with a capacity of 500,000 gallons per day were operated, both covered and closed tanks being used, with little difference in the results obtained, and the city of Manchester is now building a sewage disposal system whereby the sewage will first be treated in septic tanks and then upon double contact filters. At this city in 1900 the volume of sewage to be disposed of reached 30,000,000 gallons per day. From the operation of their experimental tanks it was estimated there that it would be fair to assume that fully thirty-five per cent. of the sludge would not become liquefied in the tanks, but would have to be removed from time to time. That is to say, where they were in 1899 carrying 237,000 tons of wet sludge to sea per year, it was estimated that only about 75,000 tons would have to be carried to sea after the construction of the system; the remaining organic matter being disposed of by bacterial action in the tanks and on the filters.

At Worcester, Mass., this method of treatment has been experimented with for several years, a tank of 350,000 gallons capacity having been used. Through this, sewage has been made to flow at a rate varying from 300,000 to 500,000 gallons per day. The sewage at Worcester is generally acid, but this has not interfered entirely with the tank action, as about twenty-five per cent. of the total solid matter has generally been removed by the tank. The odor from this tank has been very considerable, and also from the beds when this sewage has been applied to them.

Plainfield, N. J., among other places, has recently adopted this system of sewage disposal. This is a city of about 16,000 people, and has the so-called separate system of sewers. It formerly disposed of its sewage on sand filters, but these were not particularly successful owing to the extreme fineness of the sand. Hence a change was made. Two septic tanks have been constructed, fifty feet wide, one hundred feet long, and six feet deep, both being under one roof. The sewage, after it passes from these tanks, goes to a double set of contact filter beds. The average flow of sewage per day at the present time is about 800,000 gallons, and it reaches the disposal plant through a fifteen-inch pipe. At this place it enters a small influent chamber, where the flow may be diverted to either tank. The sewage enters the tanks about two feet above their floor level. In front of the inlets to the tanks are baffle walls, to deflect the flow of sewage and distribute it evenly across the whole width of each tank. The sewage flows from outlet openings, twelve in number in each tank, placed below the surface of the sewage and above the floor of the tank. In leaving the tanks the sewage passes upward over a weir into a channel to the first set of contact beds. Air and light are excluded from the septic tank, but the sewage is supposed to be aerated after passing from the tank by flowing into and through a channel extending the full length of each tank. The gate-house and roof over the septic tanks are of wood, with tar and gravel covering, all the remainder of the construction of the tank and weir being of stone, brick, or concrete. The contact beds are in two sets of four each, the first set being 5.42 feet above the level of the second set. Each bed is ninety-two feet wide, one hundred and six feet long, and five feet deep. On the concrete floor of each bed fourteen lines of four-inch horseshoe tiles are laid, radiated from the gate-chamber, and coarse stone is spread beneath and over them six inches deep. The first set of beds contain, above this coarse stone, three and one-half feet in depth of trap rock, the pieces of rock varying in size from one-fourth to one and one half inches in diameter. The second set of beds are of practically the same depth, but slag and cinders are used as filtering materials instead of the broken stone. Distribution pipes are laid in the upper foot of the material, through which the sewage is distributed over the surface of the beds. The sewage runs continuously from the septic tank through a twelve-inch pipe, built in the top and middle wall of the gate-chamber at the intersection of the division walls. Here it is diverted by wooden gates to each of the four beds in succession. After one bed is filled the sewage is turned on to the next, and so on; the height of the sewage in the beds being indicated by tell-tale balls above the roof of the gate chambers. The sewage remains in each bed an hour or more, is drawn off through a sluice-gate and passes through a pipe to the gate-chamber of the second set of beds, from which it is discharged, after a period of contact, into a brook. Each bed is at rest an hour or more between fillings. Sludge can be drawn from the tanks through eight-inch pipes to sand filters. In a year's operation of this system it was necessary to remove sludge from the septic tanks several times. The price of construction of this system of disposal is said to have been about $40,000.

Intermittent Continuous Filtration.—In the continuation of studies upon rapid methods suitable for the purification of sewage, filters of coarse material have been constructed, through which sewage is passed in a practically continuous stream. The coarseness of the material used in these filters is so great, however, and the rate of application of the sewage to them so regulated, that the surface of the filter is always practically free from sewage, and a large portion of the open space in the filtering material is always filled with air. Such filters may be constructed either of rough material such as coke, slag or cinders, or of smooth material, such as coarse gravel or broken stone. By the method of operation the sewage applied passes in thin streams or layers over the filtering material, and is in contact with air from its entrance at the surface of the filter until it passes away in the underdrains. With a filtering material of such a coarse nature, operated under conditions which assure an abundance of air within the filter, wonderful activity of the oxidizing and nitrifying bacteria is induced, and the production of nitrates is exceedingly rapid. Filters constructed in this manner, containing from eight to ten feet in depth of filtering material, can be operated, on an experimental scale at least, at rates approximating two million gallons per acre daily, and produce a highly nitrified effluent. Much of the organic matter in suspension in the sewage when it enters these filters passes away in suspension in their effluents, but in a very different and inoffensive condition from that in which it exists when applied to the filters. That is, if the filter is well constructed and properly operated, a large portion of this matter adheres for a considerable period to the filtering material throughout the entire depth of the filter, and its more easily decomposed constituents are either passed into solution, or disappear as gas, while the remainder is oxidized to a more stable form. Effluents of successful filters of this class contain organic matter in such a stable form that they are little subject to putrefaction even under adverse conditions, except after a considerable interval, and more often than otherwise they improve in character after issuing from the filter. Their steady improvement is assured if they run into a considerable body of water containing free oxygen. Filters of this class were first put into operation at the Lawrence experiment station in 1899, and have since been studied quite extensively there. Studies upon their operation and the results produced by them have also been carried on in England of late years upon a considerably larger scale than at the experiment station. They have not as yet, however, been installed on any considerable scale for the practical treatment of the sewage of a town or city. Such a filter was operated at Lawrence during 1903 at a rate, at times, of 2,250,000 gallons per acre per day, and produced an effluent often turbid, but always well nitrified and fairly stable. The average analysis of this effluent is shown in the following table, of many analyses made during the year:

TABLE VII.—PARTS PER 100,000.

Rate—gallons per acre daily	1,820,000
Color	.5700
Ammonia—	
Free	1.7400
Albuminoid	.1392
Chlorine	8.6100
Nitrogen as—	
Nitrates	2.7600
Nitrites	.0071
Oxygen consumed	1.0800
Bacteria per cubic centimetre	46,000

Résumé.—In the preceding pages nine methods of sewage disposal or purification have been described, covering the most important methods in use at the present time. They include those methods by which sewage is purified by natural means—that is, by bacteria and air—and which have promise of such developments in the future as adequately to cover all sewage purification problems. The methods are as follows:

1. Disposal by dilution.
2. Sewage farming or irrigation.
3. Filtration through intermittent sand filters.
4. Chemical precipitation, followed by filtration.
5. Mechanical straining, followed by filtration.
6. Filtration through gravel or other filters of coarse material, with forced aeration.
7. Contact filters.
8. Septic tank treatment, followed by filtration.
9. Intermittent continuous filtration.

Summarizing these methods, it can be said that disposal by dilution is extensively practised and entirely satisfactory at such places as those mentioned in the previous text.

Sewage farming is successful in many places, especially with a concentrated English or European sewage.

Filtration through intermittent filters of sand or other fine material is a process which is already extensively used and is certainly destined to be used very largely in the future wherever such filters can be built at a reasonable expense. They are entirely successful wherever used, if the material of which the beds are constructed is suitable, and if such beds are properly operated.

Where a large amount of sewage must be taken care of upon a small area, or where some clarification must be made before sewage is disposed of by dilution, chemical precipitation is of undoubted value and will be used for many years in meeting such problems.

Straining sewage through coke or other materials of a like nature is undoubtedly successful on a small scale, and the future will show whether it can be applied to larger problems.

Forced aeration and filtration through gravel is hardly entitled to serious consideration in this connection, but as it was really the first step in the various processes of rapid filtration, it has been included in the previous text. It can undoubtedly be made practical and of use where the volume of sewage to be purified is small, and where cost is a secondary consideration.

The use of contact filters will increase undoubtedly at places where sand filters cannot be easily or inexpensively constructed. If they are properly built and properly operated, good results can be obtained by their use.

Septic tank treatment is also a proved success in some cases, and will undoubtedly be used much in the future. It must never be considered, however, as it is sometimes now considered by those ignorant of the subject, that the septic tank treatment is a purification. It is simply a clarification, and a preliminary treatment whereby sludge may be destroyed and the sewage may be so changed that either purification is made more easy by subsequent filtration, or the rate of filtration made greater than could be secured without this treatment.

Intermittent continuous filters seem to have very much of promise in them, and they will undoubtedly be adopted more and more at places where sewage must be disposed of upon a small area and where the climate does not interfere with their efficient operation. *H. W. Clark.*

SEX.—In the life history of nearly every multicellular organism there is a time when a new germ (oöspermium, or *zygote*) is formed by the union of two cells (*gametes*) of different aspect. The larger, less mobile of the two cells, is the *macrogamete*, egg, or ovum (*q.v.*), and the smaller more active one is the *microgamete*, spermatozoon (*q.v.*) or its equivalent. The ability to produce a macro- or microgamete constitutes the essential distinction of *sex*. The individual which produces the latter is said to be of the *male* sex, the individual producing the former is said to be of the *female* sex. In most of the higher plants and in a few of the lower animals both sexes are included in a single individual, which is then said to be *hermaphrodite*. The union of dissimilar gametes is the essential feature of sexual reproduction (see *Impregnation*). In many of the unicellular animals, Protozoa, there is a temporary union, or *conjugation*, of similar gametes, during which there is an interchange of part of the nuclear substance. In other Protozoa the gametes are of different size and the union is complete and permanent. Thus in these lowly forms we see foreshadowed the sexual process of the higher organisms.

If our definition of sex be correct, it follows that the quality of sex cannot be an attribute of the gametes, but only of the parent organism, except in so far as the sex of the offspring may be determined by some characteristic of one or both of the gametes. This view is borne out by what is known of the history of the germ cells, which has been shown elsewhere to be identical in all essential features in the two sexes (see *Reduction Division*). The differences between the gametes of the male and those of the female are confined to the cytoplasmic structures, and are associated with a physiological division of labor; the cytoplasm of the egg being more or less laden with food yolk and unprovided with locomotor apparatus, while the spermatozoon has practically all of its cytoplasm modified into a locomotor apparatus, by means of which it may actively seek the egg. This explanation is not in accordance, however, with the views of Geddes and Thomson, who see in the visible difference between egg and sperm evidence of the same differentiation of sex that is found in the adult. They regard sex as a quality of protoplasm. It is for them a question of metabolism. In the female the anabolic processes are predominant, while the katabolic processes are predominant in the male. These characteristics are passed on to the eggs and spermatozoa respectively, and fertilization "restores the normal balance and rhythm of cellular life."

It is difficult to follow the physiology of this conception of sex, for, if the male is predominantly katabolic, one would think it might be hard for him to grow; one might almost expect him to shrink. Havelock Ellis (1894) has gathered the published data in regard to the differences in metabolism of men and women, and he finds differences in certain phases, but the general result is inconclusive. Thus, men have a larger percentage of hæmoglobin in the blood and greater lung capacity in proportion to stature; but, on the other hand, women have a higher pulse rate. It is very probable that in the period of early maturity in women there is less katabolic activity than in men as is shown by the greater tendency to store up fat. But, if the words mean anything, a predominant condition of katabolism is inconsistent with increase of weight or with life itself beyond a very limited period, and therefore can hardly be accepted as the essential feature of "maleness."

We may follow Ellis in dividing the characteristics that distinguish the sexes into primary, secondary, and tertiary. The primary characteristics are those associated with the organs concerned in the production and union of the gametes. And these organs may be divided again into the essential and the accessory reproductive organs. The former are the gonads, called ovary and testis in female and male animals respectively. In low forms, like the jelly-fishes, there are no other reproductive organs. But we need to go very little higher in the scale to find developed accessory organs that assist in the discharge and union of the gametes. Such are the oviducts, the vasa deferentia, and the appendages of these organs. Morphologically these tubes may be modified nephridea, or they may be newly developed structures. In all strictly terrestrial animals and in many of the higher groups of aquatic forms fertilization takes place within the oviduct. This is associated with a marked structural differentiation of the sexes. The male is usually provided with a special organ for the introduction of the spermatozoa. This may be a prolongation of the sexual orifice, forming a penis, or, as in the rays and higher crustacea, it may be in part a modified limb. In the female, on the other hand, the oviduct is either provided with glands to secrete a protective covering for the egg, or is modified to shelter the developing embryo, or even, as in the placental mammals, to nourish it during its fœtal life.

The secondary sexual characters are those that clearly distinguish the sexes without being directly concerned in the reproductive function. Among these characters we may distinguish clasping organs, weapons, ornamentation, voice, and appliances for the shelter or nutrition of the offspring. In a large number of animals, especially among the crustacea and insects, there are to be found special modifications of one or more limbs of the males which serve to hold the female in firm embrace during coitus. Many males are provided with weapons, as tusks, horns, spurs, or the like, which are employed in fighting with other males for the possession of the females. Often the males alone are provided with such weapons, and when they are possessed by both sexes, they may differ in the two sexes. Thus the cow has long, pointed horns adapted for defense against carnivorous enemies, while the bull has shorter, thicker horns, probably more useful for fighting with rivals.

In some cases structures that probably arose as weapons are now developed as ornaments. The most notable examples of this are the antlers of the deer family. In most cases, however, the ornamentation has arisen independently of the weapons, and consists of the most varied forms of coloring and modification of structure. Ornamental secondary sexual characters are found widely distributed among the insects, amphibia, reptiles, birds, and mammals. They are especially conspicuous among the birds. They are usually possessed by the adult males only, and reach their highest state of perfection during the mating season. After this season the deer shed their antlers, and many male birds, like the bobolink, exchange their bright plumes for the sober protective coloring of the female. This exuberance of growth and coloring in the males, together with the song of male birds, and other instances of greater activity, like the superior eagerness of the male in courtship, are taken by Geddes and Thomson as evidence for their conception of maleness as a preponderance of katabolic activity. But they leave out of consideration the fact that these conditions are not always characteristic of the male sex. In the species of phalarope—birds not uncommon on our shores—the female is the more brightly colored, the more pugnacious, and more ardent in courtship; in short, she has all characteristics usually found in a male, except that she lays eggs. The male, on the other hand, is relatively dull colored, is courted by the female, incubates the eggs, and takes entire care of the young.

The characters that we are considering are called ornamental, not because they appear beautiful to us—often they are quite the contrary—but because, according to Darwin's theory of sexual selection, they are supposed to have been developed through the choice, conscious or unconscious, of the courted sex (see *Evolution*).

In man we find ornamental secondary sexual characters in both sexes, which would seem to indicate that the courting is not all done by one sex. The chief of these characters in men is the beard. While women have longer hair on top of the head, and this is associated typically with an entire absence of visible hair on other parts of the body, except on the axilla and pubes. The layer of subcutaneous fat that develops in young women upon reaching maturity, and gives them the characteristic rounded contours of that period, may have become a fixed character of the species by the action of natural selection, owing to its value as a provision for the nutrition of prospective offspring; but, at any rate, it now forms one of the chief ornaments of women.

Sexual differences in the voice or in the method of using it are common, as every one knows, in amphibia, birds, and mammals. Witness the piping of the frogs, the song of birds, and the deep voice of men. Usually the modification of the voice is found in the males, and first appears, as in man, at the beginning of maturity. In fact, it is a general rule that when the male possesses special weapons, ornaments, or peculiarities of voice, these characteristics are not developed until about the time of the first ripening of the spermatozoa, and the immature males resemble the females. For this reason it has been inferred that the female, at least so far as these characters are concerned, represents a more primitive type than the adult male.

Devices for sheltering eggs or young are developed after different patterns in various groups of the animal kingdom, and they are usually confined to the females. Thus in most species of crustacea the female is provided with some means of carrying the eggs until they hatch. The female marsupials have a fold of the skin forming a pouch, in which the imperfectly developed young are placed at birth and are carried there until they are able to run about. The most characteristic organs of the mammalia and the ones from which the group has received its name, the mammæ, or milk glands, are possessed by the females of all species from monotremes to man. While functional only in the females, these organs are present in a rudimentary condition in the males also. Their importance as a means of rearing the young is so great that it has been questioned as to whether they should not be regarded as primary rather than secondary sexual organs. That they are essentially secondary, however, is shown by the practices of civilized women, who have largely relegated them to the position of ornaments—to the detriment of the best races of the human species.

In addition to the well-marked secondary sexual characters that distinguish males and females, there are other usually slight differences that Ellis classifies as tertiary sexual characters. We know very little in regard to these differences in the sexes of the other animals, but, thanks to Ellis, we have in his book, "Man and Woman" (1894), a very interesting and complete summary of these characters, anatomical, physiological, and psychical, in men and women. It would be impossible to summarize even his summary in the limits of this article. We can notice only a few of his conclusions and must refer the reader to the book for more.

Among the anatomical differences women show a greater youthfulness of physical type, as is common among females generally; but they show another anatomical peculiarity not found in other female mammals, and that is an enlargement of the pelvis. This, in the higher races of men, might be regarded as a secondary sexual character. A study of the brain and of the intellectual process in men and women gives the impression that the observed intellectual differences may be as much due to differences of training as to any innate differences between the sexes. In their senses women appear to be less discriminating, but more irritable, and in their emotions they show a greater affectability. Ellis thinks that women are more variable than men, but that this is true for all characters is denied by Pearson.

It is a general rule that in most species the two sexes are approximately equal in number of individuals, but in a few forms in which parthenogenesis is common there may be a large preponderance of females. From the records of 59,350,000 births in European countries Oesterlen (1874) calculated that the normal proportion of boys to girls is 106.3 to 100, and in the single countries the proportion of boys varied only between 105.2 and 107.2.

The following statistics of the numerical proportion of the sexes in other animals were collected by Darwin ("Descent of Man," Amer. ed., vol. i., pp. 293–307):

	Number of cases.	Proportion of males to 100 females.
English race-horses	25,560	99.7
Greyhounds	6,878	110.1
English and Scotch sheep	59,650	97.7
Cattle	982	94.4
Fowls (pure Cochins)	1,001	94.7
Lepidoptera, various species	1,635	122.7

These figures are all taken from records of births except in the case of the sheep, in which the sex was recorded at the time of castration, and in the case of the lepidoptera, in which the sex of the imagos was recorded after emergence from the chrysalis. In the pigeons, which have two young in a brood, there is usually one of each sex, but occasionally both will be males, more rarely both females.

The question as to the factors that determine whether any given individual shall be a male or a female has excited the greatest interest since early times, and it is probable that there is no subject within the domain of biology on which so much nonsense has been written. According to Beard, it has been estimated that there are over five hundred theories, or rather hypotheses, of sex; and still we know practically nothing as to the cause of the determination of sex in the individual. It is manifestly impossible to review any considerable number of these hypotheses within the limits of the present article, and we will confine our attention to a few that deserve special attention because they are either very recent or are founded on experimental evidence.

Waldeyer (1903) divides the hypotheses into three groups which he calls progamous, syngamous, and epigamous. 1. According to the progamous theories the sex of the future individual is determined before the fertilization of the egg from which it is to develop. (*a*) According to some authors the differentiation takes place in the spermatozoon, (*b*) while others think that it is in the unfertilized egg that this occurs. 2. The syngamous theories hold that the sex of the embryo is determined at the time of fertilization, while (3) the supporters of the epigamous theories hold that the zygote and the embryo in its early stages are sexually indifferent, and that the sex is determined by external factors acting upon the embryo during its development.

There is evidence for the progamous determination of sex in the fact that some animals like the rotifer, Hydatina; the worm, Dinophilus; and the plant louse, Philloxera, produce two forms of eggs, the larger of which always develop into females, and the smaller into males. In Dinophilus the eggs are fertilized, but in the other two they are parthenogenetic, and thus in them there can be no question of the influence of spermatozoa. Each female of Hydatina lays normally but one kind of egg, and Nussbaum has shown that if females are well fed from the time of hatching they will produce exclusively female eggs; if poorly fed, male eggs.

Beard (1902) has attempted to formulate a general theory of sex based on the idea of two kinds of eggs. He thinks that sex is determined in the oögonia or in the synapsis stage of the oöcytes (see *Reduction Division*), and denies that the spermatozoa have anything to do with the determination of sex. The basis for this view is chiefly his discovery that in very young embryos of the skate, *Raja batis*, the number of primary germ cells in females is double that in males. His argument, however, is far from clear, and is by no means convincing.

The contrary view, that it is the spermatozoon that determines sex, is expressed by McClung (1902). In certain insects there is found in the primary spermatocytes an accessory chromosome that behaves differently from the others during synapsis. It divides but once during the maturation divisions, and the halves are distributed to two of the spermatids only (*x*, Fig. 3941, in article *Reduction Division*). Thus there are formed two kinds of spermatozoa in equal numbers, and McClung suggests that the ones containing the accessory chromosome are male and the others female, the accessory chromosome not being found in female germ cells. While this hypothesis may apply to the insects in question, it is inapplicable to the forms already mentioned in which the spermatozoa can have no effect.

Allied to these theories is the view that the determination of sex is a phenomenon of heredity. This is not a new idea, but it has been brought out recently again by two authors.

Orschansky (1903) distinguishes two types of families —in one a majority of the children are male, in the other female; and he tries to show that the other characters of the parents, especially predisposition to disease, are distributed among the children in the same way that the sexual characters are. But his conclusions are not obtained by precise methods, although he deals with large numbers.

Castle (1903) attempts to explain the determination of sex on Mendel's theory of heredity (see *Reversion*). His argument is briefly this: (1) Sex is an attribute of every gamete, whether egg or spermatozoon, and is not controlled by environment. It is inherited according to Mendel's law. So the formula for the second generation should be $M + 2MF + F$. (2) But we do not get hermaphrodites usually, nor do we get pure males or females. The characteristics of one sex are always latent in the other. So the actual formula is $M(F) + F(M)$. (3) To explain this it is necessary to assume that a gamete of one sex can unite in fertilization only with a gamete of the opposite sex. (4) But one sex must be dominant and the other recessive or we should get hermaphrodites. It cannot be that one sex is always dominant. So it is necessary to assume that "Dominance, in diœcious species, is possessed sometimes by the male character, sometimes by the female." In other words, it is assumed that some organisms are male and some are female, which is the fact that we were trying to explain,—a good example of circular reasoning, and one not likely to lead us to a definite conclusion.

The only experimental evidence of the syngamous determination of sex is furnished by the bee. As was first shown by Dzieron, whose conclusions have been fully confirmed by Weismann and Petrunkewitsch, the question as to whether a given egg shall develop into a male or a female is determined by its being unfertilized or fertilized. The fertilized eggs develop into females, the unfertilized into males; another case in which McClung's theory would not apply.

Among the theories of the syngamous determination of sex are to be placed those in regard to the effect of the relative age of the parents or of the gametes, the relative sexual vigor of the parents, etc. Statistics have been gathered to show the effect of these factors. But they show at most a slight change from the normal numerical proportion of the sexes, and O. Schultze (1902) concludes from a series of experiments on mice, extending over two years, that these factors have no effect in the determination of sex. Included in this group is also the once much-heralded theory of Schenk. He thought that the sex of the zygote depends on the relative vigor of the gametes, and sought to influence this by improving the metabolic condition of the mother. His results were obtained from experiments on two or three women only, too few to afford a basis for sound generalization.

There is considerable evidence for the epigamous determination of sex by the state of nutrition of the embryo or larva. One of the earliest experimenters in this field was Mrs. Mary Treat, of Philadelphia. She divided a brood of caterpillars into two lots, and during the period between the last moult and the pupa stage one lot was well fed and the other was kept on the lowest possible diet. When the imagos emerged she found in the starved lot seventy-six males and three females, while the well-fed lot produced four males and sixty-eight females. These results were confirmed by Landois, who experimented on a thousand caterpillars of Vanessa; but doubt has been thrown on these results by Poulton, who finds that starvation produces a much higher death rate among females than among males.

Similar conclusions to those of Mrs. Treat and Landois were obtained by Yung from experiments on tadpoles. He found that normally about fifty-seven per cent. of the tadpoles developed into females. By feeding one lot with beef he raised the percentage to seventy-eight; by feeding a second lot with fish he raised the percentage still higher to eighty-one per cent.; and by feeding with the flesh of frogs he obtained as many as ninety-two per cent. of females. But these experiments, like the others, have been criticised by Pflüger and other writers as being inexact, possible factors beside nutrition having been neglected.

However, in the fresh-water polyp, Hydra, which is usually hermaphrodite, Nussbaum found that by good feeding he could stimulate the exclusive production of ovaries, and that in the ponds in the fall, when the food is becoming less, he found a greater number of males. Moreover, we know that in the plant lice sex is correlated with the condition of the food supply.

There are a good many experiments to show that in the lower plants sex may be regulated by food in the same way. On the other hand, Strasburger holds that it is impossible to influence the sex of diœcious phanerogams after the seed is formed from which the plant is to develop.

Whatever are the influences that determine sex they act primarily upon the essential reproductive organs, which in turn form the necessary condition for the development of the secondary sexual characters, as is shown by the effect of castration. If the gonads are removed before maturity the appropriate secondary sexual characters fail to develop, as in the familiar cases of horses, oxen, and capons. Moreover, diseases or removal of these organs after maturity affect the structure of the secondary sexual characters. Castration is employed sometimes by surgeons to reduce an hypertrophied prostate, and in women and in hens disease or removal of the ovaries has been observed to induce a partial development of latent male characters. How the gonads influence the rest of the body is not known, but from analogy with the thyroid gland, it is supposed to be by means of an internal secretion.

Robert Payne Bigelow.

BIBLIOGRAPHICAL REFERENCES.

Beard, J.: The Determination of Sex in Animal Development. Zool. Jahrb. Anat., 1902, pp. 701-764.
Castle, W. E.: The Heredity of Sex. Bull. Mus. Comp., Zool. Harv., vol. xl., No. 4, 1903.
Darwin, C.: Descent of Man and Selection in Relation to Sex. New York, 1872.
Ellis, H.: Man and Woman: A Study of Human Secondary Sexual Characters. London, 1894.
Geddes, P., and Thomson, J. A.: The Evolution of Sex, revised edition. London, 1901.
Henneberg, B.: Wo durch wird das Geschlechtsverhältnis beim Menschen und den höheren Tieren beeinflust? Ergeb. der Anat. u. Entw., vol. vii., 1898, pp. 697-721.
Hensen, V.: Physiologie der Zeuzung. Leipsic, 1881. (Hermann's Handb. d. Physiol., 6. Bd., ii. Th.).
Korschelt, E. und Heider, K.: Lehrbuch der vergleichenden Entwicklungsgeschichte der Wirbellosen Thiere., Allgem. Th. Jena, 1902, pp. 377-383 and 395-396.
McClung, C. E.: The Accessory Chromosome—Sex Determinant? Biol. Bulletin, vol. iii., 1902, pp. 43-84.
Oesterlen: Handbuch d. med. Statistik. Tübingen, 1874.
Orschansky, J.: Die Vererbung im gesunden und krankhaften Zustande und die Entstehung des Geschlechts beim Menschen. Stuttgart, 1903.
Schultze, O.: Was lehren uns Beobachtung und Experiment über die Ursachen männlicher und weiblicher Geschlechtsbildung bei Tieren und Pflanzen. Deut. med. Wochensch., 1902, p. 371.
Waldeyer, W.: Die Geschlechtszellen, 1903, pp. 413-415. (Hertwig's Handb. d. verg. u. exper. Entwickelungslehre der Wirbeltiere, Lief, 10-11.)

SEXUAL ORGANS, FEMALE.—The female organs of generation comprise the two genital glands or ovaries that produce the sexual elements, the two oviducts that convey them, the single uterus that protects them after impregnation, and the single vagina and vulva that serve as organs of copulation (see Fig. 4191).

Development.—Originally the male and female organs are indistinguishable, both being developed out of an undifferentiated form. In many lower vertebrates the genital gland, the oldest and primary organ, empties its products (ova, spermatozoa) directly into the peritoneal cavity, whence they pass out by means of openings in the belly wall called abdominal pores. In the next higher forms these become associated with other organs of elimination and removal. Tubular canals termed *nephridia* communicate with the peritoneal cavity by means of a funnel-shaped opening or *nephrostome*, each having also a side branch that envelops an arteriole, thus forming a glomerulus and becoming an excretory duct for urine. The nephridia are, originally, arranged metamerically and are therefore sometimes called segmental organs. This arrangement gradually disappears by the increase of the canals which come to be assembled in distinct organs, successively developed; the *pronephros*, or head kidney, very simple in structure, the only functional urinary organ in amphioxus, persisting throughout life in some fishes, but disappearing early in man, and the *mesonephros*, primitive kidney or Wolffian body (Caspar Friedrich Wolff, 1735–94), which appears behind the pronephros, and which likewise consists of a series of nephridial tubules to each of which a glomerulus is attached, and which open into a duct (segmental duct, Wolffian duct) that, in common with the intestine, discharges into the cloaca, a short receptacle for excreta just above the anus.

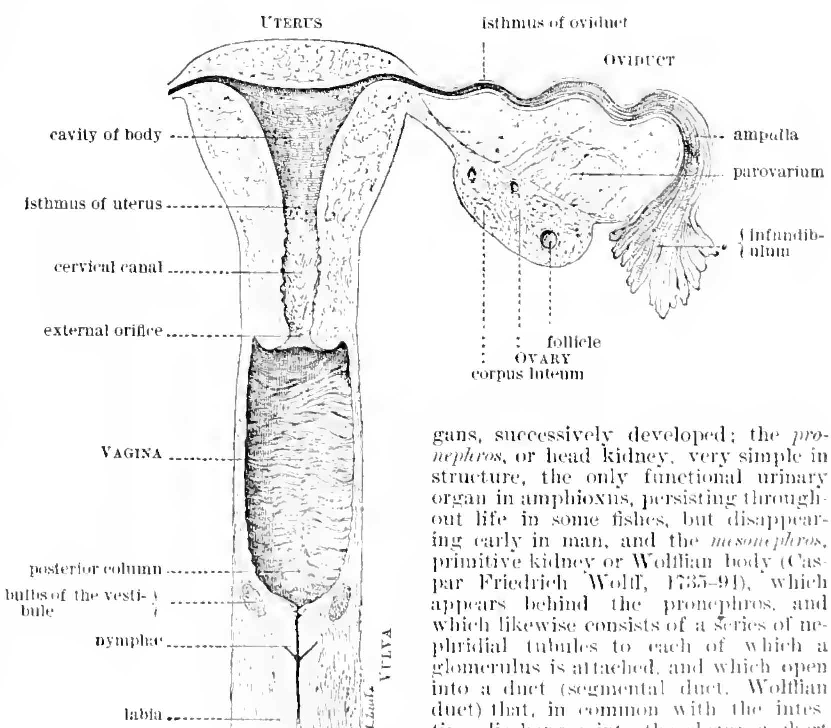

FIG. 4191. Diagrammatic Frontal Section of the Female Genital Organs passing through the Orifice of the Vagina. The oviduct and the ovary are lifted up. (Henle, modified by Rieffel.)

In some fishes and amphibians the Wolffian body remains throughout life a functionally active urinary organ, and, in amphibians, carries on the duplicate function of urinary organ and genital duct. In the higher vertebrates the

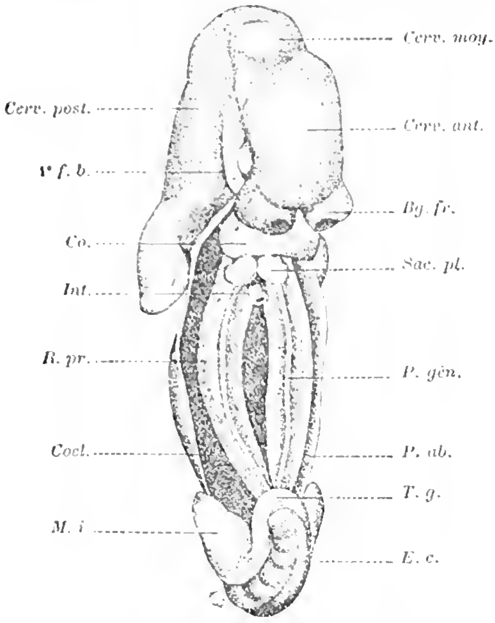

FIG. 4192. Human Embryo during the Fifth Week. The anterior wall of the trunk has been removed; the Wolffian body exposed. (Kollmann.) *Cerv. ant., moy., post.*, Forebrain, midbrain, and hindbrain; *1° f.b.*, first branchial cleft; *Bg. fr.*, frontal process; *Co.*, heart; *Sac. pl.*, pulmonary diverticulum; *Coel.*, celom; *P.ab.*, lateral wall of the abdomen; *M.i.*, rudiment of the lower extremity; *P.gén.*, genital ridge; *R.pr.*, Wolffian body; *Int.*, intestine; *T.g.*, genital eminence; *E.c.*, caudal extremity.

urinary function is taken on by the permanent kidney and the Wolffian body, as such, atrophies, portions of it remaining, however, as ducts for removing the sexual products.

The first rudiment of the genito-urinary apparatus is the genito-urinary ridge (Fig. 4192, *P.gén.*), a thickened, longitudinal band of epithelium that appears in the em-

FIG. 4193. Wolffian Body and the Genital Gland. Human embryo 17 mm. long. (Kollmann.) *L.dg.*, suspensory ligament; *G.g.*, genital gland; *C.W.*, Wolffian duct; *R.pr.*, Wolffian body, mesonephros, or primitive kidney; *Int.*, intestine; *A.o.*, umbilical artery; *Al.*, duct of the allantois; *Gub.*, gubernaculum of the genital gland or ligamentum genitoinguinale; *C.wf.*, canaliculi of the Wolffian body.

bryo of the fifth week near the spine and the primitive mesentery. This gradually increases in size, assumes an oval form, and detaches itself from the body wall as the Wolffian body (Fig. 4193, *R.pr.*) with its excretory duct (Fig. 4193, *C.W.*). Close beside this duct and following the same general course there develops a second tubule, Müller's duct (Johannes Müller, 1801–58) (Fig. 4194, *M*). It has a nephridial character, opening into the abdominal cavity by a nephrostome (Fig. 4194, *m'*), but has no glomerulus connected with it. In the female it becomes the oviduct; in the male it soon atrophies, only vestiges of it remaining. It is the Wolffian duct, however, that atrophies in the female, a trace of it remaining as the ductus epoophori longitudinalis, and the duct of Gärtner.

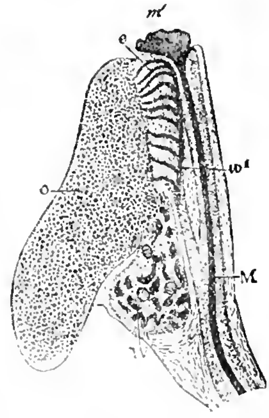

FIG. 4194.—Longitudinal Section through Genito-urinary Ridge of Human Female Embryo of about Fourteen Weeks (3.5 in. long). (Waldeyer.) *o*, Ovary; *e*, tubes of upper part of Wolffian body forming the epoophoron; *W*, lower part of Wolffian body, forming paroophoron; *w'*, remnant of Wolffian duct; *M*, Müller's duct; *m'*, its funnel-shaped peritoneal opening or nephrostome.

Not all of the genito-urinary ridge goes to form the Wolffian body. A portion of it, along its ventral aspect, is destined to form the genital gland proper. This portion is termed the genital ridge or fold, and is covered with large-celled epithelium (germinal epithelium) that produces the essential sexual elements, ova or spermatozoa. In mammals, the Wolffian body atrophies in large part, the genital ridge assumes an oval form and becomes either an ovary or a testis. A vestige of the upper part of the ridge becomes, in the female, the suspensory ligament of the ovary; a vestige of the lower end becomes, in the male, the gubernaculum of the genital gland (ligamentum genitoinguinale), which, in the female, becomes attached to Müller's duct where the latter crosses over it, and thus becomes divided into the ligament of the

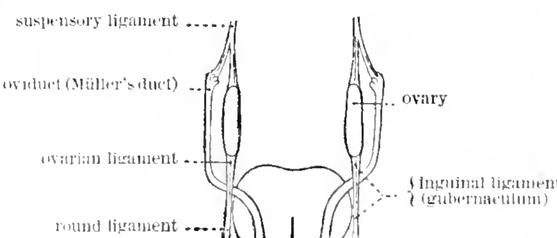

FIG. 4195. Scheme showing the Genesis of the Primitive Broad Ligament or Mesonephridium. From a human embryo 5.5 cm. long. (Fredet.) Müller's duct should pass *over* the inguinal ligament. The mesonephridium stretches longitudinally from the diaphragm to the inguinal region on each side of the pelvic cavity, ensheathing the structures shown in the diagram.

ovary and the round ligament of the uterus, which pass respectively from the ovary to the uterus, and thence to the groin.

As the Wolffian and Müllerian ducts converge from either side toward the median line, they become united in a common cord, the genital cord, and, before reaching the cloaca, the Müllerian ducts blend in a single passage which, by enlargement and thickening of the walls, becomes the uterus and the vagina. Occasional traces of the Wolffian duct are found along the sides of these organs, forming the so-called duct of Gärtner, described by the Danish anatomist Gärtner in 1822 in the sow, but previously noted in 1681 by Malpighi in the cow.

Sexual Organs.

The genito-urinary ridge, like the rest of the walls of the body cavity, is covered over with peritoneum. As the Wolffian body becomes detached it is still held to the walls by a fold of peritoneum—the *mesonephridium* of Waldeyer, which invests both the free portions of the Wolffian and the Müllerian ducts and the upper part of the genital cord (Figs. 4195, 4196, and 4197). The mesonephridia of opposite sides are therefore continuous with each other across the median line, and, as the Wolffian body atrophies and the uterus develops, there is thus formed the large transverse fold of peritoneum known as the broad ligaments of the uterus, which invest the remains of the Wolffian body, the ovaries, the oviducts, and the upper part of the uterus.

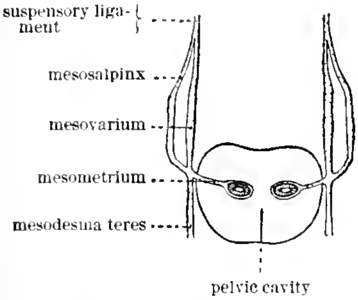

FIG. 4196.—Diagram of Section of the Mesonephridium at its Base. (Fredet.) The duct of Müller descending into the pelvic cavity forms a primitive mesometrium.

A change in the position of the ovary occurs, arising from the difference in the growth of the ovarian attachments and that of the general body. This, the "descent of the ovary," is analogous to the descent of the testis in the male, but is not usually so complete, because of the interposition of the uterus by the attachment of the gubernaculum thereto (Fig. 4197). It places the organ in the pelvic cavity. Rarely it has been known to proceed along the course of the round ligament of the uterus and reach the interior of the labium majus, the analogue of the scrotum of the male.

In the female there develop, from the deeper layers of the germinal epithelium, cells of two kinds, one of which, large, with reticular nuclei, becomes the sexual cells or ova; others, smaller and more cubical, surround the former and separate them from the invading mesodermal connective tissue. The sexual cells form, at first, chaplet-like strings known as egg columns or Pflüger's tubules (E. F. W. Pflüger, born 1829); later these are broken up, each sexual cell forming, with its investing elements, a primitive follicle or ovisac (Fig. 4198).

The cloaca or common passage into which the intestine and the genito-urinary ducts discharge is at first closed from the exterior by a thin partition termed the cloacal

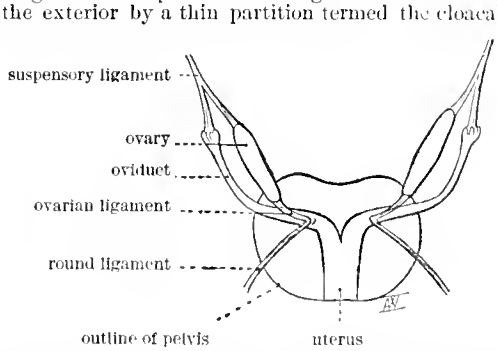

FIG. 4197.—Diagram showing Formation of the Permanent Broad Ligament. (Fredet.) The mesodesma suspensorium (peritoneum around suspensory ligament), the mesovarium, the mesodesma teres (peritoneum around round ligament), and the mesosalpinx, which form at first a continuous fold on either side (the primitive broad ligament) are drawn together and united across the middle line (mesometrium) by the union of the ducts of Müller. The oviduct should pass *over* the round ligament.

membrane, extending from the rudimentary coccyx forward, and marked by a slight depression of the exterior surface known as the cloacal fossa (Fig. 4199). In front of this there forms a conical outgrowth known as the genital eminence (*eminentia genitalis*) which increases rapidly in size and forms at its top a rounded projection (*tuberculum*

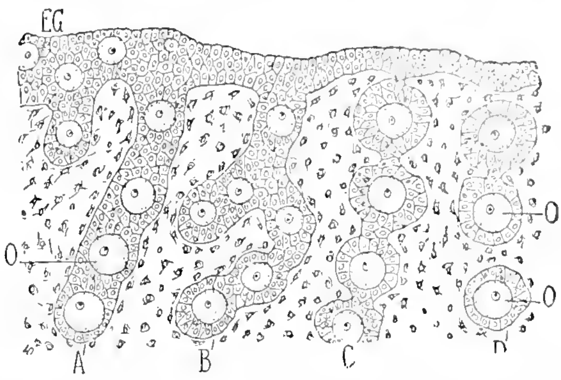

FIG. 4198.—Egg Columns or Pflüger's Tubules, showing the Divers Phases in the Production of the Ovisacs. (Duval.) *EG*, Germinal epithelium with the primordial ovisacs; *A*, egg column or tubule of Pflüger in its primitive state; *B* and *C*, tubules assuming a chaplet-like form; *D*, breaking up of the chaplet, the ovisacs become independent; *O, O, O*, ova.

genitale) that becomes, later, either the clitoris or the glans penis (Fig. 4199). Behind this occurs a slit-like depression of the cloacal membrane, the urogenital cleft (*rima genitalis*) bounded on each side by two folds, the inner genital folds (*plicæ genitales*), which finally become, in the female, the nymphæ and the frenulum of the clitoris.

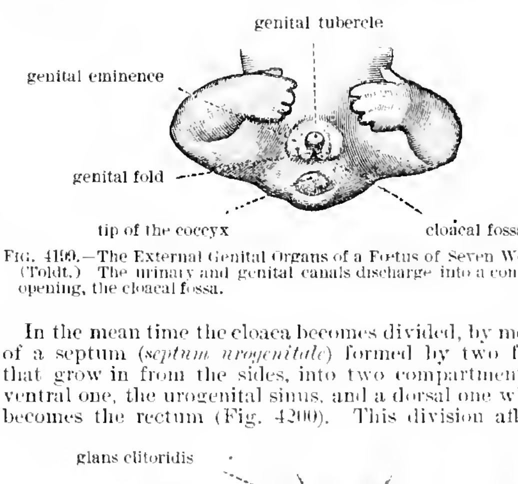

FIG. 4199.—The External Genital Organs of a Fœtus of Seven Weeks. (Toldt.) The urinary and genital canals discharge into a common opening, the cloacal fossa.

In the mean time the cloaca becomes divided, by means of a septum (*septum urogenitale*) formed by two folds that grow in from the sides, into two compartments, a ventral one, the urogenital sinus, and a dorsal one which becomes the rectum (Fig. 4200). This division affects

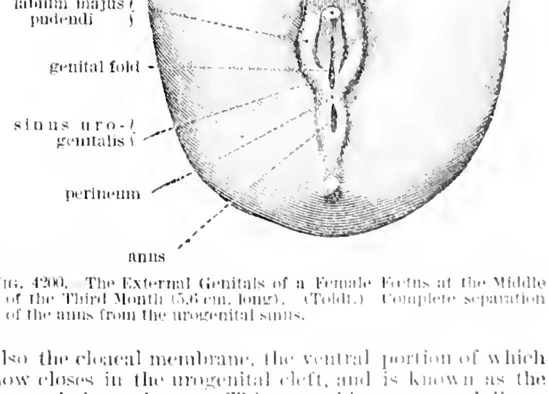

FIG. 4200. The External Genitals of a Female Fœtus at the Middle of the Third Month (5.6 cm. long). (Toldt.) Complete separation of the anus from the urogenital sinus.

also the cloacal membrane, the ventral portion of which now closes in the urogenital cleft, and is known as the urogenital membrane. This soon thins away and disappears so that the cleft opens immediately into the uro-genital sinus.

There now arise, at the base of the genital eminence on either side, two rounded folds, the outer genital or labio-

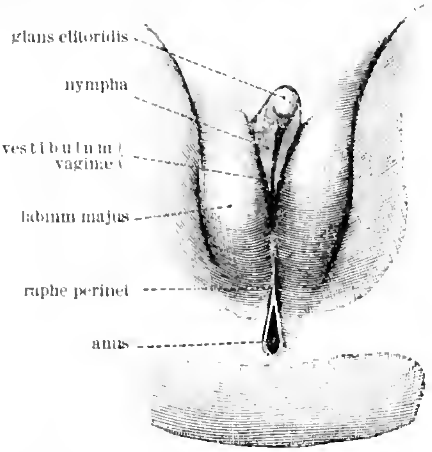

FIG. 4201.—The External Genitals of a Female Fœtus at the End of the Fifth Month (11.5 cm. long). (Toldt.)

scrotal folds (*tori genitales*), which extend backward as far as the anus and join each other in front around the genital eminence. These become the labia majora of the female or the scrotum of the male (Fig. 4201).

THE OVARIES.—*Etymology.*—From the Neo-Latin *ovarium*, a derivative from *ovum*, an egg. Greek, ὠοφόρον, from whence many compounds arise, such as *oophorectomy*, *oophoralgia*, *oophoritis*, etc. French, *ovaire*; Italian, *ovario*; German, *Eierstock*. The name was first used in 1667 by the Danish anatomist, Nil Stensen, who supposed the ovisacs to be ova. The ancients, recognizing their analogy to the male genital glands, called them testes muliebres.

History.—The Alexandrian anatomists probably knew them, and they were described by Soranus of Ephesus (A.D. 117) who considered them as useless bodies, and also by Galen, who supposed them to secrete a female semen, very fluid and "cold," which was conveyed to the uterus by the oviducts. Athenæus (A.D. 69) denied this, as did afterward Fallopius. It was, however, generally held up to the time of De Graaf, who, in 1672, insisted that their proper use was to generate ova, to nourish them, and to bring them to maturity.

The ovisacs were known and mentioned under various names by Vesalius, Fallopius, Bartholinus, and others. Jan Van Horne, professor at Leyden, was the first to call them *ova*, and thus emphasize the egg producing function of the ovary. The veritable ovum was not discovered until 1827, when von Baer described it.

Definition.—The organs of the female, in which are developed the ova, or essential sexual products. They differ from ordinary secreting glands in that they do not form new products, but merely develop and mature structures that already exist in them, in a rudimentary condition, at birth.

Form.—The human ovary (Fig. 4202, *4*) is a solid, almond-shaped body, about 4 cm. long by 2 cm. wide and 1 cm. thick ($1\frac{1}{2} \times \frac{4}{5} \times \frac{1}{3}$ in.) in the adult (Fig. 4203); in childhood and old age considerably less. It may vary from this typical form and be disc-like, cylindrical, triangular, or irregular. The right ovary is slightly larger than the left. The attached edge of the ovary is nearly straight, the free edge usually curved. Its extremities, also called poles, are distinguished as inferior, or uterine, and superior, or tubal, the latter being attached to the infundibulum of the oviduct.

Color.—This is a soft, dull, reddish-gray, like that of a mucous membrane, easily distinguished from the smooth, glistening appearance of the neighboring organs due to their peritoneal covering. The peritoneum, forming the broad ligament and the mesovarium, abruptly ceases at the attached edge of the ovary at a crenulated line (Fig. 4203, *1*, Farre's line; Arthur Farre, physician of London, *circa*, 1840), and the organ presents its bare surface in the abdominal cavity, being the only one that, in the strict sense of the word, is within the peritoneal sac. The reddish tint increases during the hyperæmia preceding menstruation and decreases after the menopause.

Consistency.—Although in youth quite dense and resistant to pressure, the development of the vascular tissue in the ovaries is such as to make them slightly spongy, and at puberty they are not as firm as the testes of the male. Their density increases after the menopause. Before menstruation the surface is smooth, but afterward the development and rupture of the ovisacs produce on the surface elevations and depressions that have been compared to those of a peach stone or to the convolutions of the brain (*ovarium gyratum*, Abel).

Weight.—This naturally varies with the size of the ovary, being 50–60 cgm. at birth, 4 or 5 gm. at puberty, 6–8 gm. in the adult, and decreasing gradually to a gram or less in old age. It is thought that a rapid increase of weight occurs from the hyperæmia of the menstrual period.

Attachments.—The cavity of the pelvis is transversely divided into two compartments by the broad ligament, a fold of peritoneum that encloses the uterus and the oviducts. The ovaries are attached edgewise to the postero-superior surface of this fold by a short peritoneal duplicature termed the *mesovarium* (Fig. 4202, *c*, Fig. 4203, *2*), which is continued upward from the superior pole of the ovary as a triangular band, the suspensory ligament (Fig. 4201), containing the ovarian vessels and nerves, some unstriped muscular fibres, and a long fimbria from the

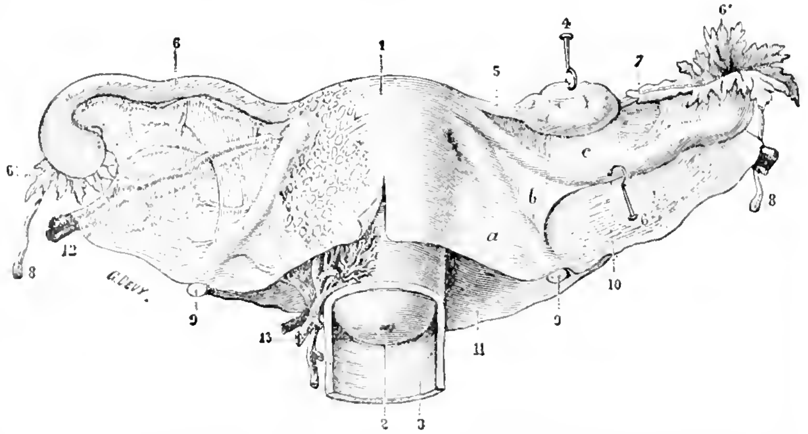

FIG. 4202. The Uterus and Annexa seen from Before. (On the left side the oviduct is turned down to show the ovary which is slightly raised.) 1. Body of the uterus, covered by peritoneum; 2, its cervix, with the external orifice; 3, vagina, its anterior wall removed; 4, left ovary; 5, ligament of the ovary; 6, oviduct, with 6', its infundibulum; 7, ovarian fimbria and tubo-ovarian ligament; 8, hydatid of Morgagni; 9, round ligament; 10, broad ligament, with *a*, *b*, *c*, its three divisions or "*ailerons*"; 11, posterior layer of the broad ligament; 12, ovarian vessels; 13, uterine vessels.

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extremity of the oviduct (Fig. 4202, *7*). At the inferior pole is attached the ligament of the ovary (Fig. 4202, *5*), a fibro-areolar structure containing some muscular fibres, that extends in the folds of the broad ligament to the

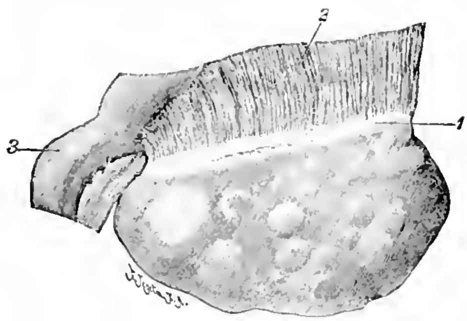

FIG. 4203.—The Human Ovary. (Nagel.) 1, Farre's line; 2, mesovarium; 3, oviduct and fimbria ovarica.

uterus. The ovary has considerable mobility, turning, hinge-like, around its mesovarian margin, and is also subject to displacement by a stretching of its attachments and the dragging of the broad ligament itself, which is affected by the position of the uterus.

Situation.—Varying greatly in weight under different normal conditions and at different periods of life, it is not surprising to find the ovaries varying also in position. This is influenced by a variety of conditions, such as posture, pregnancy, the state of repletion of the bladder and rectum, and inflammatory conditions which may cause adhesions between the ovary and the surrounding viscera. However, in the adult female, when the uterus is normally placed, the ovary, if not affected by repeated pregnancies or by pathological conditions, usually lies in a nearly vertical position (Fig. 4204) in a shallow depression, the fossa ovarica, on the lateral wall of the pelvis, in the acute angle made by the superior vesical (hypogastric) artery externally, and the ureter and uterine artery internally. Anteriorly it is sustained by the shelf-like broad ligament. The oviduct, bending around its lateral and medial surfaces and upper end, leaves a pouch-like depression of the broad ligament between itself and the ovary, which is termed the bursa ovarii. The external iliac vessels and the psoas muscle lie to the outer side of the fossa ovarica, and under its floor, covered by peritoneum and surrounded by subperitoneal fat, run the obturator vessels and nerve, these separating the ovary from the obturator internus muscle. In a standing position the mesovarian margin looks forward and outward, but is concealed by the oviduct. Its free margin looks inward and backward toward the rectum and is in relation with the ureter.

Often the ovary is not easily seen upon casual inspection of the pelvic contents. A line connecting the two ovaries lies behind the body of the uterus when that organ is in its normal position. Therefore, when the ovary, by increasing in weight, stretches its attachments, if not adherent it usually falls into the recto vaginal pouch.

Referred to the exterior of the body the site of the ovary is usually behind a point on the abdominal wall about two inches medially from the anterior superior spine of the ilium. The sagittal plane that cuts it is midway between the spine and the symphysis. The frontal plane tangent to the promontory either cuts it or passes close behind it, while the frontal plane corresponding to the ischiatic spines passes considerably behind it. Horizontally, it is above the lesser sciatic foramen and on a level with the infrapyriform foramen and the upper margin of the acetabulum (see article *Pelvis*).

The ovary may be reached by both vaginal and rectal examination. In the vaginal method the patient is placed in dorsal decubitus with the thighs flexed, and one or more fingers, pushed into the posterior cul-de-sac of the vagina, explore the pelvic wall. With the other hand the surface of the abdomen is depressed over the region above described as the site of the ovary. The internal border of the psoas may usually be made out as a rounded ridge, and the ovary will be found to the inner side of this, and may usually be grasped between the internal and external fingers.

Structure.—A section of the ovary (Figs. 4205, 4206) shows that besides its investing epithelium (derived from the germinal epithelium of the embryo) its substance, or stroma, may be divided into an external, cortical, or ovigenous layer, crowded with small round bodies, varying in size from that of a mustard-seed to that of a pea; and

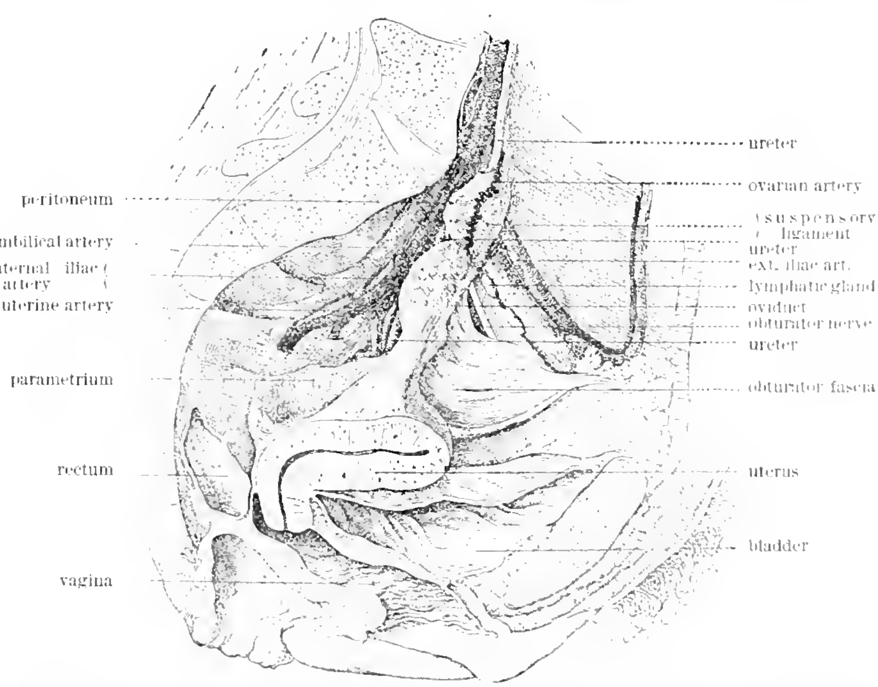

FIG. 4204. Median, Antero-posterior Section of the Pelvis of an Adult Female. (Rieffel.) The uterus is low and very near the coccyx. The anus is gaping, the vagina open and the bladder much spread out. The peritoneum is removed in front and behind the suspensory ligament of the ovary, to show the subjacent organs. The ovary is in place.

a medullary layer rich in vessels and nerves, with spindle-shaped connective tissue cells, some elastic fibres and plain muscular tissue. The round bodies are the ovisacs (Figs. 4205, 4206, 4207—Graafian follicles, from the Dutch anatomist, Regnier de Graaf, 1641–73), already mentioned as derived from the epithelial layer. The smaller ones (primordial ovisacs, *A A A*, Fig. 4206; *A*, Fig. 4207) contain no fluid, but the larger ones are distended by an al-

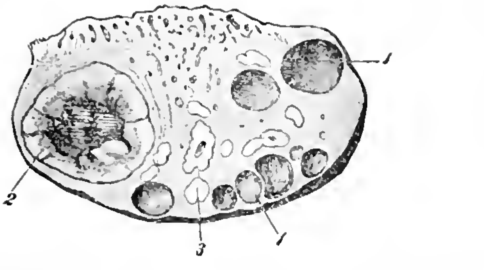

FIG. 4205.—Section of a Human Ovary. (Nagel.) 1, Ovisac; 2, corpus luteum; 3, corpus albicans (several such are seen on the surface of the section).

buminous liquid, the *liquor folliculi* (7, Fig 4207). Within each ovisac is a large sexual cell or ovum, surrounded by a layer of smaller cubical cells that form an epithelial investment termed the membrana granulosa. The larger ovisacs have a distinct connective-tissue investment (*theca folliculi*) derived from the stroma and richly supplied with blood-vessels. This consists of two layers, the *tunica externa* and *interna* (4, 5, Fig. 4207). The former blends with the surrounding stroma; the latter is composed of cells resembling those of embryonal connective tissue, many of which are large, rounded, and infiltrated at maturity with yellow granulations (4', Fig. 4207). These have been termed lutein cells, and are believed to be connective-tissue cells transformed for the nutrition of the follicles.

The liquor folliculi is secreted from the membrana granulosa, whose cells multiply and come to be arranged in several layers, surrounding the ovum, which remains single, always attached to the side of the follicle by an accumulation of the cells (*cumulus oophorus*, Fig. 4207, 6.) The ovisac continues to swell, both by the multiplication of the granulosa and by the increase of fluid, and thus gradually pushes its way outward and appears on the surface of the ovary as a fluctuating vesicle. Blood vessels ramify abundantly on its walls, except at a superficial pole called the *stigma*, where they are wholly wanting. It is at this spot, and probably from some increase of vascular tension, that the vesicle finally ruptures. Preceding this the granulosa attaching the ovum to the wall of the vesicle becomes softened, probably by invasion of lutein cells, and, at the rupture, the ovum with a portion of the cumulus adhering to it is thrown out of the sac. Some slight hemorrhage from ruptured capillaries occurs into the empty sac. This act is known as *ovulation*.

At birth the ovary is crowded with primordial ovisacs. Waldeyer estimates their number at 100,000, while some observers place it much higher, Sappey noting a case in which they exceeded 1,000,000. Most of them degenerate, however, there being not more than 30,000 or 40,000 at puberty, and but few of these ever come to maturity. Olshausen could find but from 50 to 100 follicles visible to the naked eye in an adult female. They entirely disappear after the menopause.

Corpora Lutea.—Some of the follicles that thus abort acquire a certain degree of development before disappearing, and, without rupturing, form, apparently by a multiplication of the lutein cells, a yellowish body known as a *corpus luteum* (*corpus luteum atreticum*). In completely matured and ruptured follicles, the formation of a corpus luteum is much more marked (Fig. 4208). It is produced by a hypertrophy of the walls of the follicle, these becoming imbricated and vascularized about the

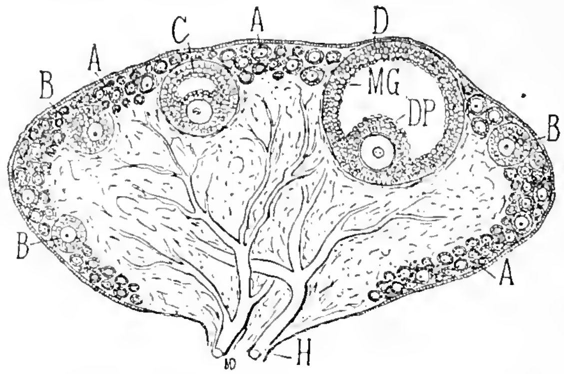

FIG. 4206.—Diagrammatic Section of the Ovary showing its Cortical or Ovigenous Layer, Formed of Ovisacs in various Stages of Evolution. (Duval.) *A, A, A*, Primordial ovisacs; *B, B, B*, ovisacs further developed; *C*, ovisac approaching maturity; *D*, ripe ovisac with its proligerous disk (*D P*) containing the ovum; *M G*, membrana granulosa; *H*, hilum of ovary.

central clot, which contracts. The folds finally become united with each other and a yellowish body is formed, having a size considerably greater than that of the original ovisac. If pregnancy intervenes after the discharge of the ovum, the corpus luteum persists during a greater part of the period, and usually attains a great size (*corpus luteum graviditatis, corpus luteum verum*); but if there is no pregnancy it begins to atrophy, and disappears in the course of two or three weeks (*corpus luteum menstruationis, corpus luteum spurium*). It was formerly believed that certain information regarding a pregnancy could

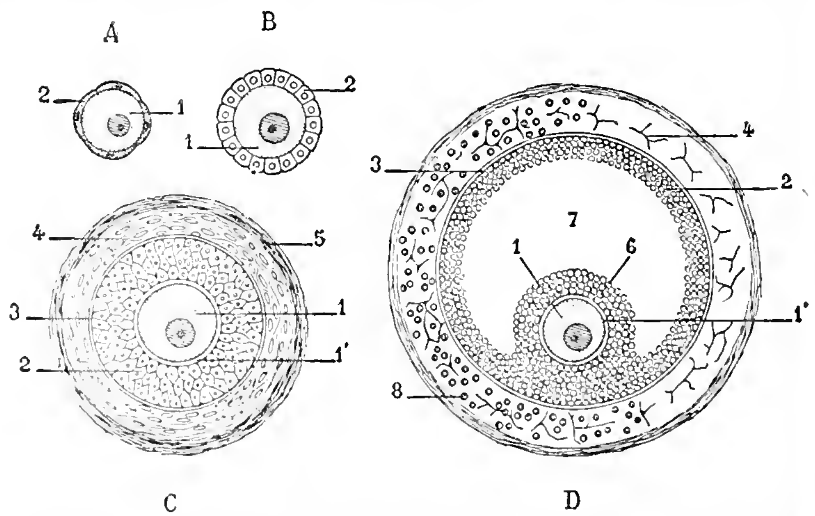

FIG. 4207. Ovisacs. *A*, Primordial ovisac; *B, C, D*, ovisacs at various stages of their development (diagrammatic). (Testut.) 1, Ovum; 1' (*C*), vitelline membrane; 2, membrana granulosa; 3, membrana propria; 4, tunica propria; 4' (*D*), reticular tissue replacing the tunica propria; 5, tunica fibrosa; 6, cumulus oophorus; 7, liquor folliculi; 8, leucocytes in the reticular tissue (shown only at left of *D*).

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be obtained from examination of the corpora lutea, but this is not strictly correct, for the structure of the two is identical, and cases have been noted in which the corpus luteum of menstruation equalled in size that of pregnancy.

On microscopic examination it is found that a corpus luteum is made up of very large cells with rounded angles, having an appearance very like that of liver cells. These are lutein cells, so called from granules of a yellow substance found within them, associated with fat and known as lutein. The tunica externa of the theca remains, and there develop from it radiate septa that extend throughout the body to a central nucleus, representing the site of the original clot, where crystals of hæmatoidin are often found. By fatty degeneration and absorption the lutein cells finally disappear; the connective tissue contracts to a whitish mass (*corpus albicans*), and finally to a fibrous remnant (*corpus fibrosum*), which is at last also removed by hyaline degeneration.

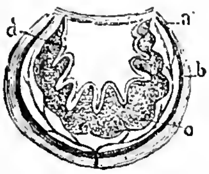

FIG. 4208.—Diagrammatic Section of a Recent Corpus Luteum. (Balbiani.) *a*, Ovarian stroma; *b*, tunica fibrosa or external layer of the ovisac; *c*, internal tunic hypertrophied and folded; *d*, remains of the membrana granulosa. *e*, vessel supplying the ovisac.

Observers are not fully in accord as to the origin of the lutein cells. Sobotta, after very careful observations on the mouse, concludes that they are of epithelial origin, arising from a hypertrophy of the granulosa (Fig. 4209), and in this he is supported by Bischoff, Pflüger, and many others. Another view, is that they are of connective-tissue origin, arising from the cells of the tunica interna, and that the granulosa wholly disappears. Observations on abortive ovisacs seem to support this view, which is warmly defended by Clark, Minot, Paladino, and others. The matter cannot be definitely settled until human material, showing the earlier stages, is more fully investigated.

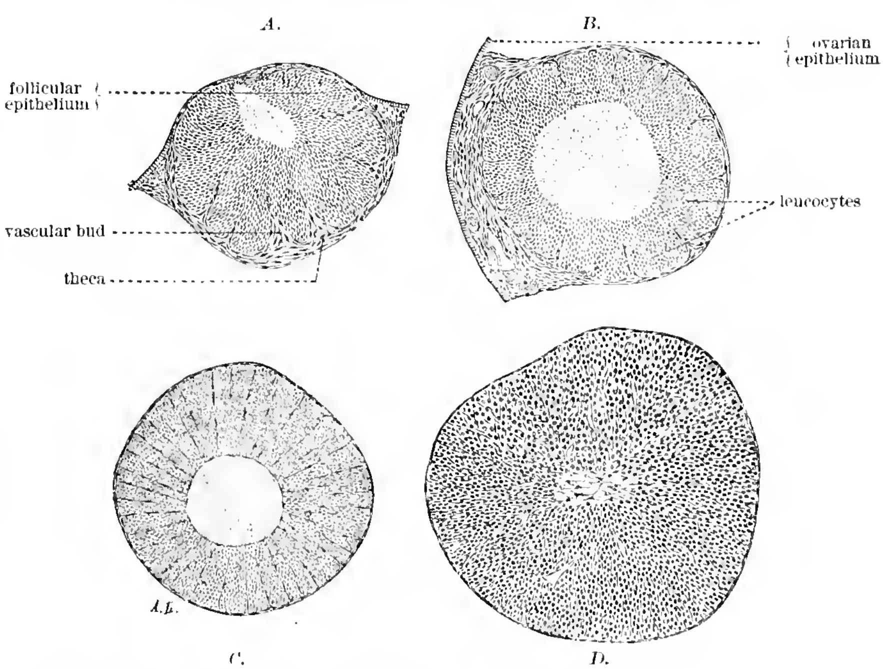

FIG. 4209.—Formation of the Corpora Lutea according to Sobotta. Four successive stages in the mouse. *A*, Vascular budding of the tunica interna invading the hypertrophied follicular epithelium; *B*, the vascular buds converge toward a central cavity. Between them the follicular cells, which are rapidly multiplying, are arranged in columns. Among these cells leucocytes are found. *C*, A more advanced stage; the columns are now narrower and the trabeculæ more numerous. *D*, The central cavity is now occupied by a gelatinous connective tissue; the trabeculæ, by anastomosing with each other, have destroyed the columnar arrangement of the lutein cells.

The function of the corpus luteum has been the subject of much discussion. Born, struck with the resemblance of its structure to that of the suprarenal capsule, advanced the hypothesis that the organ is a ductless gland that modifies the blood so as to produce the changes in the uterus necessary for the encapsulation and subsequent nutrition of the ovum. He argued that the corpus luteum is much larger than would be necessary for the mere restoration of the ovarian tissue, and that the growth of the uterus during pregnancy is not due to distention by the growing ovum, but is accompanied by profound structural changes, which may be initiated without the ovum being in the uterus at all, as in the well-known case of extra-uterine pregnancy. Further, mammals that have a placenta which becomes firmly attached to the uterus have a well-developed corpus luteum, while the aplacental mammals (monotremes, marsupials) have only a rudimentary one or none at all. Fränkel and Cohn found that in rabbits the removal of both ovaries within six days after copulation always prevented pregnancy. According to this view, the corpus luteum of menstruation may have an effect upon the restoration of the uterus.

Clark and others contend that the organ is required to maintain the peripheral circulation and proper surface tension in the ovary by preventing the formation of cicatricial tissue at the point of discharge of the ovum. If each rupture of an ovisac were followed by a typical scar, the entire surface of the ovary would soon be reduced to inactivity.

Arteries.—The ovary is supplied by the ovarian artery, which arises from the abdominal aorta just below the renal arteries, and descends by a flexuous course into the pelvis through the suspensory ligament of the ovary, its long course being explained by the fact that the ovary was primitively an abdominal organ. It gives off a tubal branch that supplies the fimbriated extremity of the oviduct, ten to fifteen ovarian branches, and is continued to make a free, anastomotic loop with the uterine artery. During pregnancy, when it is greatly enlarged, it is an important supplementary source of supply for the rapidly growing uterus. The small ovarian branches penetrate the ovary along its attached border, the place of entrance, which also serves for veins, nerves, and lymphatics, being called the hilum. Their course is helicine or corkscrew-like, not only in the broad ligament, but also in the substance of the organ. In the medullary portion they form the rich anastomoses which cause this to be named the vascular zone; and at the confines of the cortical and medullary portions they form imperfect arcades from which arterioles are given off which pene-

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trate to the ovisacs and the corpora lutea and form a capillary network about them.

Veins.—These are large, sinuous, spiroid in character, and accompanied by bands of smooth, muscular fibre

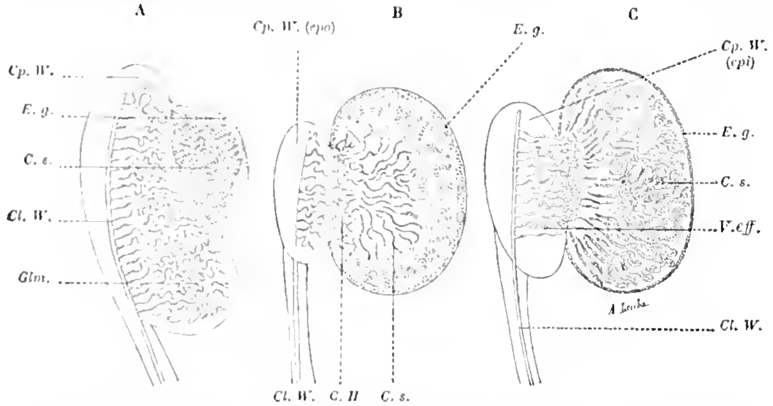

FIG. 4210—Scheme Showing the Development of the Sexual Gland and its Ducts. (Mihalkovics.) *A*, Indifferent stage; *B*, female; *C*, male; *Cp.w.*, Wolffian body with the epoophoron (*epo*) and the epididymus (*epi*); *Cl.w.*, Wolffian duct; *C.s.*, sexual radiations; *Glm.*, Wolffian glomeruli; *C.H.*, body of Highmore (rete ovarii); *E.g.*, germinal epithelium; *V.eff.*, efferent ducts of the testis.

like those of erectile tissue. In the hilum, mesovarium, and neighboring folds of the broad ligament the veins form a vascular protuberance called by Rouget the bulb of the ovary, and believed by him to have some function in ovulation. Leaving the broad ligament, the veins unite to form the pampiniform plexus and finally discharge into the uterine and ovarian veins.

Lymphatics.—These are very numerous. They originate in the stroma and about the ovisacs, some of the smaller sacs being often nearly surrounded by a lymph sinus. Converging to eight to ten trunks, they pass out at the hilum, accompany the vessels and discharge into glands situated in front of the aorta.

Nerves.—These are derived from a sympathetic plexus that is given off from the renal plexus and accompanies the ovarian artery. The exact terminations are imperfectly known. They have been traced to the walls of vessels, to smooth muscular fibres, to the surface epithelium, and to the tunica interna of the Graafian follicles.

Vestigial Structures.—There remain within the ovary, in the folds of the broad ligament and elsewhere, certain vestiges of the fœtal condition of the organs that it is necessary to briefly mention. These are as follows:

The *epoophoron, parovarium,* or *body of Rosenmuller* (Fig. 4210, *B*, Fig. 4211) consists of six to twelve nearly parallel tubes containing a clear fluid, which are found within the folds of the mesosalpinx. They converge toward the hilus of the ovary, and may in young animals be traced into its substance (see Fig. 4210 *B*, *C.s.*). Toward the oviduct they end in a longitudinal canal, the remains of the Wolffian duct. They represent vestiges of the sexual part of the Wolffian body, and are homologous with the seminiferous tubules and vasa efferentia of the male.

The *paroophoron* is a similar series of tubes found in the broad ligament nearer the uterus, and representing the unused urinary part of the Wolffian body (*Glm*, *A*, Fig. 4210). They are of a yellowish color and usually disappear early.

Gärtner's Canal.—This is the remains of the lower part of the Wolffian duct occasionally found in the wall of the uterus and vagina. It is homologous with the vas deferens of the male.

Hydatids of Morgagni.—In about twenty per cent. of subjects there is found connected with the infundibulum of the oviduct, usually with the ovarian fimbria, a small hollow cyst known as the hydatid of Morgagni. Similar structures may be found in the folds of the broad ligament in connection with the epoophoron. Their homologies and origin are obscure.

THE OVIDUCTS.—*Etymology.*—From the Neo-Latin *oviductus*, derived from the Latin *ovum*, an egg, and *ductus*, a leading, a passage. Greek, σαλπιγξ, from whence many compounds, such as *salpingitis*, *salpingotomy*, etc.; French, *oviducte, trompe uterine;* Italian, *oviduto, tromba de Falloppio;* German, *Eileiter, Muttertrompete.* The name was first used by De Graaf, about 1672. The older anatomists styled them *vasa deferentia.* Often called the Fallopian tubes, from Gabriello Falloppio (1523–62), professor at Ferrara, Pisa, and Padua, who compared their expanded ends to that of a brazen *tuba* or trumpet. This name was first given them by Riolanus about 1618. In the nomenclature of the German Anatomische Gesellschaft they are known as the *tubæ uterinæ.* Some authors restrict the term oviduct to the genital passages of animals possessing no uterus. There seems no good reason for this.

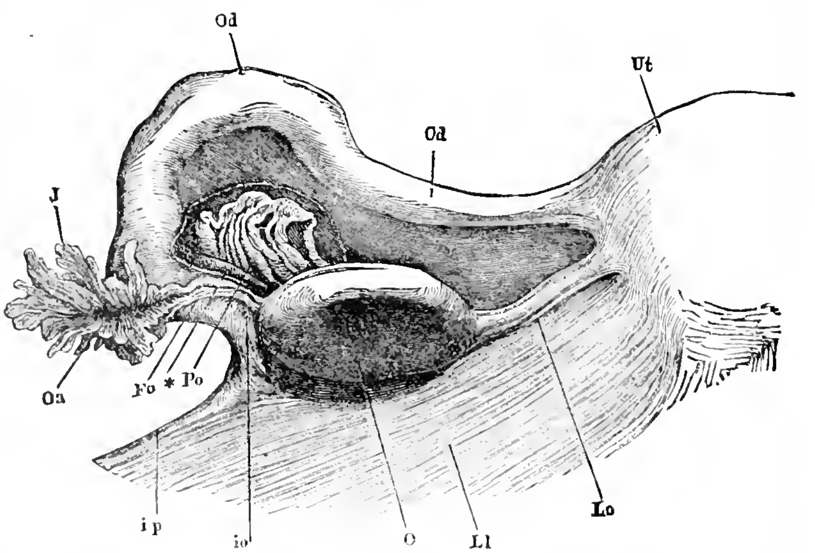

FIG. 4211. View of Lateral Angle of Uterus with Broad Ligament from Behind. (Henle.) *Ut*, Uterus; *Ll*, broad ligament; *Od*, isthmus of oviduct; *Od'*, ampulla of oviduct; *J*, infundibulum; *Oa*, abdominal opening of oviduct; *Fo*, ovarian fimbria; *ip*, suspensory ligament; *Po*, epoophoron laid bare by removal of part of the posterior lamella of the broad ligament.

History.—They were probably known to Herophilus

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(335–280 B.C.). Eudemus (290 B.C.) described the fimbriated extremity. Rufus of Ephesus demonstrated them in the sheep about A.D. 50. They were generally supposed to convey the product of the ovary, the hypothetical female semen. Fallopius showed that they did not closely connect with the ovaries, and considered that "fuliginous vapors" exhaled from the uterus through them into the abdomen. Others supposed them to be spiracles through which "spirits" could pass from the mother to the fœtus.

Definition.—Paired tubular structures, extending from near either ovary to the uterus, by which the mature ova are conveyed from the peritoneal cavity to the latter organ. They differ from the ducts of secreting glands in being detached from the organ whose products they are intended to convey.

Form.—The general shape of an oviduct (see Fig. 4191) is that of a gradually expanding, sinuous trumpet, extending laterally from either angle of the uterus, of which it appears to be a continuation. This is even more striking in the lower animals, in whom the fusion of the Müllerian ducts is not so complete, and who consequently possess a bicornuate uterus.

Divisions.—Starting from the uterine cavity we may distinguish (Figs. 4191 and 4202): (1) a uterine, intramural, or *interstitial* portion, passing through the walls of the uterus, in which the lumen of the duct is reduced to very small dimensions; (2) the *isthmus*, a narrow, comparatively straight portion, having no well-defined limit, but generally reckoned as about one-third the length of the duct; (3) the *ampulla*, an enlarged, sinuous portion which terminates by (4) the *infundibulum* or *fimbriated extremity*, a funnel-shaped expansion surrounded by a fringe-like border by which the duct opens into the peritoneal cavity. The junction of the infundibulum with the ampulla, sometimes slightly constricted in young persons, is occasionally called the *neck*.

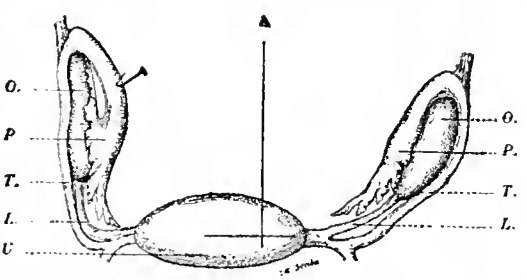

FIG. 4212.—Relations of the Ovary and the Oviduct. (His.) *O*, Ovary; *P*, infundibulum; *T*, oviduct; *L*, ovarian ligament; *U*, uterus. The annexa are held up by the suspensory ligament. The fundus of the uterus deviates somewhat from the median line.

The uterine orifice is small, inextensible, and often stopped by a plug of mucus. It is practically impossible to catheterize it, and fluids injected into the cavity of the uterus do not readily pass through it. The abdominal orifice is larger and extensible. It is said to be closed in tubes cut from the living, but open after death. We may, with Waldeyer, consider the oviduct according to the directions which its different parts assume. A *horizontal* portion extends from the angle of the uterus outward and a little backward to the inferior pole of the ovary, an *ascending* portion, nearly at right angles to the preceding, which mounts vertically along the pelvic wall and the mesovarian margin as far as the superior pole, and a short *descending* portion which makes an acute angle with the latter, passing downward and inward, forming the so-called tubal loop, the infundibulum embracing the internal face and posterior border of the ovary (Fig. 4212). These portions are, however, by no means of fixed dimensions, as they depend largely upon the position of the uterus and upon the various influences that may displace the ovary and the folds of the broad ligament. The oviduct, with its attached peritoneum, often so covers the internal face of the ovary that that organ is not perceived when the pelvic cavity is opened.

Dimensions.—The following table shows the principal measurements of the oviduct:

Average length	12 to 14	cm.
Minimum length	6	"
Maximum length	20	"
Length of interstitial portion	1	"
Length of isthmus	3	"
Length of ampulla	8	"
Length of infundibulum	2	"
Length of ovarian fimbria	2.5 to 3	"
Length of other fimbriæ	1 to 1.5	"
Calibre of uterine orifice	.05 to .1	"
Calibre of interstitial portion	.05	"
Calibre of isthmus near uterus	.3	"
Calibre of ampulla, maximum	.8	"
Calibre of peritoneal orifice	.2 to .3	"
Thickness of walls, average	.2 to .3	"

At its uterine termination the tube so gradually expands into the cavity of the superior cornu that its exact point of termination is difficult to determine.

Attachments.—Continuous with the angle of the uterus at its inner extremity, the oviduct lies in the superior or free edge of the broad ligament, hereafter to be described, and is attached at its lateral end by one of the fimbria, longer than the others (ovarian fimbria, *fimbria ovarica*, Figs. 4202 and 4203), to the suspensory ligament of the ovary. The triangular fold of the broad ligament that encloses it is known as the *mesosalpinx* (Fig. 4202, *b*). At its extremities the duct shares the movements of the organs to which it is attached, while its intermediate portion may move independently, its freedom depending upon the length of the duct and the laxity of the mesosalpinx.

Interstitial Portion.—In nulliparæ the oviduct is clearly seen to be a contracted continuation of the superior cornu of the uterus, and the narrowest point is not at the uterine orifice, but a little beyond. In multiparæ, however, the orifice is the narrowest portion. While passing through the uterine wall the duct is slightly bent with downward concavity. A layer of connective tissue separates it from the uterine substance proper.

Isthmus.—This resembles the vas deferens in its cord-like, resistant character and cylindrical form. It lies in the para-uterine fossa of Waldeyer, the round ligament of the uterus being before and below, the ovarian ligament and tubo-ovarian artery behind.

Ampulla.—This portion, slightly flattened from before backward, has a thinner wall and softer consistence than the isthmus. It is slightly irregular in calibre, with flexuosities which are more marked in the young. Its loop runs in front of the ovarian vessels and its descending branch is close against the external iliac vein.

Infundibulum.—This funnel-like expansion (Fig. 4202, *c*) is cut into twelve to fifteen laciniate, fringe-like processes or fimbriæ, and is hence often called the *fimbriated extremity*. The French, carrying out the similarity of the duct to a trumpet, call it the *pavillon*, a name also applied to the flaring mouth or bell of a trumpet. The ancients compared its gnawed appearance to the premorse root of the *Scabiosa succisa*, popularly known as the "devil's bite," the legend being that the arch enemy, angered at the good done by the medicinal virtues of the root, attempted to destroy it by biting it off, but only succeeded in leaving a ragged edge showing the marks of his attack. It is from the resemblance of the infundibulum to this root, and not from any evil influence it was supposed to exert, that it was called the *morsus diaboli*. It has also been compared to the corolla of a flower with a double row of petals (Henle), to a crinoid or sea-lily (Nagle), and to a medusa head.

The single fimbriæ are lanceolate, ovate, or filiform, not infrequently with irregularly notched edges, so that there may arise fimbriæ of the second or third order. Sometimes they may be fenestrated or form a lattice-work. One of them, larger than the others, has already been referred to as the ovarian fimbria (Fig. 4202, *f*). Attached to a groove in the suspensory ligament, it does not usually quite reach the ovary, and from its termination there may extend, along the suspensory ligament, supplementary fringes (tubo-ovarian fimbriæ). The primary fimbriæ are usually plicated, the folds corresponding to those of the mucous membrane of the interior of

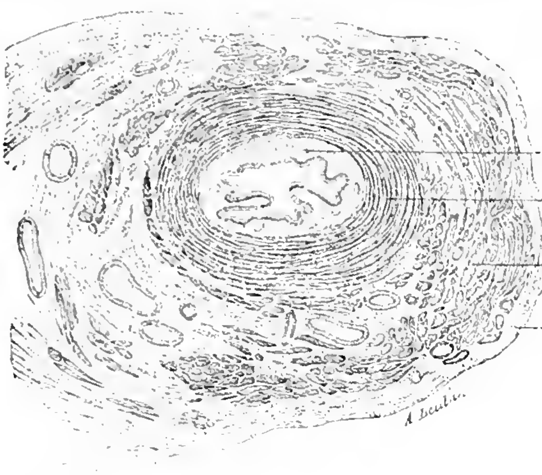

FIG. 4213.—Cross-Section of the Oviduct near the Uterine Orifice. (Orthmann.)

the tube. In consequence of this arrangement, the abdominal orifice of the tube is not usually visible, at least in nulliparæ. It can, however, always be displayed by parting the plications, and is large enough to admit a small probe.

It is by this orifice that the ova leave the abdominal cavity, and many attempts have been made to clearly explain how they come to enter it. It was formerly supposed that at the time of ovulation the infundibulum suffered a species of erection by vascular congestion, and that then it clasped itself firmly around the ovary and prevented the escape of the ovum into the peritoneal cavity. Injection of the vessels in the cadaver does not confirm this, and, as Henle says, it is difficult to see how the infundibulum can select the exact place upon the ovarian surface where a follicle is about to rupture, or how it can be depended upon to execute such an act in view of the pressure and movements of the intestines. Others have supposed that there must exist in the ducts, in the fimbriæ, or in the broad ligaments muscular fibres by which adaptation of the infundibulum to the surface of the ovary is effected. This, too, appears to be without foundation. Excitation of the muscular coat of the oviduct in living animals merely produces vermicular movements, the direction of the fibres of the muscular tissue of the broad ligament is such that they draw the ovaries together rather than bring the infundibulum to the ovary, and the existence in the fimbriæ of special fibres capable of clasping the ovary cannot be demonstrated.

Experiments upon animals have shown, however, that both ova and semen may pass from one side of the abdomen to the other, and that it does not necessarily follow that, because an ovum does not at once reach the infundibulum, it may not eventually do so. Its movement is doubtless directed by the ciliated epithelium that lines the interior of the infundibulum and the ovarian fimbria. Notwithstanding this there is unquestionably a great loss of ova owing to the lack of accurate adaptation between the mouth of the oviduct and the ovary.

Interior Configuration.—The interior of the oviduct is lined with mucous membrane continuous with that of the uterus, but destitute of the glands that are so prominent a feature of that organ. This membrane has a striking peculiarity in that it is arranged in numerous longitudinal folds that form an intricate series of narrow passages—the tubal labyrinth (Figs. 4213, 4214)—affording a free though retarded passage to fluids and minute bodies that pass from the abdominal cavity to the uterus. These folds appear in the interstitial portion as two or three small crests which are, in the isthmus, prolonged and multiplied as *principal* folds, which, however, disappear on distention of the tube, and attain their greatest development in the ampulla, where they no longer disappear on distention and vary greatly in size, some passing across the lumen of the tube to the opposite side and developing on their faces secondary and tertiary folds, so that a cross-section of them resembles the arbor vitæ of the cerebellum. These folds are continued, much reduced in size, upon the infundibulum.

The arrangement seems admirably adapted for retarding the movements of the ovum and the spermatozoa, which probably meet each other at this point. It indeed seems likely that the ampulla is a *receptaculum seminis*, and that it becomes, after repeated copulations, charged with spermatozoa, which may remain there in an active state for several days, so that when a matured ovum once enters, its fecundation is practically assured.

Investigations on animals show that the ovum is from three to eight days in passing through the oviduct. Hyrtl found a human ovum in the uterine end of the duct four days after menstruation. The period of eight days cannot be much exceeded in the human species, as the ovum attains in the second week a diameter of 3–6 mm., which is greater than that of the uterine orifice of the tube.

On the other hand, the progress upward of the spermatozoa is comparatively rapid. Having a flagellate movement of their own, they are able to travel without the assistance of the female organs. In guinea-pigs they have been known to reach the middle of the oviduct within fifteen minutes after copulation, and from what is known of their rapidity of progress in other situations, it

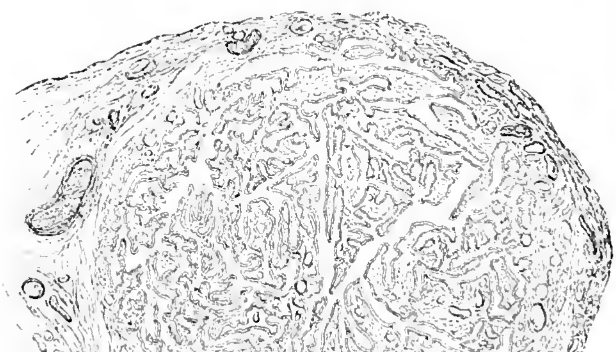

FIG. 4214.—Cross-Section of the Oviduct near the Abdominal Orifice. The folds of the mucous membrane are very numerous and complicated, forming the tubal labyrinth; the muscular coat is very thin but rich in vessels. (Orthmann.)

seems probable that in the human species they require about two hours for a similar migration.

Structure.—The oviduct is a muscular tube outwardly invested with a serous layer derived from the peritoneum, inwardly lined with a mucous membrane. The serous coating forms a complete investment, the vessels entering

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along its inferior border through the folds of the mesosalpinx. It is continuous internally with the serous investment of the uterus, and externally is continued over the external surface of the fimbriæ. A loose, subserous, connective tissue unites it to the muscular coat.

The muscular tunic is composed of smooth fibres arranged in two layers, an inner one of circular fibres and an outer one in which the fibres are arranged longitudinally. The circular layer is a continuation of the similar fibres of the uterus, is thicker at the uterine extremity, and at the infundibulum forms a sphincter-like ring. The longitudinal fibres are continuous with the transverse fibres of the uterus and are continued as a very thin sheet upon the infundibulum, one fascicle extending upon the fimbria ovarica, and constituting what is sometimes called the *musculus attrahens tubæ.*

The mucous membrane is composed of a layer of ciliated epithelium seated upon a submucous connective tissue containing some round cells resembling those of the uterus, and which are believed to assist in forming a decidua in the case of tubal pregnancy. It possesses no glands. The epithelium increases somewhat in thickness toward the abdominal orifice. The direction of the ciliary wave is toward the uterus, and experimental injections of minute bodies into the abdominal cavity show that it is an efficient cause of the progression of the ovum through the duct. The epithelium lines the interior of the infundibulum and becomes continuous at the edge of the fimbriæ with the peritoneum. Upon the ovarian fimbria or along the suspensory ligament it is continued as far as the ovary, becoming continuous there with the cubical epithelium of that organ.

Arteries.—From the anastomotic loop formed by the ovarian and uterine arteries three branches are given off for the supply of the oviduct. These are, respectively, the *external tubal*, derived from the ovarian, which passes in front of the fimbria ovarica and ascends along it, supplying it and sending a branch to each of the other fimbriæ, and ending by anastomosing with the middle or internal tubal; the *internal tubal*, derived from the uterine, supplying the interstitial portion and isthmus of the oviduct, and curving outward to form by anastomosis with the external tubal the infratubal arch; and the *middle tubal*, usually given off from the uterine a little farther out. It passes in front of the ovary and divides into two branches, which anastomose with the external and internal tubal, forming a second infratubal arch.

Veins.—These also form a vascular arcade with more frequent anastomoses. They discharge into the uterine and ovarian veins. One branch runs along the round ligament of the uterus and communicates with the epigastric vein.

Lymphatics.—These take origin from the mucous membrane, from a subperitoneal network, and discharge into two or three trunks which extend along the oviduct, unite with others coming from the uterus, and ascend along the suspensory ligament to the lumbar glands.

Nerves.—These are derived from the ovarian plexus and are closely connected with the uterine nerves. They unite under the peritoneum to form what is called by Jaques the *fundamental* plexus, from which finer fibres penetrate between the muscular layers, forming a second or intramuscular plexus which supplies the muscle fibres; from this again fibres are distributed to the epithelium.

THE UTERUS.—*Etymology.*—From the Latin *uterus*, the womb, probably connected with *uter*, a skin bottle or bag. The later Latin appellation, *matrix*, is also sometimes used. This originally meant a breeding animal. Greek *μήτρα*, *ὑστέρα* (the last, the uterus being the last organ that presents in the pelvis), whence come many modern derivatives, such as metralgia, metritis, metrorrhagia, hysteria, hysterectomy, etc. Another Greek appellation, used by Hippocrates, was *δελφύς*, whence are derived several terms used in zoological classification, such as Monodelphia, Didelphia, Ornithodelphia. French, *uterus, matrice;* Italian, *utero, genitura;* German, *Gebärmutter, Mutter, Fruchthälter.* The Talmudists called the uterus "the sleeping chamber," of which the cervix was "the porch."

History.—It was probably known to the ancients from an early period, though it would seem that at first no very clear distinction was made between it and the vagina. The Greek physicians supposed it to be movable, ascending upward toward the diaphragm when excited and thus producing a variety of disorders. Plato calls it a wild beast which never follows reason, and which, through non satisfaction of its desires, roams about in the body and also excites inordinate lust. That this view existed also among the Hebrews may perhaps be inferred from Prov. xxx. 15, 16. Soranus first showed that its attachments were such that this movement was impossible, yet the error did not disappear from medical science

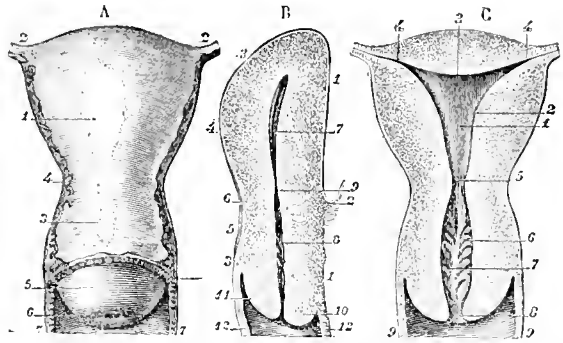

FIG. 4215.—Virgin Uterus of Twenty-two Years. (Sappey.) *A. Anterior face*—1, Body; 2, 2, superior angles; 3, cervix; 4, isthmus; 5, intravaginal portion of cervix; 6, its external orifice; 7, vagina. *B. Median section*—1, 1, Profile of anterior face; 2, vesico-uterine cul-de-sac of peritoneum dividing this face into two nearly equal parts; 3, 3, profile of posterior face; 4, body; 5, cervix; 6, isthmus; 7, cavity of body; 8, cervical canal; 9, internal orifice; 10, anterior lip of the os uteri; 11, posterior lip; 12, 12, vagina. *C. Frontal section*—1, Cavity of body; 2, its left lateral border; 3, its superior border; 4, 4, its lateral angles; 5, its inferior angle forming the internal orifice; 6, cervical canal; 7, arbor vitæ of its posterior wall; 8, its lower extremity; 9, vagina.

until the practice of dissection became general. Galen, considering that the female should possess all the organs of the male, supposed it to be the homologue of the penis, withdrawn from sight in accordance with the colder nature of the sex. The muscular character of the uterus was first demonstrated by Arantius (1530–89).

Definition.—A single, hollow, median, and symmetrical structure, peculiar to mammals, situated in the cavity of the pelvis between the rectum and the urinary bladder. It is formed by the thickened confluence of the Müllerian ducts, and serves as the organ of gestation and parturition. It receives the impregnated ovum, maintains it during embryonic and fetal development, and expels the fœtus at maturity.

The function of child-bearing, which appears to be the most important one of the female economy, has a remarkable effect upon the organ that contains and nourishes the developing embryo, affecting profoundly its size and its anatomical organization. It is also subject to a series of rhythmic changes, habits impressed upon it as a periodical preparation of gestation and known as menstruation. This function of gestation, and in a minor degree that of menstruation, entail anatomical variations greater than are found in any other organ of the body.

Form.—The nulliparous uterus (Fig. 4215) has the shape of an inverted flask, flattened and slightly bent, from behind forward. The older anatomists compared it to a *cucurbitula* or cupping glass, so called because of resemblance in shape to a small gourd or cucumber. Indeed, the shape of the uterus is quite accurately represented by that of a short cucumber, slightly larger at one end than at the other, and bent near the smaller end.

Divisions.—Its expanded upper portion is the *body* or *corpus*, its narrower, lower part the *neck* or *cervix*, while the slight constriction between these is the *isthmus*. From either side of the organ, at its upper part, are given off the so-called *annexa:* the oviduct, the round and ovarian ligaments, which latter connect with the ovaries (see Fig. 4202). The part of the uterine body above the plane passing horizontally through the insertions of the annexa is termed the *fundus*, and the part below that plane is sometimes distinguished as the body proper (*corpus proprium*).

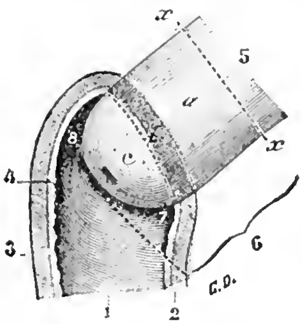

FIG. 4216.—Junction of the Uterus and the Vagina, showing the Segments of the Cervix. (Testut.) 1, Vagina, with 2, its anterior wall; 3, its posterior wall; 4, its mucous membrane; 5, body of the uterus; 6, cervix of uterus, with *a*, its extravaginal portion; *b*, its vaginal portion; *c*, its intravaginal portion of os uteri; 7, anterior cul-de-sac; 8, posterior cul-de-sac; *x*, *x*, separates the body and the neck of the uterus.

The lower part of the neck is embraced by the vagina, like a sleeve, the line of adherence running obliquely and extending farther down in front than behind (Fig. 4216). The cervix is thus divided into a *supravaginal* and a *vaginal* portion. To the palpating finger the vaginal portion feels like a hard, smooth projection with a central depression or slit, the *orificium externum*, or external orifice of the cavity of the uterus. Its peculiar shape and consistence led Lieutaud to call it the *museau de tanche*, the tench's muzzle, or, in Latin, *os tincæ*, which has become by usage *os uteri* or *os uteri externum*, the mouth of the uterus. It will be perceived that this term applies to the entire vaginal portion of the cervix rather than to the orifice itself. This orifice is rounded in nulliparæ, and in those who have borne children is a short, transverse slit, often with somewhat irregular edges, the *lips* or *labia* (Fig. 4217). The anterior lip is the thicker and the lower. Both lips are in contact with the walls of the undistended vagina (Fig. 4218).

From the sides of the uterus its peritoneal investment is continued laterally in the form of the broad ligament, between whose layers are the vessels and nerves for the supply of the organ, which thus penetrate at what may be called its lateral edges.

The body comprises about two-thirds of the entire organ. Its upper end, the fundus, is free and covered by closely adherent peritoneum. It is smooth and glistening, and the superincumbent coils of intestine glide over it with a minimum of friction. In nulliparæ it has but little convexity, but after repeated pregnancies it becomes markedly rounded both antero-posteriorly and

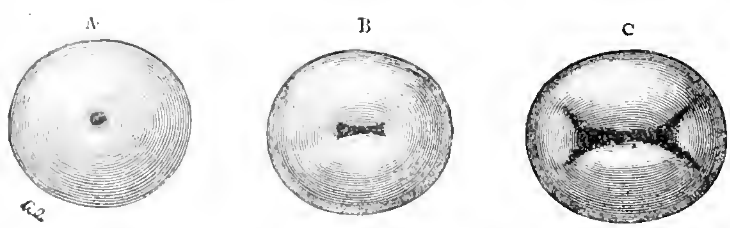

FIG. 4217. The Os Uteri and its Orifice. (Testut.) *A*, In the virgin; *B*, in a primipara; *C*, in a multipara.

from side to side (Fig. 4219). By its continuity on either side with the oviducts are formed the *angles* of the uterus. In most lower animals these angles are much more marked owing to a less complete fusion of the Müllerian ducts. In the human species also a bicornuate uterus is occasionally seen. The posterior surface of the body, rounded and smooth, can be seen from above when the pelvic cavity is opened and the intestines are removed; the anterior surface, however, is not visible, it being in contact with the bladder, which imparts to it a slight flattening.

The cervix is of a nearly cylindrical form, slightly enlarged at the middle in nulliparæ, much less or not at all in those who have had repeated pregnancies.

The vaginal (intravaginal) portion of the cervix or os uteri is a rounded projection, having under physiological conditions a rosy color and a firm consistence. Its base is circular in virgins, slightly elliptical in those who have borne children (Fig. 4217). The external orifice varies much in shape and in the appearance of its lips. Rounded in the virgin, it becomes a slit in the primipara, and after repeated pregnancies is gaping, irregular, and puckered, the lips often presenting scars or fissures. In these cases the cervix undergoes considerable absorption.

Cavity. — The walls of the uterus are from 10 to 15 mm. thick in nulliparæ (Fig. 4215, *B*, *C*), somewhat greater in multiparæ (Fig. 4219, *B*), diminished a little at the neck and at the orifices of the oviducts. This thickness nearly obliterates the lumen, but there is a virtual cavity divisible into two parts: an upper, triangular, transversely placed cleft, the *cavum uteri*, belonging to the body of the uterus; and a lower, fusiform portion, the *cervical canal* (*canalis cervicis*) belonging to the neck. A contracted pass, the *internal orifice* (*os uteri internum*), unites the two.

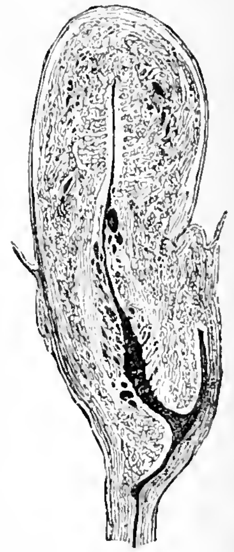

FIG. 4218.—Section through the Middle of the Uterus and Upper Part of Vagina. (Henle.)

The shape of the cavum uteri is triangular, or, more accurately, it is formed by three slender triangles united by their bases; the two upper ones, the cornua, leading to the orifices of the oviducts, the third leading downward to the internal orifice. In multiparæ this shape is somewhat modified, the cornua enlarging at the expense of the lower triangle. Traces of the primitive union of the Müllerian ducts can usually be found in young persons, either as a marked raphe or as a triangular depression on the anterior and posterior walls. Sometimes the entire cavity is divided and the uterus thus becomes bilocular like that of rodents. Among the older, fanciful views with reference to generation, was one that male children were developed on the right side of the uterus, females on the left, the male seeking the warmth of the liver (Galen). It has been suggested that the rare cases of superfœtation that have been noted can be explained by an anomalous, bilocular condition of the uterus.

The internal orifice, often called the internal os, is really a passage 4 or 5 mm. in length, corresponding to the isthmus of the uterus. It frequently is smaller than the external orifice, and offers more resistance to the probe. The columns of the next section are prolonged into it.

The cervical canal expands somewhat on passing from either end toward the middle. The mucous membrane of its anterior and posterior surfaces presents series of remarkable folds, constituting the *arbor vitæ uterina* of the older anatomists (Fig. 4220). Running axially along each wall is a slightly elevated ridge or *column*, from which arises a series of

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penniform folds, the *plicæ palmatæ*, which may divide and subdivide, the whole presenting an appearance somewhat like the ribs of a leaf. The folds are so arranged that those on opposite sides of the neck fit into each other.

The capacity of the cavity of the unimpregnated nulliparous uterus is but slight, the walls being for the most part everywhere in contact or separated by a thin layer of mucus. It is estimated at from 2 to 5 c.c., or fl. ℥ ss. to fl. ℥ 1⅛. In multiparæ it increases to from 5 to 8 c.c., or fl. ℥ 1⅛ to 2⅛ (Guyon).

Dimensions.—The following table represents averages from measurements made by Rieffel, Waldeyer, and others.

	Nulliparæ. Millimetres.	Multiparæ. Millimetres.
Total length	60	70
Length of body	35	45
Length of neck	25	25
Length of vaginal portion of neck	10	10
Breadth between insertions of oviducts	40	45
Breadth at isthmus	20	30
Breadth at middle of cervix	25	30
Thickness (antero-posterior diameter) of body	20	30
Thickness (antero-posterior diameter) of neck	20	25
Total length of cavity	55	60–65
Length of cavity of body	25	31–40
Length of cavity of isthmus	5	3–5
Length of cavity of neck	25	20–24
Breadth of cavity between oviducts	24	30–35
Breadth of cavity at isthmus	4	
Breadth of cavity at middle of cervix	8	9
Depth (antero-posterior diameter) of cavity	[illegible]	12
Thickness of walls of body	10–15	20
Thickness of walls of neck	8–10	15

	Millimetres.
Total length of uterus of child	25–35
Total length of senile and atrophied uterus	30
Pregnant uterus in the last month:	
Greatest length	360
Breadth of body	250
Thickness of body	240
Length of cervix	45–50

As a general, rough estimation it may be said that the adult, nulliparous uterus is three inches long by two inches wide and one inch thick.

Weight.—According to Rieffel the weight of the nulliparous uterus averages 40 gm., ranging from 32 to 50.

A B

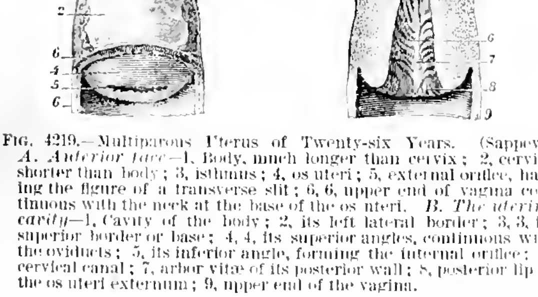

FIG. 4219.—Multiparous Uterus of Twenty-six Years. (Sappey.) *A. Anterior face*—1, Body, much longer than cervix; 2, cervix, shorter than body; 3, isthmus; 4, os uteri; 5, external orifice, having the figure of a transverse slit; 6, 6, upper end of vagina continuous with the neck at the base of the os uteri. *B. The uterine cavity*—1, Cavity of the body; 2, its left lateral border; 3, 3, its superior border or base; 4, 4, its superior angles, continuous with the oviducts; 5, its inferior angle, forming the internal orifice; 6, cervical canal; 7, arbor vitæ of its posterior wall; 8, posterior lip of the os uteri externum; 9, upper end of the vagina.

The weight of the multiparous uterus is considerably greater, averaging 55 gm. and varying from 48 to 70. Waldeyer reports the weight of the uterus during the last month of pregnancy as from 900 to 1,200 gm. Roughly speaking, it may be said that the weight of the uterus varies from one ounce avoidupois in the unimpregnated female to two pounds in the parturient one. The specific gravity of the uterine substance is 1.052.

Consistence.—During life the uterus is soft, depressible, and flexible, especially at the isthmus. This is more marked in nulliparæ. After death, from cadaveric rigidity and the emptying of the vessels, it becomes more firm and unyielding.

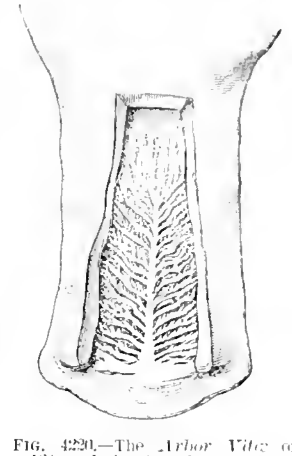

FIG. 4220.—The *Arbor Vitæ* or *Plicæ Palmatæ* of the Wall of the Cervical Canal shown by Cutting a Section from the Wall. (Nagel.)

Position.—The uterus, not being rigidly bound, is subject to a wide range of variations in position, many of which are compatible with health. Thus it may, as a whole, be turned forward, backward, or sideways (anteversion, retroversion, lateroversion); it may, as a whole, be displaced in the horizontal plane (anteposition, retroposition, lateroposition); it may be raised or lowered (elevation, depression); it may be bent upon itself (anteflexion, retroflexion, lateroflexion), the bending usually occurring at the isthmus; or it may be twisted upon its own axis (torsion). Several of these displacements are often combined. It is not surprising, therefore, that there should have been much discussion as to the normal position of the organ. Nagel, Waldeyer, Rieffel, and most recent writers hold that the *typical* position of the uterus, as derived from a study of its embryonic development and general tendencies, is as follows:

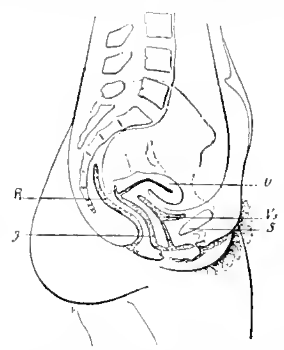

FIG. 4221.—Normal Position of the Uterus in the Virgin. (Schultze.) *R*, Rectum; *U*, uterus; *Vg*, vagina; *Vs*, bladder; *S*, symphysis.

In the healthy and normal adult female, standing in the erect position, with rectum and bladder approximately empty, the uterus is anteverted and anteflexed (Figs. 4204, 4221, 4222, 4223). The axis of the cervical canal corresponds nearly to the axis of the pelvis, the external orifice being at the height of the top of the symphysis pubis. The axis of the body is nearly horizontal, the fundus does not reach the plane of the superior strait, and is some distance behind the symphysis.

This typical position may be altered by a variety of causes and thus a number of secondary positions be produced, all of which may be normal in the sense that they in no way interfere with the functions of the uterus nor with those of the surrounding organs. Thus it may be pushed backward by a distention of the bladder (Fig. 4223), or forward by a distention of the rectum, or considerably elevated by a distention of both at the same time (Fig. 4221). The posture of the subject, acting upon

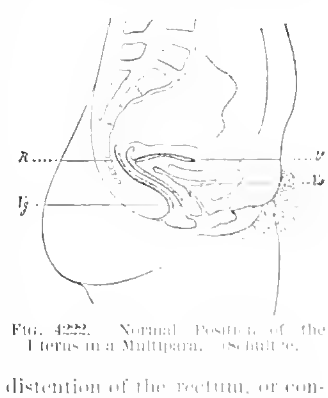

FIG. 4222.—Normal Position of the Uterus in a Multipara. (Schultze.)

the abdominal contents as well as upon the uterus, has some effect. Thus the knee-elbow position of gynæcologists throws the viscera toward the diaphragm and causes the fundus of the uterus to be directed more toward the umbilicus. The expulsive action of the muscles of the abdominal wall, by pushing downward the intestines, affects the anteflexion and anteversion, and at the same time depresses the organ. Even the action of respiration has a slight effect. The state of tonicity of the pelvic floor and the vaginal walls and the repletion of the vessels have also considerable influence.

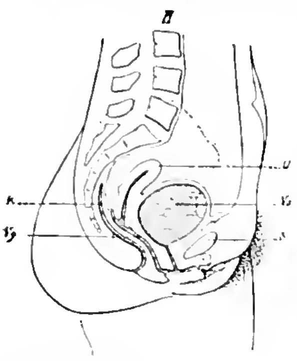

FIG. 4223.—Situation of the Uterus during Repletion of the Bladder. (Schultze.)

Fixation. — The position of the uterus is maintained by the following connections: (1) with the vagina and bladder; (2) with the pelvic fascia by means of the parametrium and its vessels; (3) with the pelvic peritoneum by the broad ligament; (4) by special bands known as the round and utero-sacral ligaments.

The attachment of the vagina (Fig. 4216) is along a zone from 6 to 8 mm. in breadth, and is very intimate, the muscular and connective tissue and the mucous membrane of the two organs being continuous, as might be expected, considering that both were originally developed from the same tubular structure.

The neck of the uterus is attached to the fundus of the bladder by loose connective tissue containing numerous veins. The vesico-uterine fold of the peritoneum closes the connection above. This usually descends only as far as the isthmus of the uterus (Fig. 4215, *B*, 2), but in multiparæ is occasionally seen to reach the vagina, in which case the uterus has no immediate union with the bladder.

The pelvic fascia, or sheet of connective tissue that lines the pelvic cavity, has necessarily important relations with the uterus, since that organ is itself a portion of the pelvic floor. This fascia varies greatly in its consistency, in some situations being loose and offering but little resistance; in others being condensed into bands and sheets that fix and restrain the organs with which it is united. It is particularly associated with the great vascular trunks, and often contains in its meshes masses of fat. Virchow proposed the name *parametrium* for the extensions of this fascia that invest and are immediately adjacent to the uterus. They reach the viscus by the base of the broad ligament, along the branches of the uterine artery, and cover its lateral edges and the supra-vaginal portion of the cervix, extending upward a varying distance under the peritoneal covering and gradually disappearing as they reach the upper part of the body.

Behind, a utero-sacral sheet can be traced along the sides of the rectum to the sacrum and the coccyx; in front a utero-pubic sheet passes to the bladder and thence to the pubis. Some thickened bands of this have been called the vesico-uterine ligaments. Laterally, through the base of the broad ligament, along the vessels and nerves that enter here and themselves constitute an elastic band, can be traced sustaining bands that have been called by Kocks the cardinal ligaments. It will be seen that the neck of the uterus is thus suspended hammock-wise in a network of connective-tissue cordage.

The broad ligaments (*ligamenta lata uteri*, Figs. 4202, 4226, 4227) are formed by reflections of the pelvic peritoneum upon the uterus and the annexa. Together they constitute a common mesentery for these organs. When spread out each has the appearance and shape of a membranous wing, which led De Graaf to style it the *ala vespertilionis*, or bat's wing; and the French anatomists still use the term *ailerons*, or little wings, for its subordinate divisions (Fig. 4202, *a*, *b*, *c*). The external insertion or hilum—that is to say, the line where the ligament is reflected upon the lateral wall of the pelvis—is about 2 cm. behind the transverse diameter of the superior strait, a little in front of the internal iliac artery. It passes up over the psoas and the external iliac vessels, surrounding the suspensory ligament of the ovary and the ovarian vessels and nerves, where it is lost. Waldeyer has given to this upwardly extending process the name of *mesodesma suspensorium*. Its inferior or basal insertion is broad and situated on the pelvic floor nearly in the biischiatic line (Fig. 4228). Its upper edge contains the oviduct, and, beyond the ovary, is continued upon the suspensory ligament. From its anterior surface is raised a small fold containing the round ligament (*mesodesma teres* of Waldeyer), while from its posterior surface the ovarian ligament and the ovary itself are suspended by the *mesovarium*. The portion above this fold is thin, contains the remains of the Wolffian body and its ducts with but little connective tissue, and is known as the *mesosalpinx*; that below is thicker, and,

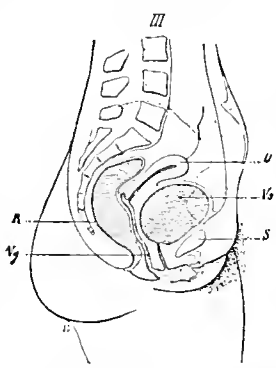

FIG. 4224.—Situation of the Uterus during Repletion of the Bladder and Rectum. (Schultze.)

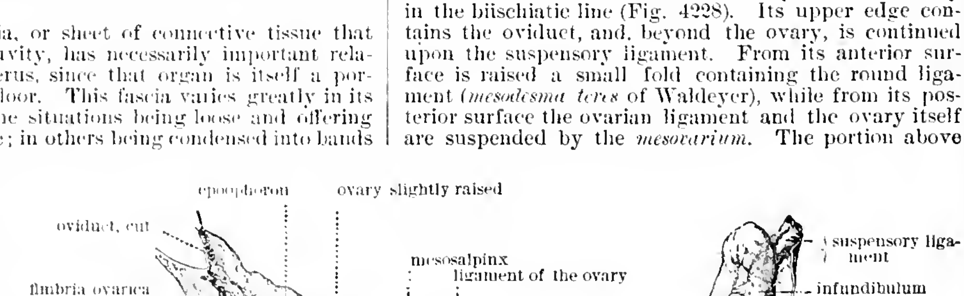

FIG. 4225. The Uterus, Oviducts, and Ovaries, seen from Behind. (Spalteholz.)

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since it affords the special investment of the uterus, is called the *mesometrium.* There is here found a considerable amount of loose connective tissue (parametrium),

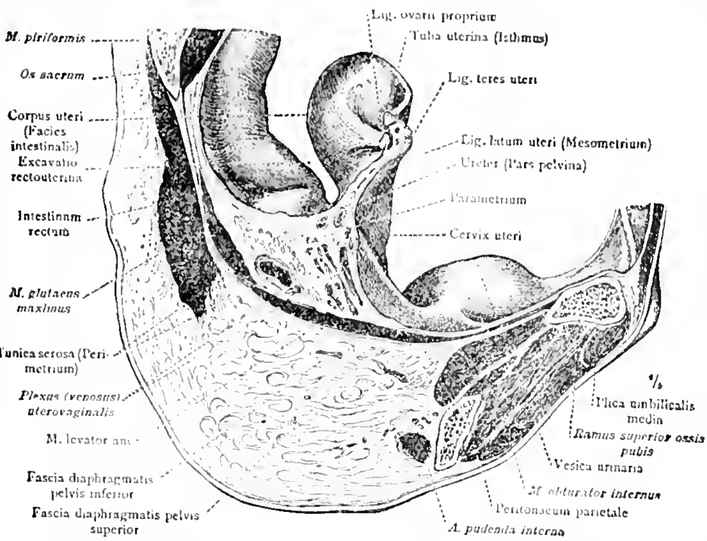

FIG. 4226.—Antero-posterior Section through the Female Pelvis 4 cm. to the Right of the Median Line. (Toldt.) The section cuts the broad ligament and shows the continuity of its two peritoneal layers with the parietal peritoneum of the pelvic floor. It also shows the parametrium, the pelvic diaphragm, and, under it, the fatty tissue of the ischio-rectal fossa. The uterus is shown more erect than normal. Made from a frozen preparation.

the uterine vessels and nerves and the ureter, besides a thin layer of smooth muscular fibres continuous with the muscular tissue of the uterus.

The anteflexed position of the uterus bends forward the two ligaments so that they form a shelf that supports the intestines (Fig. 4225), and which, while almost vertical at the sides, is nearly horizontal in the middle. It divides the pelvis into two cavities or pockets, a recto-uterine behind and a vesico-uterine in front.

The portion of the mesometrium that immediately invests the uterus is called the *perimetrium.* Behind, it is continuous with the peritoneal covering of the rectum; in front, with that of the bladder. In the latter situation it reaches the uterus about at the isthmus, forming the *utero-vesical fold,* and is then reflected over the anterior surface of the body, the fundus, the posterior surface of the body, and the supravaginal surface of the neck, passing thence to the upper part of the vagina and then being reflected upon the rectum, forming the *recto-vaginal fold* (fold of Douglas, Fig. 4226). This fold is interrupted laterally by two bundles of smooth muscular fibres which pass from the uterus along the sides of the rectum to the sacrum. These, the *utero-sacral ligaments,* do not reach as low as the bottom of the fold, and there is consequently formed between them a well-marked pocket, lying between the uterus in front and the rectum behind, which is known as the *recto-vaginal* pouch or pouch of Douglas (*excavatio recto-uterina*), from James Douglas, professor of anatomy and surgery in London (b. 1642, d. 1675). This pouch is the lowest portion of the abdominal cavity, and any effusions are likely to collect there. It can easily be palpated through the vagina.

It has already been mentioned that the ovarian and round ligaments represent portions of the genito-inguinal ligament or gubernaculum of the genital gland, which, instead of remaining free throughout its course, has become attached to the uterus—that is to say, to the enlarged Müllerian duct (Fig. 4197). Accordingly the ovarian ligament is inserted upon the uterus behind the superior cornu, while the round ligament arises from in front of the same, a little below the insertion of the oviduct. The round ligament then passes down between the layers of the mesometrium and the parametrium, above the ureter, the uterine, the vesico vaginal, the obturator, and the external iliac vessels to the internal abdominal ring, lifting up the peritoneum as it passes to form a slight investment (*mesodesma teres,* Waldeyer). It then passes through the inguinal canal, sometimes surrounded by a peritoneal diverticulum, called the canal of Nuck (Anton Nuck, professor at Leyden, 1650–92) and having about the same relations as the spermatic cord of the male. Finally its fibres separate to be inserted in the subcutaneous tissue of the labium majus. The round ligaments deserve that appellation only in the middle of their course; in their upper part they are flattened, below expanded in a fan-like manner. They are 12–15 cm. in length, about 3–5 cm. broad, and are composed mostly of muscular tissue, having, therefore, no great tensile strength. During pregnancy they increase to four times their normal size.

The utero-sacral ligaments have already been mentioned. They are fibro-muscular bundles that pass, from just below the isthmus of the uterus, backward along the sides of the rectum to the sacrum. Occasionally secondary *utero-lumbar* bands are seen that are inserted on the last lumbar vertebra.

Relations.—The antero-inferior surface of the body is often called the vesical surface because of its contact with the bladder. It appears normally to remain in contact with that organ, lying upon it as upon a water-bed and adapting itself to

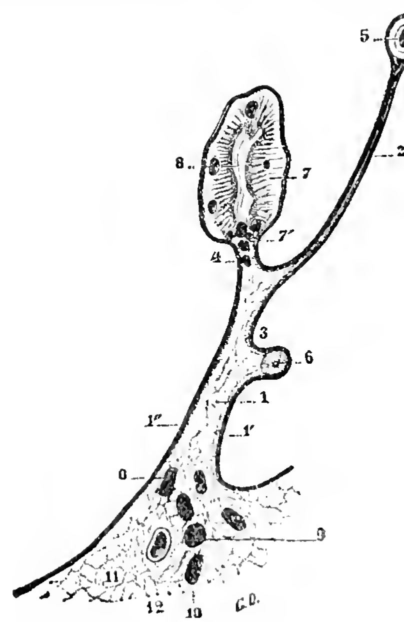

FIG. 4227.—Sagittal Section of the Broad Ligament (right side, inner surface of section.) (Testut.) 1, Broad ligament, with 1′, its anterior layer; 1″, its posterior layer; 2, mesosalpinx; 3, mesodesma teres; 4, mesovarium; 5, oviduct; 6, round ligament; 7, ovary, with 7′, its hilum and vessels; 8, ovisacs; 9, uterine artery; 10, uterine veins; 11, areolar tissue of pelvis; 12, ureter.

its states of repletion and depletion. Coils of intestines rarely insinuate themselves between these organs. The supero-posterior surface is called the intestinal surface because it is covered with coils of the small intestine or of the pelvic colon. These never descend, however, into the pouch of Douglas.

The principal relations of the neck of the uterus are with the ureter and the uterine artery. The ureter, passing down obliquely through the base of the broad ligament, crosses the external border of the neck a little below its internal orifice, passes along the cervical attachment of the vagina for about 1 cm., and reaches the anterior wall of the vagina at about the level of the external orifice of the cervix. It is here surrounded by loose connective tissue

FIG. 4228.—Scheme showing the Relations of the Uterus to the Skeleton. (Rieffel.) *x*, *y*, Axis of pelvic cavity; *a*, *b*, plane of superior strait; *c*, *d*, line from superior fourth of symphysis to sacrococcygeal articulation; *e*, *f*, horizontal through union of fourth and fifth sacral vertebræ; *M*, vertical through fundus; *N*, vertical through internal orifice; *P*, vertical through external orifice.

and by veins. In this course the ureter may lie immediately against the cervix and is rarely more than 2 cm. from it. The uterine artery crosses the ureter about at the level of the vaginal portion of the cervix and at an average distance of 2 cm. from its border.

The relations of the uterus to the skeletal framework have already been mentioned. From Fig. 4228 it will be seen that the external surface of the cervix is situated near the point where a line drawn from the upper fourth of the symphysis pubis to the sacrococcygeal articulation intersects the pelvic cavity. It is really slightly behind this point and therefore a little nearer the posterior wall of the true pelvis. According to Waldeyer it is in the frontal plane passing through the two spines of the ischium. In the figure it is shown slightly forward of this plane. The fundus is about 20 to 25 mm. behind the symphysis pubis. The lowest point of the uterus—that is to say, the anterior lip of the os—is on a level with the superior third of the symphysis and the last coccygeal vertebra. The highest part of the uterus in its typical position is not the fundus but the posterior surface of the body. It corresponds to a horizontal plane carried through the fourth sacral vertebra (Waldeyer) or a little below (Rieffel). A vertical through the internal orifice of the cervix passes a little behind the middle of the perineum. Another through the external orifice passes through the posterior fourth of the perineum. According to Waldeyer, a vertical passing through the anterior part of the fundus reaches the middle of the urethro-vaginal septum. In the figure it is thrown a little forward of that. As the uterus is subject to considerable changes of position, these data can only be approximate.

Structure.—The walls of the uterus are formed of a serous coating derived from the peritoneum—the *perimetrium*; a subserous layer of loose connective tissue—the *parametrium*; a thick mass of unstriped muscular fibres—the *myometrium*; and the mucous membrane or *endometrium* that lines the interior. These distinctions are of especial value in studying the pathological conditions of the organ.

The peritoneal investment has already been considered. Its attachments to the subjacent layer, or parametrium, are of considerable importance. Where the latter tissue is abundant, as upon the posterior portion of the cervix, the peritoneum can be readily lifted into folds or stripped off by the finger or the handle of the scalpel. Where entirely wanting, as on the fundus and the greater portion of the body, the peritoneum cannot be readily removed from the subjacent muscular layer. Between these areas there is an intermediate zone both on the anterior and on the posterior surfaces of the uterus, in which the parametrium is scanty, but still in sufficient quantity to permit one to dissect off the serous layer. These zones are crescentic in form, the points of the crescent being at the insertion of the round ligament in front and the ovarian ligament behind. The posterior crescent extends rather farther downward than does the anterior one. The application of these facts to operative surgery is obvious.

The *myometrium* or muscular tissue of the uterus constitutes almost its entire mass. Indeed it may be said that the whole organ is one dense, closely knit muscle, composed of fibres interwoven with each other in every direction, interspersed with bundles of white fibrous and yellow elastic connective tissue. The elastic fibres are especially numerous near the external orifice, and are believed to be of advantage in the expansion of the os that occurs during labor.

While it is not possible to make an accurate separation of the muscular tissue into sheets distinguished by the direction of the fibres, as is done in other hollow viscera, it is convenient and customary to speak of three layers. Of these the middle one is the most important, as it is distinguished by the presence of large venous trunks, the uterine sinuses, which have given it the name of the *vascular layer*. The muscle bundles surround the vessels in every direction, so that when they contract the blood is practically squeezed out, thus affording an important means of stopping hemorrhage after labor. This arrangement is particularly noticeable in the fundus, the usual seat of the placenta, and is not found upon the cervix.

The external layer is also composed of fibres having every direction; it is not, however, so rich in vessels. It is extended outward beyond the uterus proper upon the attachments of the organ: the broad, round, ovarian, and utero-sacral ligaments, the oviducts, the vagina, the bladder, and the rectum. The internal layer is thin and formed of a network of longitudinal, oblique, and circular fibres, the latter forming sphincter-like rings around the entrance of the oviducts. At the internal orifice of the cervix they form an annular bundle sometimes called the cervical sphincter.

The *endometrium*, or mucous lining, has, in the healthy uterus, a grayish-pink appearance, is soft, and easily torn. At the oviducts and vagina it is continuous with the mucous membrane lining those organs. It is composed throughout of a ciliated epithelium which is well developed only during the period of sexual activity, the direction of the ciliary wave being toward the external orifice. The epithelium is seated upon a membrana propria, but without any submucosa, a matter which should be remembered in the curetting of the uterus, as the instrument readily passes through into the muscular layers and may produce extensive lacerations and even perforation.

Some differences occur between the lining of the body and that of the cervix. In the body the epithelium is cylindrical, its nuclei being placed at about the middle of the cell; the protoplasm is easily stainable. The membrana propria is a network of connective-tissue fibres with stellate cells, and in its meshes are found cells having the character of leucocytes, so that the tissue appears to have a lymphoid character. On the surface of the membrane are seen, spaced at distances of about 0.1–0.2 mm., the openings of tubular glands, resembling in form the glands of Lieberkühn of the small intestine. These are

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usually simple but sometimes branched. They are lined with ciliated epithelium, the direction of the ciliary wave being from the fundus toward the mouth of the gland. Their secretion is not, in a healthy state, very abundant, as the surface is merely moistened with mucus which has an alkaline reaction.

In the cervix the epithelial cells are longer, thinner, and narrowed at the base; their nuclei are either in several rows or situated nearer the base, and the protoplasm is not readily stained. The glands here are more utricular in character and incline to be branched. They secrete an extremely viscid mucus, difficult to remove, which fills up the cervical canal, especially during pregnancy and before menstruation is established. There are not infrequently found here small retention cysts caused by the closure of the blind ends of these glands. These are the so-called ovules of Naboth, being described by Martin Naboth of Leipsic (1675–1721), who supposed them to be veritable ova.

Toward the cornua of the body the epithelium becomes less elongated and gradually merges with that of the oviducts. There is also a gradual transition at the internal os, between the epithelium of the body and that of the cervix. At the external orifice the ciliated epithelium disappears gradually, giving place to the many-layered epithelium of the vagina. The line of demarcation is, in the virgin, at the external orifice, but after repeated pregnancies it is found higher up within the cervix.

Arteries.—The uterine artery is the principal one that supplies the organ, but blood also reaches it by the ovarian artery and the artery of the round ligament.

The uterine artery arises from the anterior trunk of the internal iliac, often in common with the superior vesical artery. It passes down along the lateral wall of the pelvis nearly to the level of the spine of the ischium, then curves forward, enters the base of the broad ligament, and proceeds almost horizontally toward the supravaginal portion of the cervix. It then ascends along the lateral border of the uterus as far as the fundus, where it curves back and enters the mesosalpinx, and divides into its terminal branches. In its course it lies alongside the ureter which is on its inner side, separating it from the peritoneum. In order to reach the uterus it must cross this conduit, which it does about 2 cm. from the lateral edge of the cervix, a little below the isthmus. Its pulsation can sometimes be felt during vaginal examination. Its course along the sides of the uterus is tortuous, especially in multiparæ. It gives off branches to the broad ligament and to the ureter, a cervico-vaginal branch of considerable size that descends from the upper part of the vagina, numerous branches for the cervix and body of the uterus, and finally divides into two branches, one for the fundus and one for the oviduct—the internal tubal. The free anastomosis with the ovarian artery has already been mentioned. This is so free during pregnancy that some authors have considered that the ovarian vessel gives the principal supply to the uterus.

The artery of the round ligament is analogous to the cremasteric artery of the male. It is derived from the epigastric artery and sends a small branch upward along the ligament to the uterus.

Veins.—The veins of the uterus are extremely numerous. They have very thin walls, so that on section they stand open and appear not unlike the sinuses of the dura mater. From the vascular layer of the uterine wall they pass out as trunks of considerable size, uniting along the edge of the organ into a rich network—the utero-vaginal plexus—which extends along the entire length of the uterus and the vagina, surrounded by connective tissue and smooth muscular fibres. This discharges at the height of the external orifice into the uterine veins, which pass outward, following the general course of the artery.

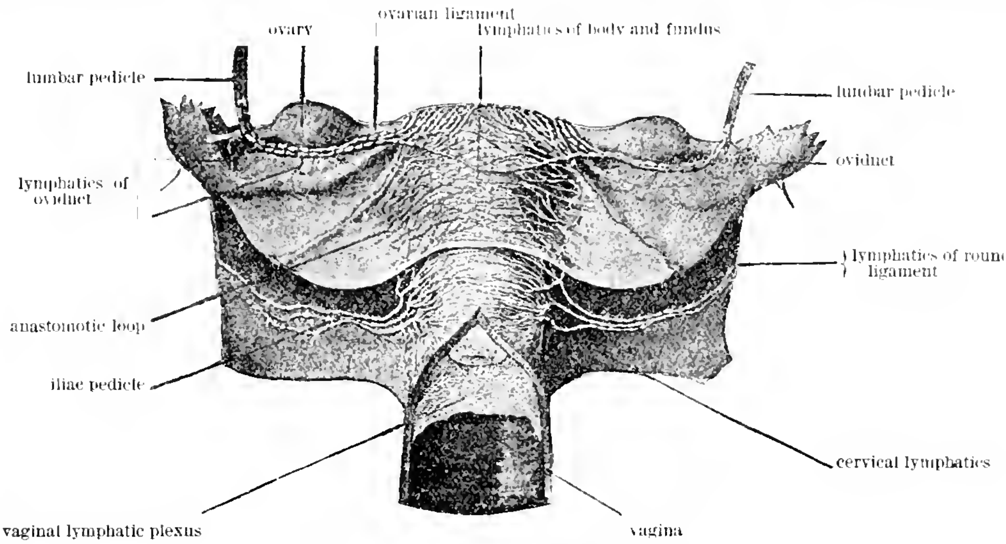

FIG. 4229.—Lymphatic Vessels of the Uterus. (Poirier.)

Lymphatics.—The lymphatics of the uterus (Fig. 4229) arise from three plexuses: one submucous, another muscular, and a third subserous. The trunks from these all unite in the subperitoneal tissue to form a fourth plexus, from which are given off efferent trunks that reach the lumbar glands.

Nerves.—These are derived from the hypogastric and ovarian plexuses of the sympathetic and from the third and fourth sacral nerves of the cerebro-spinal system. The fibres are mostly of the non-medullated variety, though a considerable number of medullated fibres appear, most of them fine but some of considerable size. They unite near the vaginal junction to form the utero-vaginal plexus, which contains a plexiform ganglion, the cervical ganglion, or ganglion of Lee (R. Lee, 1842). Other ganglia are said to occur near the uterine attachment of the ovarian ligament. Rein found, in rabbits and guinea-pigs, numerous small ganglia about the cervix, and was led to believe that no nerves reached the organ without passing through a ganglion. This has not, as yet, been shown in the human species. As to the endings of the nerves, Gawronsky and Kalischer saw rounded and plate-like endings in the epithelium and the muscular tissue, and Herlizka describes medullated fibres that end with free dendrites in the uterine wall. These would appear to be sensitive, cerebro spinal nerves, required for reflex action.

THE VAGINA.—*Etymology.*—From the Latin *vagina*, a sheath or covering, particularly the scabbard of a sword. It was only occasionally and figuratively used to indicate the sexual passage. The older anatomists did not use it in this sense, but designated the organ as the *collum uteri*. Its modern use was established by De Graaf. Greek, *κόλπος*, a sinus, the womb; whence colpitis, colpocele, colporrhagia, etc.; also *ἔλυτρον*, a case, a sheath; whence elytrotomy, elytroptosis, elytroplasty, etc. French, *vagin*; Italian, *vagina*; German, *Scheide*, *Mutterscheide*.

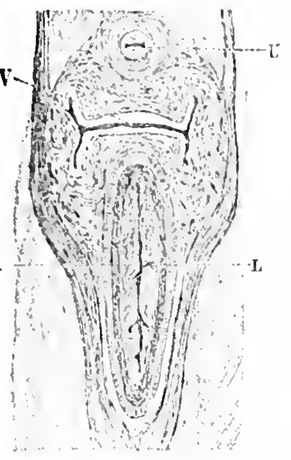

FIG. 4230.—Cross-section of the Vagina. (Henle.) *L*, Levator ani; *R*, rectum; *U*, urethra, cut obliquely; *V*, vagina.

Definition.—The dilatable, musculo-membranous conduit that extends from the uterus through the pelvic floor to the vulva. It serves as an organ of copulation, as a passage for the evacuation of menstrual and other fluids from the uterus, and for the delivery of the child at term.

Form.—The vagina is a collapsible tube whose walls are in contact with each other, and whose cavity exists only when it is distended. In general appearance it is not unlike some parts of the alimentary canal, and it has, indeed, been called the "genital intestine." The arrangement of the apposed walls is affected by the neighboring organs. Above, where they surround the os uteri, a transverse section shows the tube to be nearly circular; at the middle, where the muscular walls of the ureter in front and of the rectum behind impinge upon them, a section has the form of a transverse slit with vertical branches at either end, like a letter **H** with a long transverse bar (Fig. 4230); at the lower end, where the tube unites with the antero-posterior cleft of the vulva it becomes stretched in a sagittal direction, and in virgins is usually partially closed by a fold of mucous membrane termed the *hymen*. In children the tube may present a stellate appearance on section, and after frequent parturition it may become quite irregular.

When distended the cavity tapers slightly from above downward, being narrowest at its lower extremity. The widest part is, however, a little above the middle.

Division.—The upper part of the vagina, where it encircles the cervix (Fig. 4216), is known as the *fornix* or vault. This extends higher behind than in front, owing to the anteverted position of the uterus. It is usual to designate the different portions of this ring-like space as the *anterior*, *posterior*, and *lateral* fornices or *culs-de-sac*. The main portion of the tube is called the *body* of the vagina (*corpus vaginæ*); its widest part is the *ampulla*, and the entrance, visible when the labia are separated, the *external orifice* or *introitus*.

Dimensions.—Measured from the introitus to the external orifice of the uterus, the average length of the vagina

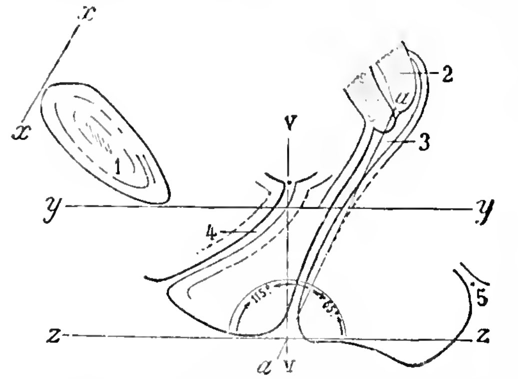

FIG. 4231.—Direction of the Vagina (frozen subject, twenty-four years.) (Testut.) 1, Symphysis pubis; 2, cervix of uterus; 3, vagina; 4, urethra; 5, anus; *x*, *x*, plane of the superior strait; *y*, *y*, subpubic horizontal; *z*, *z*, horizontal drawn through inferior orifice of vagina; *v*, *v*, vertical drawn through that orifice; *a*, *a*, axis of the vagina, inclined about 60° to the horizontal.

is 7 cm. (2¾ in.), varying between 4 or 5 cm. and 14 cm. This is one-fifteenth that of the entire body, exclusive of the limbs. In the new-born the length is 2.5–3.5 cm., which is relatively greater, being one-ninth of the body length (Luschka). The length of the shorter or anterior wall is from 6.5 to 7.5 cm. (2½ in.) while the longer, posterior wall is from 8 to 8.5 cm. (3¼ in.). In girls of thirteen years Symington found the anterior wall to measure 5.5 cm., the posterior 6.5 cm. The anterior cul-de-sac is shallow, being only from 2 to 5 mm. in depth, while the

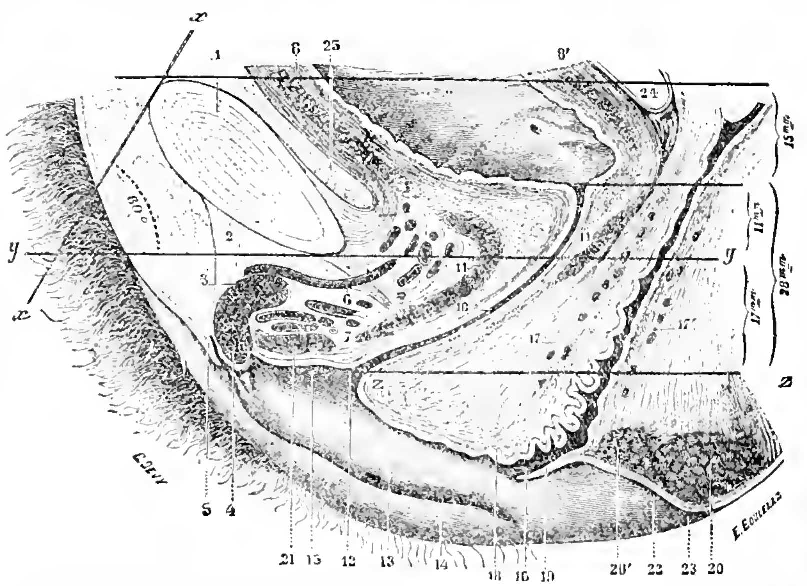

FIG. 4232. Median Section of the Female Pelvis (subject frozen, twenty-four years old.) (Testut.) 1, Symphysis pubis; 2, suspensory ligament of clitoris; 3, corpus cavernosum of clitoris; 4, glans of clitoris; 5, prepuce of clitoris; 6, dorsal vein of clitoris; 7, intermediary plexus; 8, 8', anterior and posterior walls of bladder; 9, neck of the bladder; 10, urethra; 11, external sphincter of urethra; 12, meatus urinarius; 13, nympha; 14, labium; 15, vestibule; 16, inferior orifice of vagina; 17, 17', anterior and posterior columns of the vagina; 18, vaginal tubercle; 19, hymen; 20, external sphincter of anus; 20', constrictor of the vulva; 21, fascicles of this muscle between the clitoris and the urethra; 22, fossa navicularis; 23, fourchette; 24, vesico-uterine cul-de-sac; 25, prevesical space; *x*, *x*, plane of the superior strait; *y*, *y*, horizontal drawn through lower border of symphysis; *z*, *z*, horizontal drawn through meatus urinarius.

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posterior cul-de-sac is much deeper, being from 10 to 25 mm. The vagina is susceptible of enormous dilatation without injury, enlarging sufficiently to permit the passage of the fœtal head during labor. Its calibre is somewhat greater in those who have borne children.

Situation and Direction.—In its passage through the pelvic floor the vagina lies between two other great conduits: that for urine, represented by the bladder and the ureter, being in front: the alimentary canal, represented by the rectum, behind. Divergent below, these approach each other above (Fig. 4231). The vagina is usually bent backward a little below and forward above, having a course like a much elongated reversed italic *S*. It does not depart widely from the axis of the pelvic cavity, but at least half of its length is extrapelvic, being below a line drawn from the lower border of the symphysis to the tip of the coccyx. Its direction is nearly parallel to the plane of the superior strait, varying somewhat with the state of repletion of the bladder and the rectum. Its axis makes nearly a right angle with that of the uterus when that organ is in its typical anteverted position and the bladder is not more than half full (Fig. 4232).

Fixation.—The vagina penetrates both the pelvic diaphragm (levator ani and coccygeus with associated fascia) and the genito-urinary diaphragm (triangular ligament with associated muscles) and receives support from both.

The upper part has much the same suspensory apparatus as has been already described for the cervix of the uterus. In addition, muscular fibres pass from the vagina to the sacrum behind and to the pelvis in front. Its adherence to the bladder is quite firm, but to the rectum much less, owing to the intervention of the pouch of Douglas.

The levator ani descends from the sides of the pelvis funnel-wise (Fig. 4233), and its fibres pass along the vagina, without becoming attached to it, to be inserted upon the rectum. They thus limit, to some extent, the displacements of the tube, without interfering with its distention.

Both sheets of the triangular ligament are firmly inserted upon the vaginal walls, affording them a fixed support. In addition, the lower part of the vagina is united to the rectum by means of the perineal body and still more closely adherent to the urethra. It will be seen, therefore, that the organ is more effectively supported in its lower segments than at any other portion.

Relations.—The anterior wall may be divided into a detachable, *vesical* portion above, connected with the fundus and trigone of the bladder, and a non-detachable, *urethral* portion below. The vesico-vaginal septum is about 3 cm. long and wedge-shaped in vertical section, being 6–7 mm. thick below and increasing upward. Exploration for stone is readily made along this wall, and it is here that vesico-vaginal fistula forms, usually from injuries received during labor. The upper part of this septum, composed of loose areolar tissue containing numerous veins, is continuous above with the cervico-vesical septum and like it can be easily separated into two layers corresponding to the related viscera. It has already been remarked that, after repeated pregnancies, there may be sufficient separation to permit the vesico-uterine fold of peritoneum to extend as far down as the upper part of the vagina. Over the trigone the tissue is denser and separation becomes more difficult, while along the urethra the two canals are so closely united that anatomical isolation becomes impossible. The urethro-vaginal septum is from 5 to 12 mm. thick.

The posterior wall is divisible according to its relations into three portions: *peritoneal*, above; *rectal*, in the middle; and *perineal* below. The peritoneal portion is from 10 to 15 mm. in vertical extent and comprises the part in contact with the pouch of Douglas. This may contain convolutions of the intestine, or a prolapsed ovary or oviduct. The recto-vaginal septum is about 4 cm. long and 3–4 mm. thick, and contains veins and lymphatics. The two tubes are readily separable. Below this portion of closest contact the rectum bends sharply backward to end in the anal canal, leaving between itself and the vagina a space triangular in section, about 25 mm. in length from above downward, and the same in thickness. This is called the perineal body and is composed of the external sphincter of the anus, the transversus perinei superficialis muscle, and the thin muscular bands called the constrictor vaginæ, all being intimately united.

Laterally we may also distinguish three portions: *pelvic*, above the levator ani; *intramuscular*, where it passes through that muscle; and *perineal*, below it. The pelvic

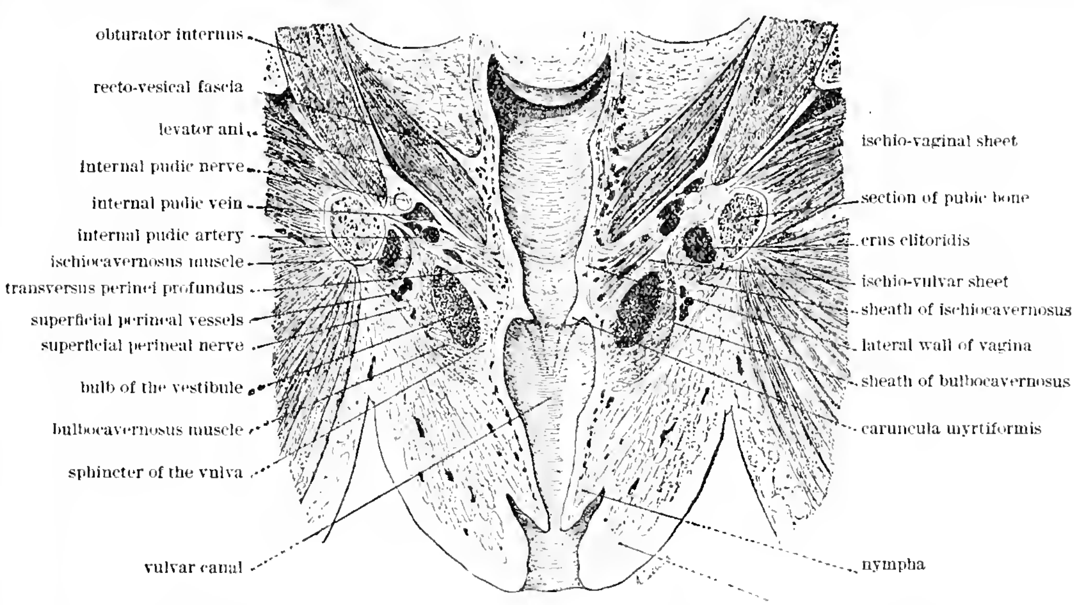

FIG. 4233.—Lower Part of a Vertical Transverse Section of the Female Pelvis, showing the Urogenital Diaphragm, the Vagina, and the External Genital Organs. (Farabeuf.) The former position of the hymen is indicated by dotted lines.

portion is composed of areolar tissue like that which forms the parametrium, of which it is a continuation. It is often called the paravaginal tissue. Waldeyer proposes for it the term *paracolpium*, which is etymologically more correct.

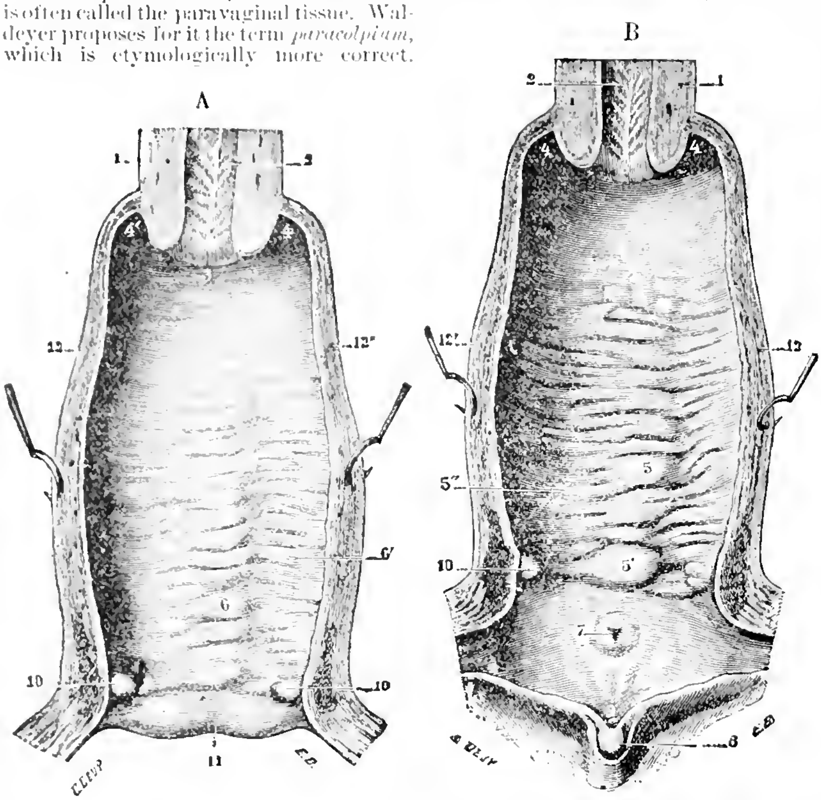

FIG. 4234. Section of the Vagina through its Lateral Borders. (Testut.) *A*, Posterior segment showing posterior wall; *B*, anterior segment showing anterior wall; 1, cervix uteri; 2, cervical canal with arbores vitæ; 3, external orifice; 4, 4', lateral culs-de-sac of the vagina; 5, anterior column, with 5', the vaginal tubercle, and 5", the transverse folds of the anterior wall; 6, posterior column, with 6', transverse folds of the posterior wall; 7, meatus urinarius; 8, clitoris; 9, vestibule; 10, 10, carunculæ myrtiformes; 11, fossa navicularis; 12, 12', sections of the lateral walls of the vagina.

It contains abundant plexuses of veins surrounding the vaginal, cervico-vaginal, and vesico-vaginal arteries. Sometimes the loop of the uterine artery itself descends to this level, lying about 15 mm. outside the vaginal wall. The ureters are at first about 15 cm. from the lateral cul-de-sac. As they pass forward they approach the wall and finally almost touch it anteriorly. The ganglion of Lee lies against the upper lateral portion, and remnants of the Wolffian duct, known as the ducts of Gärtner, are occasionally found there. The fibres of the levator ani cross obliquely, adherent only by loose areolar tissue. By its contraction the muscle closes the vaginal passage. The tissues below this crossing belong to what is known as the urogenital diaphragm, which is composed of the two layers of the triangular ligament, here distinguished as the ischio-vaginal and the ischio-vulvar sheets, and the muscles which lie between them, viz., the transversus perinei profundus and the constrictor urethræ. Below the diaphragm and impinging upon the vulva are found the vulvo-vaginal glands and the bulbocavernosus muscle surrounding the bulbs of the vestibule, hereafter to be described.

Interior Configuration.—In the young person who has not borne children the interior of the vagina is by no means smooth (Fig. 4234). At its lower part it is crossed by transverse folds or rugæ, which thin away laterally but medially thicken to form a longitudinal elevation on both the anterior and the posterior wall. These are known as the *columns* of the vagina (*columnæ rugarum*). Both the columns and the rugæ are better developed below and on the anterior wall than above and behind.

The anterior column follows quite closely the course of the urethra, and on that account is sometimes called the *carina urethralis*. It usually terminates below in a well-marked elevation, the *vaginal tubercle*, situated just behind the meatus urinarius. The column and the tubercle afford an excellent guide to the meatus in catheterization of the urethra. These elevations become gradually less marked toward the fornix and wholly disappear in the upper part of the vagina. In the fœtus of eight or nine months the rugæ are found throughout the entire extent of the canal, and resemble in appearance the valvulæ conniventes of the small intestine. After considerable distention of the vagina they tend to disappear, and only traces of them can be found in multiparæ. They appear to be less frequent among some of the lower human races and are absent in apes.

The adherence of the upper part of the anterior wall to the trigone of the bladder is marked by a smooth, triangular area over which the rugæ and columns are entirely effaced. This is known as the *vaginal triangle*, or triangle of Pawlick (*area trigonalis vaginæ*, Fig. 4235). It is situated 25 or 30 mm. below the external orifice of the uterus. Its two superior angles mark the points where the ureters enter the bladder, and are of importance as guides in the catheterization of those conduits.

In virgins the orifice of the vagina is normally partially closed by a fold developed from its posterior wall, called the *hymen* (*hymen femininus*), from the Greek *ὑμήν*, a membrane, not from the Latin deity who presided over marriage. Much discussion has arisen as to the morphological character of this fold. As it appears to be developed from the Müllerian duct it would seem that it must belong to the vagina. The duct is formed from a solid cord of cells by the degeneration of the centrally situated portions. At the lower end some portions of the cord persist and form the hymen (Fig. 4236).

As might be expected from its peculiar origin, the hymen varies much in its extent and shape. Some of the earlier anatomists denied its existence, and even Ve-

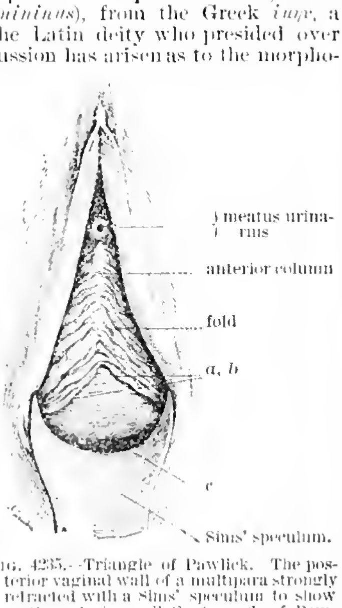

FIG. 4235.—Triangle of Pawlick. The posterior vaginal wall of a multipara strongly retracted with a Sims' speculum to show on the anterior wall the triangle of Pawlick (*a*, *b*, *c*). (Rieffel.)

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salius considered it rare. It is indeed occasionally absent altogether. Its usual form is that of an unbroken, semilunar fold of sufficient size to occlude the greater portion of the vaginal orifice, leaving an opening large enough to permit the evacuation of the menstrual flow (Fig. 4237, *A*). Frequently it surrounds the orifice in a ring-like manner (*hymen annularis*), the opening being either medially or laterally situated. This opening may, however, take the form of a slit, having two lips laterally situated (*hymen bilobatus, seu bilabiatus* Fig. 4237, *C*). There may be two openings (*hymen biperforatus*, Fig. 4237, *D*), several openings (*hymen cribriformis*, Fig. 4237, *E*), or none at all (*hymen imperforatus*). This latter form requires surgical interference to effect the proper menstrual evacuation. The edges of the hymen may be variously cut (*hymen fimbriatus*, Fig. 4237, *B*), simulating the ruptures seen after defloration. The membrane may be unusually thick (*hymen carnosus*), even resembling cartilage and able to resist rupture.

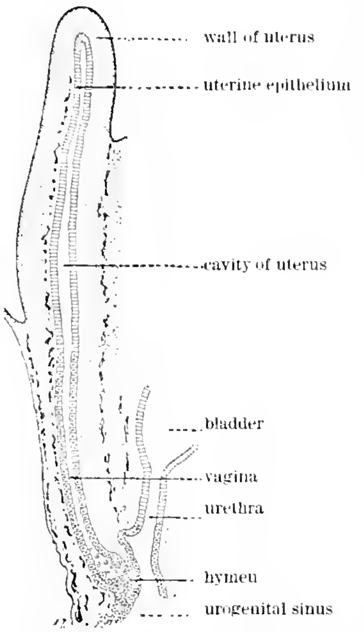

FIG. 4236.—From a Human Fœtus 10 cm. Long. Longitudinal section passing through the genital cord. (Tourneux.)

It is, however, usually ruptured at the first sexual approach. It then shows irregular jagged tears, some of which reach to the outer circumference. After healing, which is not long delayed, there are produced a number of rounded nodules (*lobi hymenales*) united by thickened edges. This form (*hymen defloratus*, Fig. 4238) may be distinguished from the fimbriate variety by the character of the lacerations, which in the deflorate form usually reach the circumference, in the fimbriate are less extensive and united by fine filaments.

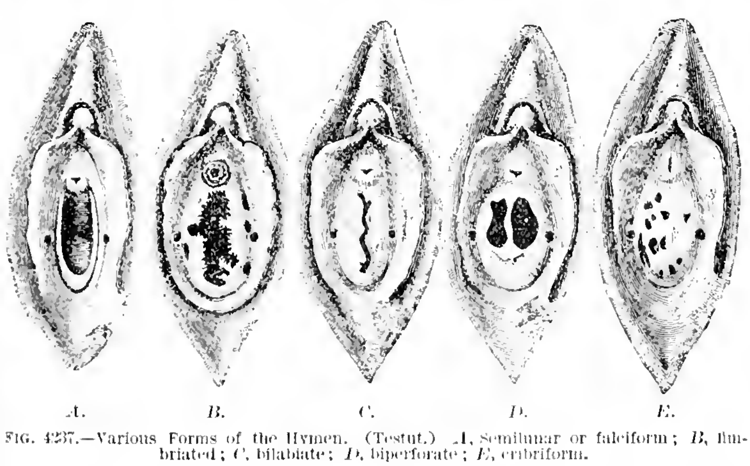

FIG. 4237.—Various Forms of the Hymen. (Testut.) *A*, Semilunar or falciform; *B*, fimbriated; *C*, bilabiate; *D*, biperforate; *E*, cribriform.

When labor ensues, the lobi hymenales are stretched and torn so that they afterward appear as a number of flattened, cicatrized elevations. In this state they are called the *carunculæ hymenales* or *myrtiformes* (Fig. 4240).

A hymen usually contains blood-vessels, and it is popularly supposed that its rupture is always accompanied by hemorrhage. Among the Eastern nations much reliance is placed on this "sign of virginity." The ancient Hebrews appear to have accepted it, as will be seen from Lev. xxii. 13-21. While slight hemorrhage is usual, and dangerous loss of blood has been known to occur, yet it often happens that the membrane is ruptured without such signs, and pregnancy not infrequently ensues with the hymen uninjured. (Fig. 4239.)

The great differences that occur in the hymen—it sometimes being torn by very slight violence, by the fingers or by some accidental circumstance, while at other times it remains intact after sexual approach and even after delivery—detract from its value as a matter of evidence in medico-legal cases. Haberda believes that it is often impossible to determine positively whether coitus has occurred. The carunculæ hymenales are more reliable, as they are found only in those who have borne children.

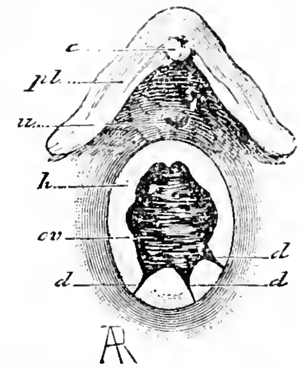

FIG. 4238.—Deflorate Hymen. Condition after first sexual approach. (Budin.) *c*, Clitoris; *pl*, nymphæ; *u*, meatus urinarius; *ov*, orifice of vagina; *h*, remains of hymen; *d*, *d*, *d*, tears.

Structure.—We may consider the vagina as possessing three coats: external, or adventitious; middle, or muscular; internal, or mucous.

The *external* coat can hardly be said to be an intimate part of the tube, but rather the packing of connective tissue that surrounds and connects it with other organs, it being the paravaginal tissue already adverted to. It contains smooth, muscular fibres, elastic fibres, deposits of fat and contorted, vascular plexuses that give it a loose, spongy character.

The *muscular* coat is composed of smooth fibres that cannot, in all parts, be definitely separated into layers. Externally they communicate with the muscular fibres found in the paravaginal tissue. Longitudinal bands lie along the anterior wall, connecting with the bladder above. The inner fibres are, for the most part, circular. They increase greatly in size and number during pregnancy. Above, the muscular tissue is continuous with that of the cervix; below, it is so much thickened that some authors describe a sphincter of smooth fibres. Luschka mentions longitudinal fibres that pass to the triangular ligament, constituting a *levator vaginæ*, said to elevate and dilate the vaginal orifice. A considerable amount of white fibrous and yellow elastic tissue is mingled with the muscular elements of this coat.

The mucous layer resembles the skin, being a stratified, pavement epithelium resting upon dermal papillæ. Its color is pinkish when inactive, red during menstrual or sexual excitement, and purplish red during pregnancy, when it is considerably congested. It is from 1 to 1.5 mm. thick, quite firm and attached to the subjacent, muscular layer without any intervening areolar tissue. During operations it is easily stripped off, but in that case usually carries with it portions of the muscular layer. The papillary part contains many elastic fibres, some scattered lymphoid cells, and occasional closed follicles. The mucous membrane contains no glands, and the acid mucus found on the vaginal walls is either an exudation, or, perhaps, the secretion of the uterine glands altered by bacterial agencies. A number of species of bacteria are found on the membrane, some of which appear to be peculiar to this locality.

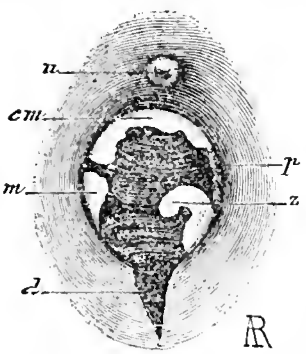

FIG. 4239. — Hymen After Childbirth. (Budin.) *n*, Meatus urinarius; *d*, tear; *cm*, carunculæ myrtiformes; *z*, detached floating tatter of the hymen; *p*, raw edge.

Arteries. — These are derived from several sources. Above, the cervico-vaginal branches of the uterine artery supply the fornix and upper third of the vagina; in the middle portion the vaginal artery proper, from the internal iliac, is distributed; while the lower part is supplied by a twig from the inferior hemorrhoidal, known as the inferior vaginal. The vaginal artery proper often arises in common with the uterine, the middle hemorrhoidal, or the inferior vesical. It is not unusual to find it represented by several branches. The arteries anastomose freely along the walls of the conduit and with the arteries of the neighboring organs. The arteries of opposite sides may unite to form median anterior and posterior vessels, running longitudinally, the so-called *azygos* arteries. Deficiency in one branch of supply is usually supplemented by an increase in the others. Arterioles reach all the layers of the vagina, being especially abundant in the papillæ of the mucous membrane.

Veins.—These are so numerous that they were considered by Kobelt as forming an erectile tissue, but they lack the special characters of that structure. They are particularly developed at the sides of the vagina, forming a large plexus that is continuous with the uterine plexus above, the vesical plexus in front, and the hemorrhoidal plexus behind. Hyrtl has shown that they also communicate with the portal system by anastomosis with the superior hemorrhoidal vein. They may thus discharge in three directions: below the levator into the perineal system, above it into the internal iliac and portal veins. Very few valves are found in these veins. They are surrounded by connective tissue and smooth muscular fibres, which cause them to remain open when cut. Hemorrhage from them is therefore difficult to stop and septic infection is easy.

FIG. 4240. — Hymen Before Childbirth. (Budin.) *n*, Meatus urinarius; *h*, hymen whose edges are intact notwithstanding the sexual approaches.

Lymphatics.—Both the mucous membrane and the muscular coat contain a great number of lymphatics (Fig. 4241). The mucous coat has a fine-meshed plexus that communicates with that of the cervix above and that of the external genitals below. The muscular coat also has a plexus with much larger meshes. The two communicate freely. According to Poirier, they discharge by three groups of collecting vessels: a superior set that ends in glands that lie along the course of the internal iliac artery; a middle set that terminates in glands along the internal iliac; and an inferior set that passes along the sacrum to end in glands near the promontory. By anastomoses with other vessels these may communicate with the inguinal glands. Morau states that communications also exist between the middle set and the glands within the fibrous sheath of the rectum.

Nerves.—The upper and middle portions of the vagina are supplied from the same sources as the uterus. These parts are not very sensitive. The anterior wall, particularly, can be operated on without much pain to the patient. The lower portion is supplied with additional filaments from the internal pudic nerve, and is much more sensitive. Intra-epithelial plexuses and terminations occur as in other stratified epithelium.

THE VULVA.—*Etymology.*—From the vulgar Latin *vulva* or *volva*, a covering or wrap, hence the womb. Derived from *volvere*, to roll around or about. Celsus used it for the combined uterus and vagina. Spigelius derived it from the Latin *valva*, a double or folding door. The more usual Latin term for the external genitals was *cunnus*, probably derived from *cuneus*, a wedge, referring to the shape either of the mons veneris and labia as seen with the thighs closed, or of the expanded genital cleft. A synonym often used is *pudendum*, from *pudere*, to feel shame. French, *vulve;* Italian, *vulva;* German, *Scham*.

Definition.—The external genital organs of the female, including all those derived from the urogenital sinus and found below the urogenital diaphragm. They are a series of related organs rather than the parts of a single one. Together they form an ovoid or wedge-shaped eminence situated on the surface of the body at the lower part of the abdomen, between the thighs. They include: (1) a median cleft like space, the *vestibule*, with the vestibular glands; (2) the *labia* and *nymphæ*, tegumentary folds that limit this on either side; (3) the erectile apparatus, comprising the *clitoris* and *bulbs*. Some authors use the term merely to designate the genital opening with the labia.

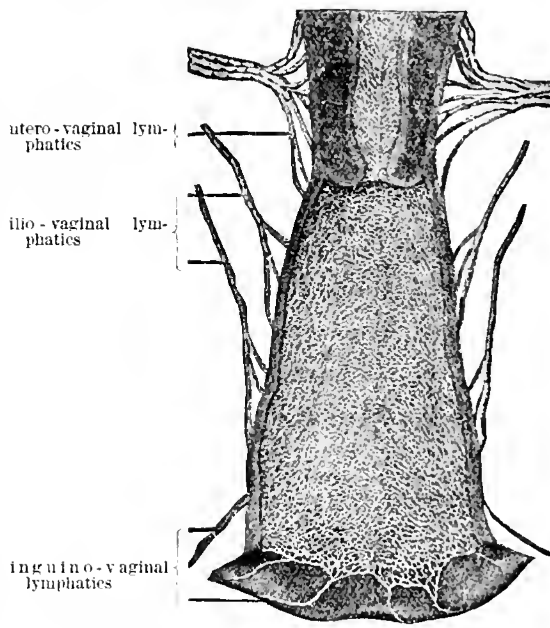

FIG. 4241.—Network of Lymphatics of the Vaginal Mucous Membrane. Efferent trunks of the vagina. (Poirier.)

General Arrangement.—But little of the external genitals is visible when a female is standing erect. Only a fleshy protuberance, covered with hair, the *mons pubis* or *mons veneris*, appears at the lower extremity of the abdomen, limited externally by the thighs and below passing into two fleshy folds, the *labia*, between which is seen

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the half-effaced end of the *rima pudendi*, or genital cleft. In some cases the end of the clitoris may protrude at the upper end of the cleft, and, still more rarely, the edges of the nymphæ may be seen.

When the subject is placed in the dorsal position with widely parted thighs, flexed upon the abdomen, the genital cleft is stretched apart and forms a wedge-shaped fossa, rhomboidal in outline, limited on either side by the labia, extending in front to the mons pubis, behind to about 3 cm. in front of the anus (Figs. 4242, 4243). Within this space, running parallel to the labia majora, are seen two reddish folds, the *nymphæ*, which unite anteriorly by embracing a small penile appendage, the *clitoris*. The space between them is known as the *vestibule*. The vaginal orifice may be perceived posteriorly, and beneath the mucous membrane on either side of this are found masses of erectile tissue known as the *bulbs of the vestibule*.

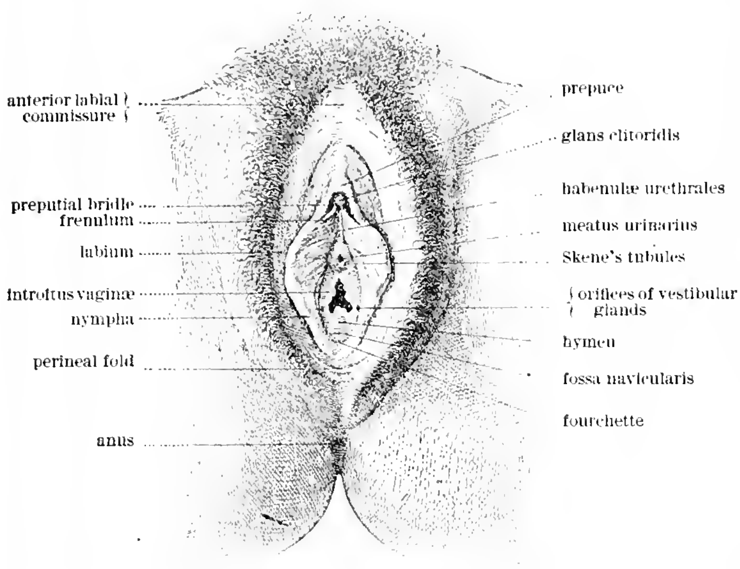

FIG. 4242.—External Genital Organs of a Virgin as seen after Separating the Labia and the Nymphæ. (Rieffel.)

The Vestibule.—This may be defined as the portion of the urogenital cleft that lies between the nymphæ, limited in front by the clitoris, behind by the fourchette when that exists. It is not always used in this sense. Schäfer limits it behind "by a transverse line at the level of the urethra"; Gray, following the example of most French anatomists, by the entrance to the vagina. If this limitation were imposed, it would hardly be proper to speak of the "bulbs of the vestibule" or of the "vestibular glands," both of which structures are situated at the sides of or behind the vaginal opening.

Like the vagina, its walls are in contact when not stretched apart. When the thighs are separated it appears as an almond-shaped space, looking downward and a little forward, its broad, rounded end being posterior. It presents a roof, two ends and sides, the latter being the inner surfaces of the nymphæ.

The roof, which has in front a smooth, uniform surface, pinkish in color, presents, about the junction of its anterior and middle thirds, the *meatus urinarius* or external opening of the urethra. This is seated on a rounded eminence, the *urethral papilla*, which is not usually smooth, but covered with rugosities or small vegetations which may hinder the introduction of the catheter. The orifice is usually an antero-posterior slit 5-6 mm. in length, but may be of various shapes, semilunar, triangular, or puckered. While it is the smallest and least dilatable portion of the urethral canal, it may, if proper precautions are used, be gradually enlarged to 20-25 mm., or even to a greater size, without inducing incontinence of urine. Thus the finger may be introduced for exploration of the bladder, or stones and foreign bodies extracted. In some instances of absence or closure of the vagina, it is said that attempts at copulation have resulted in the introduction of the penis into the urethra. The orifice is almost vertically under the pubic arch and 25 mm. from it. Its distance from the glans of the clitoris is usually somewhat less.

Running forward from the meatus to the clitoris, there may be seen in young subjects two fine whitish lines, called by Waldeyer the *habenulæ urethrales* (Fig. 4242). They represent the vestiges of the anterior part of the corpus spongiosum which, in the female, remains rudimentary. They were first noted by Pozzi (1884), who called them the "bride masculine."

On either side of the urethral orifice there may be noted the openings of two ducts for tubular glands situated on either side of the urethra and apparently homologous with the prostatic glands of the male. These ducts are often called Skene's tubules, as they were especially

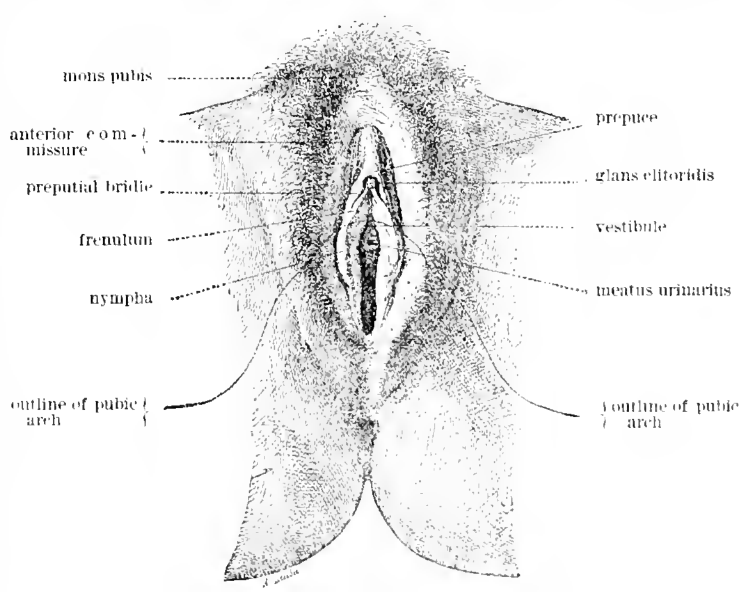

FIG. 4243.—External Genital Organs of a Multipara as seen after Slight Separation of the Labia. (Rieffel.)

studied by Skene in 1880. They were, however, known to Morgagni and De Graaf.

Behind the urethral opening is found the introitus vaginæ, closed more or less in the virgin by the hymen, and showing, in multiparæ, the carunculæ hymenales. The relation to the urethra borne by the anterior column of the vagina and the vaginal tubercle has been already mentioned. Since the hymen forms a membrane across the orifice of the vagina there is a slight groove formed between it and the nymphæ on either side, and this remains after the rupture of the structure. This is called the *nympho-hymeneal* or *nympho-caruncular sulcus.*

In this groove, opposite the lower and middle thirds of the introitus, are seen the openings of two ducts, one on either side, which belong to glands buried quite deeply in the fatty tissue between the vestibule and the ischium. These are the *greater vestibular glands* (*glandulæ vestibulares majores*, Fig. 4244), often called the glands of Bartholin, from Thomas Bartholin, who discovered them in the human subject in 1680. They had previously been seen in the cow by Duverney. Our most exact knowledge of them is due to Huguier (1849), who called them the vulvo-vaginal glands. He described them as situated, one on either side, about 1 cm. below the hymen, from 1 to 1.5 cm. from the ischium, 1 cm. from the bottom of the genito-crural fold of the integument. They are also about 3 cm. from the inferior edge of the labium. By compressing the posterior part of the labium between the thumb and forefinger, a gland can usually be felt. They are acinous glands, about as large as a pea or small bean, slightly oval in shape, and discharge by a duct 15–18 mm. long, and large enough to admit the cannula of an ordinary hypodermic syringe. They secrete a clear, viscid liquid that is discharged in considerable quantity during sexual excitement. This discharge was called by the older writers the female semen, and was long supposed to be the active generative product. It apparently serves as a lubricant to the passages during coitus. The glands attain their maximum development at puberty and atrophy during old age. They are homologous with the bulbo-urethral or Cowper's glands of the male. In normally developed virgins the nymphæ are united behind by a short transverse band, the *fourchette* or *frenulum labiorum.* This is ruptured at childbirth and sometimes by sexual approaches, and its relics may then be seen as a whitish scar. The shallow space between this band and the hymen, or the vaginal opening when the hymen is absent, is known as the *navicular fossa* (*fossa navicularis*). If the nymphæ are short the frenulum is absent. It should not be confounded with the artificial fold produced by widely separating the labia.

The Mons Pubis.—The genital cleft is bounded on either side by two pairs of tegumentary folds which unite in front below a rounded prominence situated directly over the symphysis pubis. This is the *mons pubis* or *mons veneris.* It is usually separated from the general surface of the abdomen by a shallow furrow, the *pubic sulcus,* and from the thighs by the *inguinal sulcus.* Smooth, or coated with a fine lanugo in the child, as puberty approaches it becomes covered with thick and somewhat stiff hairs that have a tendency to curl. The extent of this hairy covering varies very much in different individuals, being greatest in the races of Southern Europe. Usually it descends upon either side of the labia as far as the anus. Upward it may much exceed the limits of the mons pubis and extend upon the abdomen. The hairs usually agree in color with those of the armpits and head, but they have the general appearance of those of the male beard, though usually somewhat thinner. They are spirally twisted, have a medullary canal throughout, are stronger than the hairs of the head, and show on section a triangular, irregularly fluted outline (Waldeyer).

Beneath the integument of the mons pubis is a thick cushion of fat in which are found numerous elastic fibres continuous with those of the labia and the suspensory ligament of the clitoris. These cause a gaping of incised wounds made transversely in this region.

The Labia.—These tegumentary folds, often distinguished as the labia majora, correspond to the scrotum of the male and their external appearance is not unlike that organ when empty and considerably retracted. They are about 25–35 mm. long, 8–15 mm. in depth, and 3.5 mm. thick. They are limited on either side by a deep extension from the inguinal furrow known as the genito-femoral sulcus. Like the scrotum their outer surface is darkly colored, somewhat roughened, and covered with hair which is extended in a scattered manner to the marginal part of the inner surface. The deeper part of this surface has the appearance of the lips of the face, being smooth, reddish and humid. The groove between it and the nympha is called the nympho-labial furrow.

Immediately below the mons pubis the labia unite over the back of the clitoris (*torus clitoridis*) in an anterior commissure (commissura labiorum anterior). Behind they gradually narrow and are lost on the perineum.

Within their substance, the labia contain a layer of smooth muscular fibres analogous to the dartos of the scrotum, a considerable quantity of connective tissue, including many elastic fibres, and subcutaneous fat. A considerable mass, called the adipose body of the labium, almost wholly fills the middle portion of the lip, resembling somewhat the fat-ball found in the cheeks of the face. It is a derivation from the subperitoneal fat with which it is often continuous along the round ligament of the uterus, which, it will be remembered, passes through the inguinal canal and is inserted here. The canal of Nuck is sometimes continued down into the labium and may be the seat of a hydrocele.

The Nymphæ.—This name was introduced by Severinus Pinæus and Spigelius in the early part of the seventeenth century, "*ut enim nymphæ scaturientibus aquis præsunt,*" because, like nymphs, they control the gushing streams, it being supposed that they directed the course of the urinary jet. Though this view of their function is incorrect, the name lends itself well to combinations and ought to be retained. They are often called the labia minora or lesser lips, from their close association with the outer lips or labia proper. When the genital cleft is parted they appear as two cutaneous folds (Figs. 4242, 4243) running parallel with the labia, often more reddish in appearance, and not as smooth, being slightly roughened on their inner surfaces by small elevations, and often irregularly denticulated or incised on their free edges, an appearance which led Spigelius to compare them to a cock's comb. Their size varies much in different individuals. At birth they usually extrude beyond the labia, which are then but slightly developed. In the adults of European races they are ordinarily concealed, having a length of 25–35 mm., a breadth of 8–15 mm., and a thickness of 3–5 mm. They may, however, be large enough to extrude, and their exposed surfaces then take on a brown coloration like that of the areola of the nipple. In some African races they are enormously developed, being six to eight inches wide, extending upon the thighs to form what has been called the "Hottentot apron."

The outer surface of each nympha is separated by the nympho-labial furrow from the corresponding labium, from which it differs by its absolute freedom from hairs. The inner surface, more rough, is in contact with the opposite nympha when the genital cleft is closed. The attached surface is in contact with the bulb of the vestibule.

The anterior extremity is continued forward and embraces the clitoris by dividing into two branches (Fig. 4244), the anterior one of which unites with its fellow of its opposite side to form for the organ a small prepuce or foreskin, similar, on a diminished scale, to the prepuce of the penis of the male. It does not usually cover the glans, but may be sufficiently developed to admit of circumcision, which is said to be practised by the Abyssinians. The posterior branch is inserted, with its fellow, on the glans of the clitoris and forms a restraining band, the *frenulum* of the clitoris. Owing to the traction of the nymphæ through this band, the clitoris is bent downward toward the vaginal orifice.

The nymphæ are composed of a network of vascular, areolar tissue without fat, enclosing numerous large veins with associated, smooth, muscular fibres, which give the organ an erectile character. Its outer investment is stratified epithelium, which resembles a mucous membrane by its coloration, its smooth and humid character and its absence of hair; while, on the other hand, it resembles the skin by the character of its epithelium, which has scale-like cells that lose their nuclei, tactile corpuscles, and sebaceous glands in great numbers. In the lower animals these glands are especially active during rut, and doubtless entice the male by some characteristic odor. The epithelium becomes darker during pregnancy.

While the erectile tissue of the female genitalia is somewhat widely distributed, being found in the nymphæ and to some extent along the vagina, it is especially marked in two organs, which together are homologous with the penis of the male. These are the clitoris and the bulbs of the vestibule.

The Clitoris. — The name is neo-Latin, from the Greek κλειτορίς, said to be derived from κλείειν, to close or shut. Hyrtl thinks it is related to κλειτορίζειν, to titillate. This would be analogous to *Kitzler*, the German vernacular name for this organ.

It represents a small appendage, resembling a diminutive penis, suspended at the summit of the pubic arch (Figs. 4242, 4243, 4244, 4245, 4246) and enfolded by the anterior juncture of the nymphæ. Like the penis it possesses two corpora cavernosa, small rods of erectile tissue, united in front to form the *body* of the organ, diverging behind as its *crura*. The body is crowned with a small *glans*. Unlike the penis, the glans is not perforated by the urethra, and there is no corpus spongiosum attached to it. When lax the organ is so withdrawn within the folds of the nymphæ and labia that it is difficult to make out its form and dimensions.

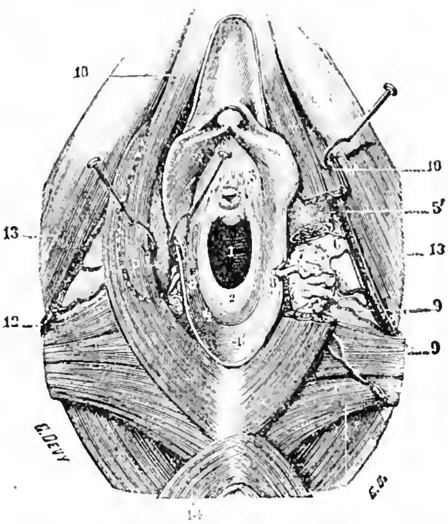

FIG. 4241.— Dissection of the Vulva, showing the Vestibular Glands. 1, Orifice of the vagina; 2, hymen; 3, meatus urinarius; 4, navicular fossa; 5, bulb of the vestibule; 6, vestibular or vulvo-vaginal glands; 7, 8, duct; 10, constrictor vaginæ; 11, transversus perinei muscle.

The crura are attached on either side to the inner aspect of the pelvic arch, half way between the tuberosity of the ischium and the symphysis. Wholly hidden within the folds of the labia, they pass forward, inward, and a little upward, along the external face of the triangular ligament, surrounded by the ischio-cavernosus muscle (*erector clitoridis*) and join each other below the symphysis to form the body, room being left between their junction and the arch to permit the passage of vessels and nerves.

Almost immediately the body is bent downward and backward, forming what is called the *angle* of the clitoris. Unlike the angle of the penis, this does not become obliterated when the organ is erect, and this doubtless subserves the function of the organ. Movements are prevented by the frenulum, which, as already mentioned, draws the glans down toward the vaginal orifice, and by the *suspensory ligament*, a fibrous band like the similar organ of the penis, that passes from the angle to the linea alba.

The body of this little organ is nearly cylindrical in shape, usually slightly grooved on its under surface because of its duplex structure. An imperfect division or *septum pectiniforme* separates the two lateral halves. Females of animal species in which the males possess a penis bone have sometimes a minute bone or

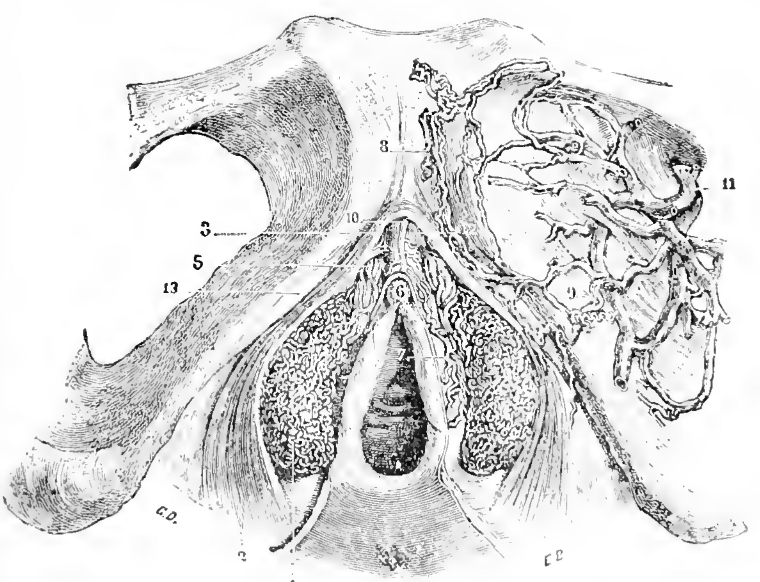

FIG. 4245.—The Bulb of the Vestibule and the Venous System of the Clitoris seen from the Front. (Kobelt.) 1, Bulb of the vestibule; 2, constrictor vulvæ muscle; 3, anterior portion of same; 4, portion that passes under the clitoris; 5, pars intermedia; 6, glans of clitoris; 7, veins from nymphæ; 8, veins passing to superficial veins of abdomen; 9, veins communicating with the obturator vein; 10, dorsal vein of clitoris; 11, obturator vein; 12, body of clitoris; 13, right crus of clitoris.

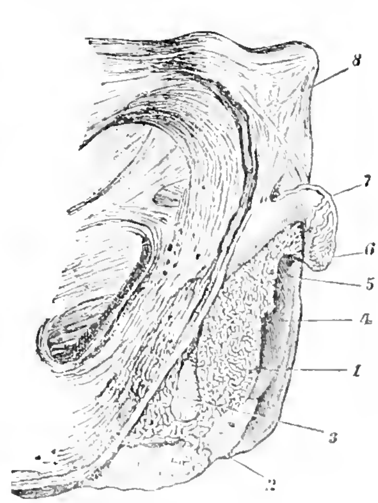

FIG. 4246. Bulb of the Vestibule and the Clitoris Seen from the Side. (Kobelt.) 1, Right bulb of the vestibule; 2, veins from its lower end that discharge into the internal pudic vein; 3, vestibular gland; 4, introitus vaginæ; 5, pars intermedia; 6, glans clitoridis (the clitoris is somewhat elevated); 7, dorsal vein of clitoris; 8, symphysis pubis.

cartilage in this septum. The greater part of the body is concealed under the anterior commissure of the labia, its swelling outline forming the *torus clitoridis.*

The glans, which terminates the organ, is a small, rounded, conoid tubercle. It is independent of the corpora cavernosa, capping over their fusiform ends as in the penis. It has a small prepuce derived from the nymphæ, and a preputial sac in which small collections of smegma may accumulate. To its under surface is attached the frenulum.

The following measurements of the clitoris are given by Krause:

	When relaxed.	When erect.
Length of body	18 mm.	29 mm.
Thickness of body	5 mm.	9 mm.
Length of crura	40 mm.	45 mm.
Thickness of crura	5 mm.	8 mm.
Diameter of glans	4–7 mm.	6–9 mm.
Total volume	2 c.c.	6 c.c.

Considerable individual variations are found. The organ may be of such size as to be mistaken for a small hypospadiate penis, and thus lead to mistake in determining the sex of a child.

The structure of the clitoris repeats, on a diminutive scale, that of the penis. Each corpus cavernosum is surrounded by a firm, elastic, fibrous envelope, the *tunica albuginea*, from whose deep surface are given off numerous bands or trabeculæ, along which run smooth, muscular fibres. These trabeculæ divide the substance of the organ into numerous small spaces, termed areolæ, which are really venous sinuses, as they are lined with endothelium and communicate widely with the veins. Into these areolæ empty arterioles (helicine arteries). Erection occurs from the rapid filling of the areolæ by the expansion of the arterial orifices through the action of vaso-dilator nerves, and the impeding of the venous discharge by the ischio-cavernosus muscle and the elastic envelope. This apparatus is by no means as well developed as in the corresponding organ of the male, consequently erection is less complete.

The glans has no albuginea, but under its epithelium is a considerable fibro-elastic network which performs a similar function. Areolæ occur and the vascular supply is similar to that of the corpora cavernosa. Its cutaneous investment is supplied with special nerve endings, which give it remarkable and special sensibility. According to Dogiel there are intra-epithelial plexuses with filaments ending in flattened platelets, tactile corpuscles within the papillæ, corpuscles of Pacini and the end bulbs of Krause in the subcutaneous tissue, while at the base of the papillæ are the special endings which Krause believes to be related to the peculiar sensibility of the organ and has named corpuscles of sexual pleasure (Wollustkörperchen). They are usually called genital corpuscles.

The Bulbs of the Vestibule.—The corpus spongiosum urethræ of the male, including the bulb of the urethra, is represented in the female by two oval masses of erectile tissue that lie beneath the nymphæ on either side of the vestibule and in front of the triangular ligament (Figs. 4245, 4246). Their lower ends are free, but they are united above over the lower end of the urethra, thus simulating the form of a horseshoe set astride of the vaginal opening. They were called by De Graaf *corpus clitoridis*, by Taylor *semi-bulbi corporis spongiosi*, and, since the time of Kobelt (1844), are generally known as the *bulbs of the vestibule* (*bulbi vestibuli*). They should be considered as the male organ separated into two portions by the intrusion of the vaginal opening in the median line.

Enlarged and rounded at their lower extremities, they are bulb-like in form. Their shape has also been compared to that of an almond, a fig, or, still more aptly, to that of an engorged leech, which they closely resemble because of their long, tapering, upper extremities which unite with each other and with the clitoris. Their dimensions vary in different individuals. Usually reaching as far back as the navicular fossa, they may not extend beyond the middle of the vaginal opening, or, on the other hand, they may be continued behind on to the perineum. When not turgid, each bulb is, in ordinary cases, about 30–40 mm. long, 10–15 mm. broad, and 5–10 mm. thick.

The bulbs are only about 8–10 mm. from the pubic arch, but are so situated with regard to the vaginal opening that they are pushed forward and away from the bones as the fœtal head descends. Rupture of one of them may, however, occur during labor, especially if instruments are used. This occasions a large hæmatoma in the corresponding labium, or, if the rupture extends through the entire integument, a serious hemorrhage.

The upper or deeper surface of the organ is applied to the ischio-vulvar or outer sheet of the triangular ligament, to which it is attached by some lax, areolar tissue. Its inferior or superficial surface is covered by the basis of the nymphæ. Like the bulb of the urethra in the male, it is invested externally by a sphincter muscle, the bulbo-cavernosus, which, by the separation of the two bulbs, becomes applied to the outer surface only, forming a constrictor of the vagina. Its internal surface embraces the vestibule, skirting the orifice of the urethra, the vagina, and the vestibular glands. Its anterior extremity, pointed and drawn out, communicates above the opening of the urethra with the glans of the clitoris and with the opposite bulb. The plexus thus formed was called by Kobelt the *pars intermedia.* It lies immediately under the habenulæ urethrales, and with them constitutes a vestige of the corpus cavernosum urethræ of the male.

In structure the bulbs resemble the corresponding organ of the male. They are invested by a thin tunica albuginea, within which is a plexus of large veins surrounded by muscular fibres sparsely distributed. The organ has the general structure of erectile tissue, but is much less perfect in that function than the clitoris, and very far below the male penis. When engorged with blood it assumes a swollen, doughy consistence rather than a complete rigidity. It is supplied by the artery of the bulb from the internal pudic. The blood, after leaving the plexus of veins found in the organ, passes into the pudic, perineal, and clitoridian veins.

Arteries.—The arterial supply of the vulva is shown in the following scheme:

Arteries.	Distribution.
From the common femoral artery	
Superior external pudic	Small branches to the mons pubis and anterior commissure of the labia.
Inferior external pudic	*Anterior labial* branches to anterior half of labia, some of which reach the nymphæ.
From the internal pudic artery	
Dorsal artery of the clitoris.	Glans clitoridis and anterior part of nymphæ, a few twigs extending upward to the mons pubis.
Artery of the corpus cavernosum.	Crura and body of clitoris, small branch to bulbs of the vestibule.
Artery of the bulb	Bulbs of the vestibule, meatus urinarius (*urethral artery*), vestibular glands.
Superficial perineal	*Posterior labial* branches to posterior half of labia and nymphæ, bulbs of the vestibule, vestibular glands.
Transverse perineal	Posterior end of labia, navicular fossa.
From the obturator artery	
Internal terminal branch.	*External labial*, to outer surface of labia.

Veins.—With one exception these have the same general arrangement as the arteries, discharging into the internal saphenous, the internal pudic, and the obturator trunks (Fig. 4245). The dorsal vein of the clitoris discharges into the vesical plexus (plexus of Santorini), whose efferent vessels terminate in the internal iliac vein. Numerous venous plexuses occur in the different organs. Thus the areolæ of the clitoris themselves constitute a plexus, the veins of the bulbs of the vestibule are arranged in a superficial large-meshed plexus and a deep, fine-meshed one, and a plexus also exists within the nymphæ.

These communicate freely with each other and with the vesical and vaginal plexuses.

Lymphatics.—The lymphatic vessels of the external genitals are very numerous, especially upon the nymphæ and the inner surface of the labia. They discharge, for the most part, into the superior internal or pubic group of superficial inguinal glands. This group lies internal to the saphenous opening and near the spine of the pubis. It includes two to four glands. Some vessels may discharge into the inferior internal group of superficial glands, or even, though rarely, reach some of the external group. In injecting the lymphatics on one side of the vulva, it is often found that the injection reaches the opposite side.

Cunéo and Marcille have recently shown that the lymphatics of the glans of the clitoris ascend by way of the mons pubis to the inguinal canal, through which they pass, to terminate in glands situated along the iliac vessels.

Nerves.—The nervous supply of the vulva is derived both from the cerebro-spinal and from the sympathetic systems. The cerebro-spinal nerves come from both the lumbar and the sacral plexuses, the sympathetic from extensions of the hypogastric plexus known as the cavernous and the utero-vaginal plexuses. From the first are given off two nerves, the greater cavernous nerves, and a number of small nerves, the lesser cavernous nerves that supply the crura, body, and glans of the clitoris. The nervous supply of the organ is far greater, in proportion to its size, than that of the penis. With the cavernous plexus are distributed the branches from the third and fourth sacral nerves that effect erection, the *nervi erigentes* of Eckhard. Other nerves from the cavernous plexus combine with the cerebro-spinal nerves, whose distribution is given in the following scheme:

Nerves.	Distribution.
From the lumbar plexus.	
Ilio hypogastric—	
Hypogastric branch....	Integument upon upper part of mons pubis.
Ilio-inguinal—	
Inguinal branch........	Integument upon lower part of mons pubis and upper part of labium.
Genito-crural—	
Genital branch.........	To labia (anterior labial nerves).
From the sacral plexus.	
Internal pudic—	
Perineal branch........	To labia (posterior labial nerves), nymphæ, prepuce and glans of clitoris, vestibule and meatus urinarius (nerve of vestibule), bulb of the vestibule.
Dorsal nerve of clitoris.	Glans, prepuce, body and crura of clitoris.
Small sciatic—	
Inferior pudendal branch.	To labia (posterior labial nerves).

LITERATURE.

The following have been freely used in the preparation of this article. In Waldeyer, Rieffel, and Nagel excellent bibliographies will be found.

Rieffel, H.: Appareil génital de la femme. In vol. v. of Poirier's Traité d'anatomie humaine, Paris, 1901.

Waldeyer, W.: Das Becken, Berlin, 1899.

Testut, L.: Traité d'anatomie humaine, vol. iii., Paris, 1894.

Nagel, W.: Die weiblichen Geschlechtsorgane. In Bardeleben's Handbuch der Anatomie des Menschen, Bd. 7, 2te Teil, 1te Abtheilung, Jena, 1896.

Frank Baker.

SEXUAL ORGANS, MALE. See *Genital Organs, Male.*

SEXUAL ORGANS, MALE, INJURIES AND DISEASES OF.—I. CONGENITAL DEFECTS OF THE PENIS. —*Abnormalities in Shape and Size of the Penis.*—Abnormalities in the size of the penis are of relatively frequent occurrence, although they do not naturally come under the surgeon's observation. No two penes are alike in size, and the general rule that the length of the penis varies inversely to the girth of its possessor is commonly accepted. It is alleged that rudimentary development of the penis is often associated with intellectual deficiency. It is also alleged that men of great intelligence have undersized genitals. Cryptorchids and sufferers from epispadias and hypospadias habitually have small penes. That sexual exercise has any influence upon the size of the penis is not proven. The so-called penis congestor is a mere gauge of gullibility.

Absence of the Penis.—When the penis is so small as to be apparently or actually absent the testicles are usually retained in the groin or in the abdomen, and the scrotum is split. As a result the genital organs resemble those of the female, and the condition is that of complete male pseudohermaphroditism.

Apparent Absence of the Penis.—The penis may be congenitally adherent to the scrotum; very rarely it is concealed beneath the skin of the abdomen or of the scrotum. Thus Bouteiller reported a case in which the penis appeared to be absent, but could be felt beneath the skin of the scrotum, whence it was liberated by a T-shaped incision. Usually, however, the penis is curved and only partially adherent. Such a condition is commonly accompanied by hypospadias.

Double Penis.—Double penis is extremely rare. A number of cases have been recorded in which the penile abnormality was associated with other evidences of fœtal inclusion. Exceptionally, the reduplication of the genital organ is the only abnormality. How frequent such a condition is it is impossible to estimate, since patients so afflicted not only fail to apply for relief, but sedulously shun observation. Four cases have been recorded.*

Torsion of the Penis.—This is an unusual feature of hypospadias and epispadias (*q. v.*). Caddy † has reported a case of torsion unaccompanied by any other defect.

II. PHIMOSIS.—Phimosis is an abnormal tightness of the prepuce. There are two kinds of phimosis: the one consists in an adhesion of the prepuce to the glans penis, and this is a normal condition in every male child at birth. The relief of such a phimosis is accomplished by forcibly stripping back the foreskin until the glans is entirely uncovered, recurrence of the adhesions thus torn being prevented by the application of dusting powders and by repeated retraction of the skin. This minor operation is noteworthy chiefly because its omission is the commonest cause of permanent cicatricial phimosis.

The second variety of phimosis is an undue tightness of the prepuce caused by a chronic thickening at the preputial orifice, and resulting in an inability to retract the prepuce. Such phimosis is commonly spoken of as being either congenital or acquired; but, strictly speaking, it is probably always acquired, since the thickening at the preputial orifice which prevents retraction seems, in the cases called congenital, to be occasioned by the adhesive phimosis noticed above, and by the balanoposthitis to which it gives rise; acquired phimosis is caused by any inflammation of the prepuce, notably by chancroids occurring at the preputial orifice. During the course of any of these inflammations a temporary phimosis, known as inflammatory phimosis, may be caused by inflammatory œdema.

Results of Phimosis.—If the prepuce be unduly tight, or merely unduly long, it may cause two different sets of conditions, the one irritative, the other obstructive. Thus in infancy it encourages balanoposthitis, adhesions, premature sexual excitement, and masturbation; while, from retention, it may cause incontinence of urine, frequent and painful micturition so painful as to lead to the suspicion of stone; while the straining to overcome the obstacle may result in hernia and rectal prolapse. In later life the obstruction may give rise to hypertrophy of the bladder and dilatation of the ureters and kidneys; while chronic retention may result in the form of preputial calculi, in intensified venereal troubles, especially gonorrhœa and chancroid (*q. v.*), and epithelioma of the penis (*q. v.*). Finally, phimosis interferes with coitus, and violent retraction of the tight prepuce may result in paraphimosis.

Treatment.—The treatment of phimosis is circumcision. The operation of dilating the prepuce is not worthy of consideration (*cf. Circumcision*).

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* Keyes: "Diseases of the Genito-Urinary Organs," third edition, 1903.

† Lancet, 1894, ii., 631.

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III. Paraphimosis.—Paraphimosis is that condition in which the phimotic prepuce, having been forcibly retracted behind the corona glandis, cannot be replaced. The immediate result of such retraction is an acute œdema of the prepuce and the glans penis, which œdema persists and tends to grow larger and more leathery, and thus to form the chief obstruction to the surgeon's efforts at retraction. When the patient is seen the glans penis is greatly swollen and congested, while behind it rises a tense, shining œdematous collar of mucous membrane, behind which again lies a deep sulcus, most marked on the dorsum of the penis. This sulcus is the site of constriction; it is often ulcerated. Behind it usually arises a second collar. If the circulation is completely obstructed, spots of gangrene will be found upon the glans and the prepuce.

Fig. 4248.

Fig. 4249.

Figs. 4248 and 4249.—Simple Methods of Reducing Paraphimosis.

Treatment.—The treatment of paraphimosis depends upon the severity of the local reaction. If the obstruction is slight and there seems to be no danger of gangrene, palliative and mechanical treatment may be employed, in the hope of reducing the œdema sufficiently to permit reposition of the prepuce; but if gangrene threatens, the paraphimosis must be relieved at once lest the patient lose a portion of his penis.

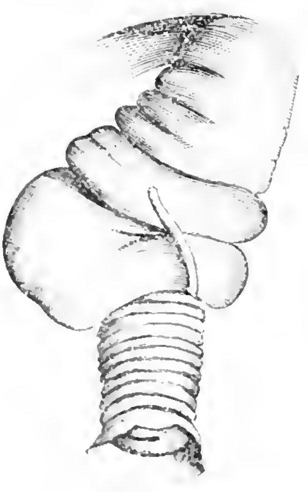

Fig. 4247. Method of Reducing Paraphimosis.

Mechanical Treatment.—The first aim of the surgeon must be to reduce the œdema as far as possible. This may be done by encircling the glans penis with tape or cotton string (Fig. 4247), or by applying over the whole penis a compressing wet dressing of boric-acid solution. Such a dressing should be applied as tightly as possible, and should be left in place not longer than an hour or two, after which reduction should be attempted. In reducing a paraphimosis the physician's efforts should be directed to slipping the constricting band over the glans penis, rather than to forcing the glans through the constriction. This may be accomplished in several ways, the simplest of which are shown in Figs. 4248 and 4249.

Surgical Treatment.—But mechanical treatment may fail, or the presence or imminence of gangrene may call for immediate relief, or the surgeon may very wisely conclude that his patient requires relief, not only from his present difficulty but also from the danger of its recurrence, a relief which can be obtained only by some sort of operation. The sole requirement is to relieve the penis from its constriction, and this is best accomplished as follows: The skin behind the constriction is rendered surgically clean, and a small area on the dorsum of the penis near its root is infiltrated with cocaine. In this area a longitudinal incision is carried through the skin to one side of the dorsal vein and just long enough to admit a small, blunt-pointed straight bistoury or tenotomy knife. This is burrowed forward through the loose, subcutaneous connective tissue until it arrives on the dorsum at the constricting band. Here some care is required to insert the knife blade beneath the constriction without puncturing it. When this is done the knife blade is turned outward and the constriction thoroughly divided, the knife immediately withdrawn, and the first incision protected with a collodion dressing. The prepuce may then be replaced, unless excessive œdema renders this impossible, and the penis is held erect and covered with a mild antiseptic wet dressing. The after-treatment requires no special comment, though circumcision may subsequently be necessary in order to obtain an æsthetic result.

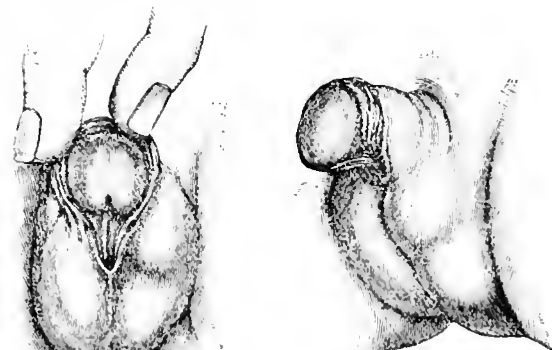

Fig. 4250. Penoscrotal Hypospadias. Front and side views.

IV. Hypospadias and Epispadias.—Hypospadias is a lack of union of the urethra upon its floor, while epispadias is a similar lack of union upon its roof. The canal may thus terminate at any point between the bladder

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and the normal meatus. Hence in hypospadias the canal may terminate (1) at the base of the glans (balanitic hypospadias), or (2) in the penile urethra (penile or penoscrotal hypospadias) (Fig. 4250), or (3) in the perineum (perineal hypospadias). Similarly epispadias may be balanitic or penile. The urethra may continue forward in front of the hypospadic or epispadic opening, or this remaining portion of the canal may exist only as a shallow gutter.

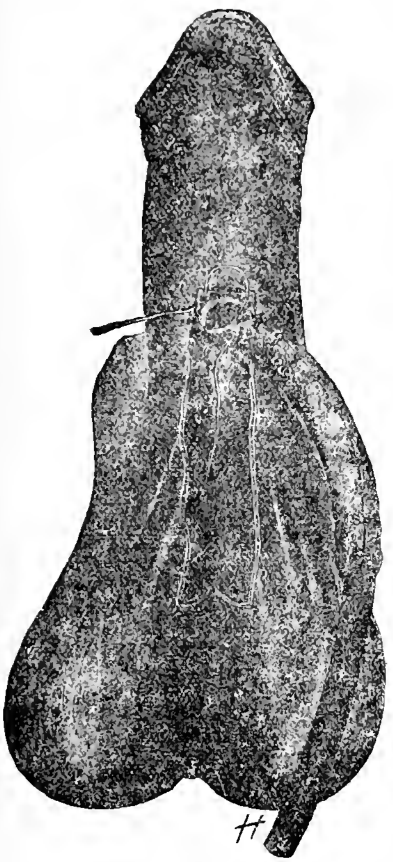

FIG. 4251.—Rochet's Modified Nové-Josserand Operation for Hypospadias. The flaps are cut, the catheter is introduced, and the scrotal flap sutured around it.

With urethral deformities of the graver sorts are often associated such deformities of the penis as incurvation, torsion, and scrotal adhesion; while with perineal hypospadias the scrotum is often split, and there may be other features of pseudohermaphroditism. Of these various deformities, balanitic hypospadias is by far the most common, while penile hypospadias stands next in order of frequency. Epispadias and perineal hypospadias are extremely rare. There seems to be a hereditary tendency to the occurrence of these urethral defects.

Symptoms.—The symptoms of hypospadias and epispadias are sexual and urinary. The sexual symptoms are incomplete erection and imperfect emission due to the urethral and penile defect, and varying in severity with the gravity of this defect. Though it is alleged that balanitic hypospadias may cause relative sterility by producing insufficient ejaculation, this theory is by no means proven; while the many known cases in which hypospadic individuals have had numerous children are at variance with the theory. The urinary symptoms of hypospadias consist in a deflection and a dribbling of the stream in all but the perineal cases; in these the patient cannot safely urinate excepting in a squatting posture. Yet the urethra always terminates in front of the triangular ligament, and, therefore, there is never incontinence of urine in hypospadias. In epispadias, however, the urethral orifice may be large and situated practically in the anterior wall of the bladder, there being little or no vesical sphincter. A patient suffering from this malformation has incontinence of urine, and is in almost as sorry a plight as he who suffers from exstrophy of the bladder. (*Cf. Bladder of the Male*—Malformations.)

Treatment.—The multiplicity of operations that have been suggested for the cure of hypospadias and epispadias attests the inefficiency of all of them. Time and again new procedures are advocated and new statistics compiled to prove the efficiency of one or the other operation. Yet it remains true to-day that no operation is ideal, that no operation can absolutely promise success, and that no operation should be attempted without the understanding that the best results can be obtained only by a succession of steps, the completion of which will certainly require several months, perhaps several years.

In general, the operation may be divided into two parts: (1) the relief of associated penile deformities, and (2) the relief of the urethral deformity.

Relief of Penile Deformities.—If there is incurvation of the penis or penoscrotal adhesion, this requires relief before the urethra is attacked. Adhesion is relieved by dividing the adhering skin transversely and suturing it longitudinally. Incurvation of the penis is relieved by carrying this transverse incision through the sheath of the corpora cavernosa and, if necessary, deeply into the intercavernous septum, and bandaging the organ in an overextended position until complete healing occurs. The urethral defect may now be attacked, the mode of attack depending upon the nature of this defect.

Relief of Balanitic Hypospadias.—While balanitic hypospadias cannot be said to demand relief, the patient may prefer that an attempt should be made to place his urethral orifice in the normal position at the end of the gland. This may best be done by Beck's operation, which is performed as follows: The prepuce is separated from the glans penis by a transverse incision running from side to side across the venter of the organ and skirting the orifice of the hypospadic urethra. The proximal flap of prepuce is then freely dissected up, exposing an inch or more of the urethra. This terminal part of the urethra is then dissected free from the surrounding tissues and carried forward until the meatus can be sutured in its proper position at the head of the glans penis, the glans having been prepared to receive the urethra by a simple incision or by puncture. The meatus is sutured in place, the preputial skin is brought forward over the urethra, and the suture and the wounds are sealed as far as possible with collodion.

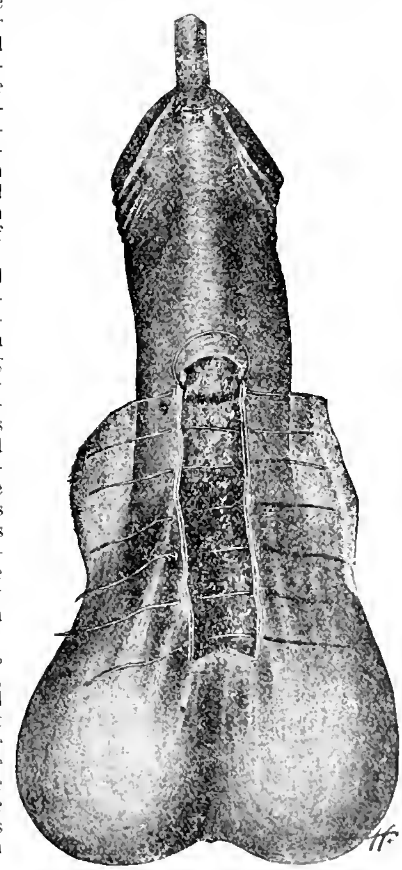

FIG. 4252.—Rochet's Modified Nové-Josserand Operation for Hypospadias. The final sutures.

Relief of Penile and Perineal Hypospadias.—Of the operations employed for the relief of penile and perineal hypospadias Duplay's is the most favored by text-books. This operation is performed as follows: A soft-rubber catheter is inserted through the urethra into the bladder and is carried forward along the groove on the under surface of the penis until it finally issues through a hole punched in the imperforate glans.

By means of a longitudinal incision, one third of an inch from the median line on each side, flaps are raised to surround this catheter, their epithelial surface inward. These are sutured with catgut, and the exposed raw surface is covered by flaps raised and carried inward from the sides of the penis.

Such operations as Duplay's have not been very successful, because the flaps do not unite well and the fistula left between the old hypospadic urethra and the new artificial one is very hard to close, both on account of the smallness of the parts—since these operations are habitually performed on children—and the befoulment by urine.

An operation which promises to avoid this difficulty is the Rochet-Nové-Josserand procedure. This is performed as follows: The hypospadic meatus having been incised in order that there may remain no stricture at this point, a transverse skin incision 2 cm. long is made just in front of it. Through this incision a stout probe is introduced and passed forward in the subcutaneous cellular tissue of the venter of the penis, thus burrowing a channel, the anterior orifice of which is formed by a slit or a puncture in the glans penis. A long rectangular flap is then cut from the perineum, its base surrounding the hypospadic orifice. It should be a little over 2 cm. wide and one-third as long as the new urethra is expected to be.

A small soft-rubber catheter is then introduced into the bladder, the flap is sutured around this with the finest catgut (Fig. 4251), and the distal end of catheter and graft is pushed through the subcutaneous canal and out at its anterior orifice, where the flap is sutured (Fig. 4252). A few skin sutures taken transversely close the perineal wound, and the child is then immobilized in a plaster-of-Paris dressing and put to bed with the penis in an erect position and the catheter leading into a urinal. This catheter should be left in place five or six days, after which spontaneous urination may be permitted.

The *after-treatment* consists in the passage of bougies every week or so in order to insure the patency of the canal. This operation reduces to a minimum the probability of fistula, and has been followed by admirable results.

Relief of Epispadias.—Epispadias is so rare that the surgery of this condition has not yet been satisfactorily developed. Duplay's operation may be applied to the epispadic urethra, while it is probable that Rochet's operation could be modified to give as good results here as in hypospadias.

The favorite operation of the text books is Thiersch's, in which the penile canal is formed by an inverted flap from one side of the penis covered by a longer direct flap carried across from the opposite, the inverted flap forming the roof of the urethra, the direct flap forming the skin covering. The fistula at the base of the penis is covered in by triangular flaps, one turned inside out and the other simply brought down and covering the raw surface, while the fistula at the base of the glans is covered by transferring the loose preputial skin from below the glans. Thiersch's original case was cured by this method after eighteen months. When epispadias is complicated by loss of the vesical sphincter, it may be regarded as a mild case of vesical exstrophy and should be treated accordingly.

It may be observed that none of these operations pretends to replace the corpus spongiosum, and the new urethra, bereft of its physiological coverings, may not be expected to perform its urinary and sexual functions in a perfect manner.

V. Injuries of the Penis.—*Contusion and Fracture.*—The flaccid penis may be expected to escape the buffets of adversity more readily than any other part of the body; injuries inflicted upon the erect penis are habitually in some manner sexual. Thus contusion may result from misguided efforts in coitus; strangulation is occasionally caused by encircling the penis with a metallic ring; and the so-called fracture, which is actually a rupture of the erectile bodies, is only a more severe injury due to like causes. Even though the contusion be but slight, hemorrhage into the loose subcutaneous tissue of the penis is likely to be free; while fracture of the erectile bodies is immediately followed by alarming subcutaneous hemorrhage, which may swell the organ to an incredible size.

The two therapeutic indications are control of hemorrhage and prevention of retention. The former is accomplished by the application of cold and pressure, or, if these fail, by incision; while the latter may require a retained catheter. In mild cases surrounding the penis with ice for a few hours is all that is required. But if the erectile bodies are fractured, it is wiser to incise immediately over the seat of the injury and to suture the torn fibrous sheath.

Open Wounds.—Open wounds require similar treatment, control of hemorrhage, and suture of the sheaths of the erectile bodies. If the injury to the erectile bodies has been severe the resultant scar may permanently impair erection.

Dislocation.—A few cases have been reported in which violent traction upon the skin of the flaccid penis has resulted in tearing this free at the balanopreputial junction and permitting the penis to slip under the integument of the thigh, the abdomen, or the scrotum. The immediate œdematous reaction conceals the absence of the penis from its cutaneous envelope, and it is not until catheterization is attempted or urination occurs that the abnormal position of the penis is discovered.

Nélaton was able in one case to replace the penis by means of an aneurism needle; but if this could not be done, it would always be possible to reach it by an incision. And in this connection it must be remembered that, even though the patient has urinated beneath his skin, unless the urine is infected it may be disregarded and will probably be absorbed.

Skin Diseases. See *Skin Diseases of the Scrotum*, below.

Balanoposthitis. See *Balanitis.*

Venereal Ulceration. See *Chancroid, Syphilis.*

Herpes Progenitalis. See *Herpes.*

Lymphangitis and Cellulitis. See *Chancroid, Gonorrhœa.*

VI. Inflammation of the Erectile Bodies.—This condition, known variously as penitis or cavernitis, is extremely rare. Spontaneous inflammation is said to occur during acute exanthemata. The inflammation which occurs as a result of injury must be combated by the usual local antisepsis and drainage and irrigation, while the inflammation of the corpus spongiosum complicating gonorrhœa and stricture is a condition which meets consideration in the articles upon those subjects.

VII. Gangrene of the Penis.—The blood supply of the penis is so generous that gangrene of this organ is most exceptional. Yet it may occur from three causes: (1) strangulation, (2) virulent infection, (3) debility.

Strangulation is the commonest cause of penile gangrene. It occurs mechanically, as when the penis is encircled by a ring, or by a paraphimotic prepuce, and from inflammation, if the inflammatory reaction is severe enough to obstruct the lymph spaces. Virulent infection, a less frequent cause, is well exemplified by phagedena (see *Chancroid*), and by infiltration of urine (see *Urethra*, etc.). Debility, whether senile or diabetic, exceptionally causes gangrene, as do also thrombosis and embolism.

Treatment.—The treatment of these various forms of gangrene consists primarily in the removal of their cause. Thus a paraphimosis causing gangrene requires immediate reduction or incision. A ring around the penis must be cut away, or, if it be gold, amalgamated by the application of metallic mercury. Infiltration of urine calls for prompt incision and drainage (see *Urethra*, etc.). Severe cellulitis requires liberating incisions and wet dressings, while phagedena demands prompt and energetic antisepsis (see *Chancroid*). Senile and diabetic

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gangrene present here as elsewhere a most gloomy prognosis; yet much may be done by stimulating and dieting the patient and by cleansing and keeping clean the dead tissue.

A discussion of this part of the treatment will be found in the article on *Gangrene*.

VIII. TUBERCULOSIS.—Tuberculous ulceration of the glans and prepuce is very rare. It may be confounded with carcinoma or with venereal ulceration. The tuberculous ulcer is "shallow, rarely attaining a great size, with characteristic edge, is made up of a succession of small, jagged indentations, caused by the degeneration of miliary tubercles, so that the lesion has an appearance as if gnawed out. The floor of the ulcer is not, as a rule, crusted, but covered with a seropurulent fluid, and occasionally yellowish elevations, representing miliary nodules, may be seen scattered over its surface. At the periphery also these miliary nodules may sometimes be seen, and their presence is of course pathognomonic, although frequently they are absent" (Bowen).

A number of cases of tuberculous infection of the prepuce following ritual circumcision have been reported. This infection is attributed to inoculation from tubercle bacilli in the mouth of the rabbi who sucks the wound. Thus Lehmann found ten children infected by one man; three of them died marasmic.

IX. CIRCUMSCRIBED FIBROSIS OF THE ERECTILE BODIES.—Circumscribed fibrosis of the erectile bodies, otherwise known as chronic inflammation or induration of the corpora cavernosa, consists of a hard fibrous deposit in the sheath and the adjoining portions of the erectile tissue of one of the erectile bodies of the penis. This fibrous mass feels like a flat plate set in but not projecting from the surface of the erectile body. It is fairly common in the corpora cavernosa, of which it may affect one or both, but is very rare in the corpus spongiosum. The nature of this growth is disputed. The few specimens that have been examined have proven to be fibromata or enchondromata. Sometimes a single specimen is fibrous in one part, cartilaginous in another, and bony in another. Such a tumor has been excised by Dr. Chetwood.

Circumscribed fibrosis habitually appears upon one or other of the corpora cavernosa of a man between thirty-five and fifty-five years of age. The patient first notices that his penis when erect deviates toward the side affected. Less often the first symptom is a slight uneasiness in the region of the growth. But the patient does not habitually recognize the presence of any abnormal tissue before he presents himself for examination. This reveals a hard, flattened mass with sharply defined margins occupying the substance of one or both corpora cavernosa near the surface, and feeling like cartilage. The edges of the mass may be slightly elevated and slightly tender. The mass is usually irregularly oval in shape. The tendency of this growth is to change. It grows either larger or smaller and either toward or away from the root of the penis, involving new portions of the corpora cavernosa as it recedes in other directions.

Thus the *prognosis* of the condition is most uncertain. It is impossible to say where it will next shift to, and whether it will grow larger or smaller.

The two *symptoms* of the disease are the very slight pain and the bending on erection, the latter being often so great as to prevent intromission. As Verneuil first observed, this condition is apparently analogous to Dupuytren's contraction of the palmar and plantar fascia, and is habitually associated with gout. It has been suggested that diabetes plays some etiological rôle, but further experience has disproven this.

I know no *treatment* that can be depended upon to remove this growth satisfactorily. The application of ointments, of iodine, of electrolysis, and of blisters has uniformly failed. Alkaline and anti-gouty remedies seem to do some good in such cases. Cures have been reported after excision, but, inasmuch as this only replaces the new growth with scar tissue, it is not justifiable to promise a cure by the knife; although operation may be undertaken if the patient is willing to recognize that it is not a certain cure.

X. CALCIFICATION AND OSSIFICATION OF THE PENIS.—Calcification of portions of the corpora cavernosa is very rare and ossification is most unusual; only five cases of the latter condition have been reported. Apparently the cartilaginous or bony tumor develops secondarily in an area of fibrosis. The only treatment is excision.

XI. HORNS.—Soft warts of the glans or prepuce may become cornified and grow as horns. These horns seem peculiarly liable to epitheliomatous degeneration.

XII. MALIGNANT NEOPLASMS.—The primary neoplasms of the penis are epithelioma and sarcoma; secondary neoplasms are extremely rare.

Primary sarcoma begins in the cavernous tissue of one of the erectile bodies; it usually appears in early manhood and develops with characteristic rapidity, promptly involving the inguinal glands. As the tumor grows it causes priapism by closing the cavernous spaces, and may also obstruct the urethra, causing retention of urine. Early amputation is the only treatment (see below).

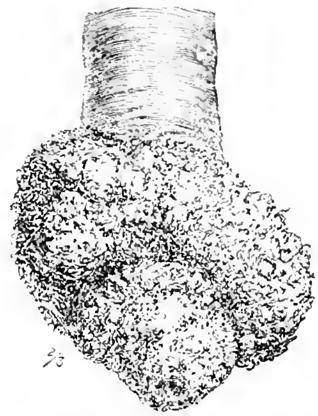

FIG. 4253.—Epithelioma of Penis.

Primary epithelioma occurs exceptionally in the urethra and fairly frequently in the prepuce and the glans (Fig. 4253). A few cases of epithelioma have been observed in early life, as, for instance, one of Freyer's at the age of seventeen. The growth may develop from scar tissue, as from urethral fistula or from the scars of injuries or of venereal sores; but the commonest sources of epithelioma are soft warts and chronic balanitis. Twenty-nine of the thirty-seven cases collected by Kaufmann began as apparently benign warts. Tight phimosis, by retaining the smegma and encouraging balanitis, seems to have a marked predisposing tendency. Thus Demarquay noted phimosis in forty-two out of fifty-nine cases, and it is claimed that the circumcised Jew does not suffer from this disease. There is no evidence that the penis may be inoculated from the carcinomatous cervix uteri.

Jacobson recognized four ways in which penile epithelioma may first show itself: 1. It usually begins as a wart, its malignancy being first recognized by the indurated and ulcerated base and the exuberant growth. 2. The first evidence may be a subepithelial lump or induration without warty excrescence or ulceration; this little, apparently innocent nodule is distinctly malignant. 3. A superficial excoriation may persist after a balanitis, comparable to the condition in the tongue when a leucoplakia becomes raw, and is the first evidence of malignant disease. 4. Very rarely the new growth begins as an ulcer, either proceeding from a venereal ulcer, arising from the scar of such an ulcer, or coming on after some injury.

Whatever be the origin of the tumor, it soon becomes frankly malignant, its base is indurated, elevated, and ulcerated; the discharge is thin, sanious, and foul, while there may or may not be exuberant warty overgrowth. The inguinal glands suffer a pyogenic as well as a cancerous infection, enlarge, become matted together, suppurate and ulcerate. The ulcers thus formed become new centres of epitheliomatous invasion. The primary disease spreads superficially, sparing the corpora cavernosa and the corpus spongiosum, although widely involving the skin and destroying the glans. If the urethra

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becomes obstructed the urine is passed through fistulous openings in the floor of the canal.

The foul discharge, the disgusting ulceration, and the liability to profuse hemorrhage are the symptoms of which the patient complains; pain is rarely troublesome until late in the disease. The ulceration spreads superficially quite as does epithelioma in other parts of the body, and the patient finally dies septic and cachectic. Lymphatic infection often gets no further than the inguinal glands, so that large visceral metastases are exceptional.

Diagnosis.—Penile epithelioma may be confused with chancre, chancroid, warts, tuberculous ulcers, and ulcers from chronic balanoposthitis. After the disease is well advanced there can be no possible doubt of its malignant nature; but in the early stages, when its character may still be doubtful, it is wiser to subject every growth of the penis which does not react promptly to treatment or which appears spontaneously or in an aged subject, to excision and microscopical examination for the purpose of determining its nature.

Treatment.—An epithelioma of the penis seen and recognized at its outset may usually be removed by circumcision if on the prepuce, or by cauterization with arsenious acid if on the glans; in this it resembles epithelioma of the other parts of the body. But if it has grown so widely as to destroy the greater part of the glans, or if the inguinal glands are already involved, the penis should be amputated close up to the pubes and the glands extirpated. Finally, if the greater part of the penis is covered by the ulcer, the treatment required is extirpation of the penis and simultaneous castration. Recurrence of the disease may be attacked by caustics or by the *x*-ray and thus controlled or even, exceptionally, cured.

XIII. Amputation of the Penis.—The patient should be prepared as for any aseptic operation; general anæsthesia is required. The operation is begun by tying a rubber catheter around the root of the penis; this may be held in place by harelip pins. Ample skin flaps are then elevated and dissected back fully an inch, after which the knife is inserted between the corpus spongiosum and the corpora cavernosa, and the latter are cut off three-fourths of an inch shorter than the former.

The elastic ligature is now removed and profuse hemorrhage immediately follows. The dorsal arteries must be caught and tied, and perhaps one or two arterial branches may require similar treatment; but after the first gush is conquered the oozing from the erectile bodies is controllable by pressure. The urethra is then split into two flaps and sutured to the skin flaps, which are then sutured in place and the whole dressed aseptically, with provision for the passage of urine through a retained catheter.

Flaps.—A circular skin incision may be employed, but neater apposition is obtained by employing skin flaps. Senn and Jacobson use long dorsal and short ventral flaps, Jacobson making the dorsal flaps so long that the urethra may be sutured into a perforation in its lower extremity. Other operators employ lateral flaps; while Dr. Davis, of Philadelphia, makes three urethral flaps each cut to a point and sutured to the skin, divided circularly. The urethra is split in order to avoid stricture at the new meatus.

After-Treatment.—The two things most to be feared are hemorrhage and tension on the flaps, both of which are due to erections. A light dressing and the free employment of bromides insure safety.

XIV. Extirpation of the Penis.—In order to remove the erectile bodies it is necessary to place the patient in the lithotomy position and to make a skin incision surrounding the base of the penis, thence splitting the scrotum from one end to the other of the raphé. Blunt dissection separates the two halves of the scrotum down to the corpus spongiosum. A sound is passed as far as the triangular ligament where the urethra is divided just in front of the bulb and thence freed back as far as the hole in the triangular ligament. The suspensory ligament is then divided, and each crus dissected out and separated from the pubic ramus by means of a stout periosteal elevator; this completes the removal of the organ. The edges of the scrotal incision are then united, the stump of the urethra being split and stitched to the lower end of the wound. Drainage is required, for there is likely to be some post-operative oozing as well as considerable hemorrhage during the operation. No retained catheter is needed.

Total Emasculation.—French surgeons seem generally agreed that it is wise, in extirpating the penis, to remove the testicles at the same time, since, as they allege, the removal of these glands lessens the hypochondriacal and maniacal tendency which this very operation has been said to cause when employed for the relief of prostatic hypertrophy. It is best in this matter to consult the wishes of the patient. The testicles are readily removed through the scrotal incision.

XV. Extirpation of the Inguinal Glands.—It is always wise to remove the inguinal glands as an accompaniment to any operation for penile epithelioma, since these glands may be infected even though they appear normal. If the glands are small they may readily be shelled out, if large or matted together there is danger of opening the femoral vein in the region of the saphenous opening in the fascia lata; hence, this should be sought for and worked away from in all difficult operations in this region.

XVI. Scrotal Injuries, Inflammations, and New Growths.—*Wounds.*—Scrotal wounds, whether surgical or accidental, bleed freely, and efficient hæmostasis of this bleeding is the most important feature of the treatment. Every bleeding vessel must be carefully caught and tied, for there is danger of the formation of an enormous hæmatoma, which may extend to the penis, thigh, and abdomen. Wounds of the scrotum, like those of the penis, heal readily and do not often suppurate.

Loss of Tissue.—Even though the greater part of the scrotum is destroyed by disease or by accident, the surgeon need not feel called upon to fill in the gap by a plastic operation. For such is the elasticity of the scrotal skin that cicatricial contraction will draw it over the exposed testicles and close the largest gaps within a few weeks, unless the patient is septic.

Contusion and Hæmatocele.—Scrotal contusions are manifested by great ecchymosis and œdema quite comparable to the familiar black eye. Compression (see Epididymitis, p. 181) and an ice-cap is the proper treatment if the case is seen early; later, absorption may be promoted by heat, while it is only in the most exceptional cases that incision is required. Extravaginal hæmatocele (blood cyst of the scrotum) is an encysted scrotal hæmatoma requiring incision (Fig. 4254).

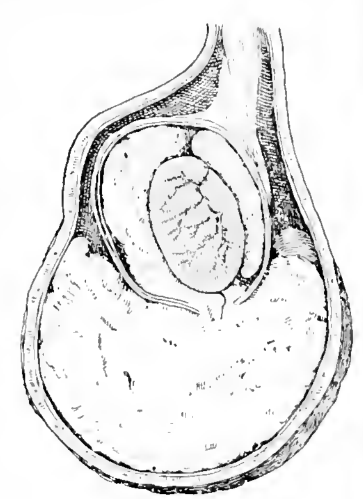
Fig. 4254.—Hæmatocele, Scrotal and Vaginal.

Scrotal Inflammations.—The inflammations of the scrotum closely resemble those of the penis in most of their characteristics. Gangrene of the scrotum following urinary infiltration in an aged or debilitated subject is often rapidly fatal, and must be combated by stimulants, free incisions, wet dressings, and excision of sloughs as fast as they form. Castration is never required.

Elephantiasis. See *Elephantiasis.*

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Cysts.—Small sebaceous cysts showing pearly white through the distended skin may occur anywhere on the penis and scrotum, but are usually found on the raphé; they may grow very large. Jacobson and Tilden Brown have recorded cases of so called cystic disease of the scrotum. Echinococcus cysts have also been found in this part of the body. Small subcutaneous capillary dilatations may occur in the skin of the scrotum; they show dark blue, and are totally harmless; but if the patient objects to them they may be cured by a minute incision and the application of nitrate of silver.

Solid Tumors.—Angioma, fibroma, lipoma, fibromyxoma, osteochondroma, and sarcoma occur in the scrotum; but the only neoplasm sufficiently common to merit notice is epithelioma, the so-called chimney-sweeps' cancer (see *Carcinoma of the Skin*).

XVII. Anomalies of the Testicle.—The accepted classification of anomalies of the testicle is that of Monod and Terrillon, as follows:

Anomalies in development	In number	In excess		Polyorchism.
		Deficient	Absence	Anorchism.
			Fusion	Synochism.
	In size	In excess		Hypertrophy.
		Deficient		Atrophy.
Anomalies in migration	Undescended	Incomplete migration		Retention.
		Abnormal migration		Ectopia.
	Descended			Inversion.

1. *Anomalies in Development.*—Polyorchism.—According to Jacobson, supernumerary testicles are sometimes found in certain animals, and the older literature contains many alleged instances of this condition in man. The only case in which the diagnosis was confirmed by microscopical examination is that reported by Arbuthnot Lane in *The British Medical Journal* of 1894. I have seen one case diagnosed by an able surgeon as polyorchism, in which the third testicle proved to be a large spermatocele.

Anorchism.—The absence of one or both testicles is rare. It is usually associated with absence of the epididymis and part of the vas. Exceptionally, the whole vas is wanting; still more rarely the testicle alone is absent. On the other hand, the testicle may be present and the seminal ducts absent. During life anorchism can be differentiated from abdominal cryptorchism only by operation.

Synorchism.—A fusion of the testicles has twice been observed, the glands being retained in the abdomen in each case.

2. *Anomalies in Migration.*—Cryptorchism.—In contrast with the rarity of the anomalies enumerated above is the familiar condition of cryptorchism, *i.e.*, absence of one or both testicles from the scrotum. The testicle may be either retained or ectopic; if retained it is arrested at some point in its normal descent; if ectopic it is lodged out of its normal path. Marshall records 11 cases of cryptorchism among 10,800 English recruits, while Rennes encountered 6 cases among 3,600 French recruits. Of these 17 cases only 1 was bilateral.

Retention of the testicle is caused by obstruction to its progress from the abdomen or by traction from behind. Thus some cases are attributed to peritoneal adhesions which close the inguinal canal at some point before the testicle has descended; in other cases there is an alleged congenital shortness of the vas.

The *etiology* of this condition, however, is very obscure, and has no direct bearing upon its clinical aspects. Suffice it to say that the commonest form of retention is the inguinal variety, the testicle lying in the inguinal canal (Fig. 4255), sometimes near the external sometimes near the internal abdominal ring. A certain freedom is usually enjoyed by the gland, so that in many young subjects a testicle in inguinal retention may be reduced either into the abdomen or into the scrotum. Puboscrotal retention, in which the testicle lies high up in the scrotum close under the pubes, is a less common condition; while abdominal retention—the testicle not having reached the inguinal canal at all—is most exceptional.

The ectopic testicle may be found in the perineum beneath the deep fascia just in front of the anus, or at the saphenous opening of the crural canal, or in the opposite side of the scrotum, or at the base of the penis in front of the pubes. These last two varieties have each been seen but twice; indeed, any form of ectopia is extremely rare.

Inversion of the testicle occurs when that organ is turned upside down in the scrotum or rotated so that its long axis is horizontal. The only clinical significance of this very rare anomaly is that, in hydrocele, the inverted testicle may lie above and in front of the sac, instead of below and behind it, and thus be punctured by the aspirating needle.

Fig. 4255.—Retained Testicle.

The pathological condition of the retained testicle is a subject of great interest, both because it is alleged that pressure of the abdominal muscles makes the gland especially liable to sarcomatous degeneration, and because it seems proved that this pressure habitually destroys the functionating power of the gland. Thus a double cryptorchid is habitually sterile. So general is this rule that Curling, after enumerating several cases of children born of women married to cryptorchids, felt compelled to doubt their paternity. Yet recent investigations have shown that retained testicles may acquire and retain, at least for a few years, the power of secreting spermatozoa. Thus Beigel found numerous spermatozoa in the semen of a double cryptorchid aged twenty-two, while Valette found a few in a retained testicle removed from a man in his twenty-first year. Yet Bellingham Smith alleges that cryptorchids never retain their virility for more than five or ten years. The question of the sterility of any given case may be determined by examination of the seminal fluid.

But apart from the atrophy and sterility of the retained testicle, this gland is subject to other dangers. Neuralgia is often the first evidence that the testicle is being affected by pressure of the surrounding muscle, and any inflammation, whether traumatic, gonorrhœal, or tuberculous, is sure to run a severe course and is habitually followed by atrophy. Finally, the great danger of these patients is that the testicle may become sarcomatous. It is difficult to estimate how frequent this sarcomatous degeneration may be, and yet, viewing it merely as a possibility taken in connection with the congenital hernia which habitually accompanies cryptorchism, it is enough to determine the surgeon always to remedy the congenital defect.

In infancy the proper *treatment* of retained testicle is the application of a truss, whereby the hernia may be reduced and the testicle forced down into the scrotum. I have succeeded in curing a number of cases in this manner, and have always preferred it as a preliminary to operation, although a cure may not be expected after the child is ten years of age. If mechanical treatment fails or if the patient has passed his tenth year herniotomy offers the only hope of cure. And this should be strongly urged upon the patient as calculated to cure his hernia, to insure him as far as possible against sterility, and to relieve him from the danger of sarcoma.

Broca has operated 138 times without a death; 79 of these cases were followed for a year or more. Of these, 31 had testicles normal both in size and position; 35 had testicles normal in size, but abnormal in position (near the external ring); while only 13 had undergone atrophy. These brilliant results were obtained on young children.

In order to reduce the testicle the usual operation of herniotomy is performed. The testicle is freed from all obstructing envelopes, and the cord is followed up as far as possible into the abdominal cavity and freed by the finger from all fascial bands. The further the cord is followed the further can the testicle be pulled out into the scrotum. Wood's device of freeing the vas from the globus major and then inverting the testicle may be mentioned as an ingenious way in which to gain an inch. If the testicle cannot be reduced it may be removed or replaced in the abdomen; but since the latter alternative leaves it subject to every danger and relieves only the hernia, it is my preference always to castrate if reduction is impossible.

Hypertrophy and Atrophy of the Testicle.—There is considerable variation in the normal size of the testicles as in that of the penis. When one testicle is defective or wanting its fellow seems to take on a certain compensatory hypertrophy. On the other hand, atrophy may occur in two ways: there may be arrest of development, or a testicle previously normal may atrophy from injury; *e.g.*, section or obstruction of the spermatic vessels; from pressure, *e.g.*, large hydrocele or varicocele; from inflammation, *e.g.*, orchitis, and rarely from injuries to the nerves, the spinal cord, or the brain. Atrophy is never due to sexual continence, to the use of the iodides, or to injury of the vas deferens alone. A microscopical atrophy is physiological in old age.

Atrophy of the testicle cannot be cured, but it may be prevented by the removal of a cause whose continued action favors atrophy.

XVIII. Injuries of the Testicles.—*Luxation and Contusion.*—Luxation of the testicle has been reported as the result of injury, the testicle being extruded under the skin of the adjoining parts or into the inguinal canal. Mild contusions of the testicle produce shock to the sympathetic system with nausea and faintness, and are followed by more or less prolonged tenderness of the parts. Severe injuries may produce ecchymosis, hæmatocele, or orchitis, and may result in atrophy, in abscess, or in gangrene. Kocher has recorded two deaths from the shock of contusion.

The *treatment* of contusion of the testicle consists in dorsal decubitus, elevation of the testicle, and application of ice. If orchitis ensues this must be combated.

Wounds.—Wounds of the testicle are very rare. Any incision of the tunica albuginea is likely to be followed by protrusion of the soft parts within (hernia testis). If the patient is seen immediately the wound should be cleaned and the tunica albuginea sutured in order to prevent hernia testis. If reduction is impossible, the hernia may be snipped off with scissors, but should not be pulled upon lest the whole testicle be eviscerated.

XIX. Torsion of the Spermatic Cord and Gangrene of the Testicle.—Gangrene of the testicle is usually caused by torsion of the spermatic cord. This occurs spontaneously and gives symptoms very closely resembling those of strangulated hernia. The groin and scrotum suddenly become swollen and sensitive; the patient vomits, feels faint, and has some fever; there may be chill and syncope. The onset of this condition is very sudden, and it may be distinguished from strangulated hernia by the mildness of the systemic disturbance after the first shock has passed. In doubtful cases immediate incision should be relied upon for an accurate diagnosis.

Dr. Charles Scudder has collected thirty-two cases, seventeen of which occurred on the right side and eleven on the left. Seventy-five per cent. of the cases occurred in patients under twenty-three years of age. In ten cases the testicle was retained in the inguinal canal, and in five others it was close under the pubes; in some the attacks were recurrent. Thus Dr. Van der Poel's patient learned to relieve his pain by untwisting the testicle.

The *treatment* of this condition consists in unrolling the testicle—if this be possible—or, if the swelling is great, as is usually the case, in incision. This operation has been performed twenty-nine times without a death; twenty-three times the testicle was removed; five times the cord was untwisted; this was followed twice by sloughing, thrice by atrophy. Once the testicle was allowed to slough away through a simple incision, and once the testicle was untwisted one hour and a half after the onset of symptoms, without incision. In this case the testicle subsequently atrophied.

Injury to the Spermatic Cord.—Tying off the veins of the cord—as is done in the operation for varicocele—has no effect upon the testicle; but if the spermatic artery is included in the ligature the testicle usually atrophies and sometimes sloughs. Similarly any injury to the cord destroying the continuity of the spermatic artery may be followed by gangrene of the testicle.

XX. Irritable and Neuralgic Testicle. — When there is pain in the testicle without disease of this organ it is said to be irritable or neuralgic. The terms are rather loosely used to cover a variety of conditions whose only obvious symptom is testicular pain; the testicle is said to be irritable if the pain is slight, neuralgic if the pain is severe.

The varieties of irritable and neuralgic testicle may be grouped under three heads:

1. Sexual excess, especially under the form of prolonged, ungratified sexual desire, is likely to be followed by what might be termed an acute neuralgia of the testicle, that gland being swollen, sore, and sometimes exquisitely tender. A single application of guaiacol and glycerin, equal parts, the wearing of a suspensory bandage, and the avoidance of the cause, are all that is required for a cure.

2. Reflex neuralgia from the prostate and seminal vesicles is the most common form of this condition. It may be due to any congestion or inflammation of the internal sexual organs, such as chronic inflammation or chronic sexual congestion. This form of the disease is both identified and treated by measures directed to the prostate and vesicles. These organs will be found sensitive, either to rectal touch or to the passage of a moderate-sized sound. The *treatment* consists of prostatic massage, with rectal douching, and perhaps the passage of a sound, or the instillation of a few drops of the nitrate of silver into the posterior urethra. Indeed, this condition is often concomitant with prostatic neuralgia and requires the same treatment, with mild counter-irritation on the scrotum as a temporary aid at the beginning of treatment.

3. Finally, there is a vague group of cases in which the testicular pain is due to causes neither sexual, nor prostatic, nor vesicular. Thus varicocele is often associated with neuralgia, although the cure of the varicocele by no means necessarily relieves the pain. Neuralgia of the testicle is sometimes due to renal or vesical calculus, and cases have been reported in which the pain was attributed to inflammations of the scrotum and of the tunica vaginalis.

If the local cause of such a neuralgia is ascertainable and can be removed a prompt cure may be expected. But in many cases this is impossible; or else the neuralgia has been started in a neurotic subject by some slight cause, which has ceased to act while the pain continues. Such is the nature of most varicocele neuralgias. These cases habitually improve under proper sexual hygiene—which is matrimony. Indeed, one never encounters them in men happily married. Cold-water applications often give great relief and may be all that is required if the pain is spasmodic; but if the agony is constant an endeavor may be made to relieve it by excising the nerves of the spermatic cord. This can be done by a careful dissection of the cord where it issues from the inguinal canal, the nerves being found close about the vas deferens. This operation, while not a sure cure, is sometimes the only hope that can be offered the patient, and should therefore not be denied him.

XXI. Inflammations of the Testicle. — The inflammations of the testicle may be divided into (1) those that pass along the seminal canals, *i.e.*, gonorrhœa, tuberculosis, and simple pyogenic infection from the pos-

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terior urethra; and (2) those inflammations that do not travel along the seminal canals, *i.e.*, traumatic inflammations, syphilis, and the inflammation of infectious diseases. In each class of cases the testicle and the epididymis may both be affected; but in the former class the epididymis is the prime point of attack, while in the latter the testicle is chiefly assailed. Therefore, while remembering that any given case may well be at once an orchitis and an epididymitis, we shall find it convenient to classify the simple and the tuberculous inflammations as epididymitis; the traumatic, the metastatic, and the syphilitic ones as orchitis. Our present concern is with gonorrhœal and simple pyogenic epididymitis.

XXII. Epididymitis.—Epididymitis is always secondary to an inflammation at the inner end of the seminal canals. It is always associated with inflammation of the seminal vesicles and usually with posterior urethritis. The inflammation reaches the epididymis by direct extension along the mucous membrane of the vas deferens, as is proven (1) by the constant presence of vesiculitis, (2) by the frequent prodromal symptoms of deferentitis, and (3) by the fact that ligation of the vas checks at once and forever the most virulent case of relapsing epididymitis.

Thus the underlying cause of epididymitis is an inflammation of the urethra, habitually an acute gonorrhœa, less frequently stricture, chronic prostatitis, or an inflamed hypertrophied prostate. The exciting cause may be anything which determines an exacerbation of the posterior urethritis or which weakens the resisting power of the individual. Thus one patient with acute gonorrhœa may acquire epididymitis in spite of every precaution, while another may escape it in spite of every dissipation. Yet, other things being equal, exposure to cold and dampness, sexual excitement, and the action of any severe strain or the possession of a lymphatic or debilitated constitution are the causes on the part of the patient to which the inflamed testicle may usually be attributed; while, on the part of the physician, epididymitis may be caused by the passage of instruments or by the employment of injections, the danger to the testicle increasing in proportion to the violence of the manipulation, to the size and roughness of the instrument, and to the strength of the injection employed.

With chronic posterior urethritis, with stricture, and with prostatic hypertrophy the infecting bacteria are not so virulent and secondary epididymitis is less frequent and occurs only as a result of considerable trauma or debility.

Epididymitis rarely occurs before the second week of a gonorrhœa, since grave inflammation of the posterior urethra is rare before that time. The exceptional instances in which epididymal swelling appears before urethral discharge are apparently attributable to previous chronic posterior urethritis, and are no evidence that the new gonorrhœal infection begins in the epididymis. Though both epididymes may be inflamed at the same time, it is most exceptional for the two inflammations to begin simultaneously.

The inflammation begins at one end of the epididymis, usually the tail. Here are felt the first swelling and pain, and here the hard lump of induration remains long after the acute attack has passed. The testicle and the remainder of the epididymis are intensely congested and œdematous during the acute attack, the tunica vaginalis being inflamed and acute hydrocele resulting. The vas is catarrhal, and this catarrh in the vas and in the epididymis may in the end cause cicatricial occlusion of the duct. It is not possible to determine in how great a proportion of cases this occlusion occurs; but it may be considered that relapse of the epididymitis is sufficient evidence that the vas is not occluded; whence the paradox that the more often the testicle is inflamed the less likely is its possessor to be sterile.

An attack of epididymitis may run an acute or a chronic course. An acute attack is preceded for perhaps twenty-four hours by a general soreness and tenderness along the course of the vas throughout the groin and often to the loin. Then a tender point appears in the epididymis, which swells so rapidly that within a few hours it is many times its normal size, and usually within twenty-four hours testis and epididymis are swollen to an ovoidal mass exquisitely sensitive to the touch and nearly as large as the closed fist. Excruciating pain accompanies the swelling and continues for two or three days, after which the pain rapidly grows less and the swelling more slowly follows suit; so that at the end of a week the pain has become bearable, the swelling has diminished considerably, and at the end of two or three weeks more the attack has completely passed, leaving behind only a nodular scar in one end of the epididymis. During the acute attack there are severe constitutional symptoms. The disease may be ushered in by chill, and there is high fever for a few days with the accompanying lassitude and want of appetite, while usually the urethral discharge is greatly diminished, sometimes even checked, during the course of the attack, only to reappear as the epididymal inflammation subsides.

A subacute or chronic epididymitis comes on very mildly as a tender swelling at one end of the epididymis, and does not spread throughout the organ with the intensity of the acute process. This tender epididymal lump may remain smouldering for months and years so long as it is fed by a focus of inflammation in the deep urethra, breaking out from time to time into subacute or acute attacks of inflammation, though generally quiescent. On the other hand, a subacute attack may last only a few days and then proceed to entire resolution.

From the frequency with which certain cases of epididymitis, whether acute or subacute, relapse, has arisen a clinical type of the disease known as *relapsing epididymitis*, the characteristic feature of which is the tendency to recurrence of the inflammation at the slightest provocation or at no provocation at all. Even though these attacks be but subacute, they may be sufficiently annoying to render the patient miserable and to merit drastic measures for their removal.

Complications.—The acute hydrocele which often accompanies acute epididymitis in some cases assumes importance as a cause of pain from tension within the tunica vaginalis during the attack and as a cause of swelling through lack of spontaneous absorption of the fluid after the attack. Suppuration occurs but rarely in gonorrhœal epididymitis; but if the inflammation occurs in an old and septic prostatic, it often suppurates, and this suppuration, by increasing the sepsis, may lead to the patient's death.

Diagnosis.—Nothing is more characteristic than an acute epididymitis. Acute orchitis is distinguished by its etiology and by the preponderance of general symptoms and the involvement of the testicle rather than the epididymis. Subacute epididymitis may closely simulate tuberculosis (see Diagnostic Table, on p. 185).

Prognosis.—Epididymitis does not endanger life or sexual potency or desire. As stated above, double epididymitis may be followed by occlusion of both vasa and sterility. It is impossible to say in what proportion of cases this occurs, but it is certainly less frequent than is commonly supposed. Benzler's investigations showed that ten per cent. of gonorrhœal cases without epididymitis, twenty per cent. of those which had had a single epididymitis, and forty-one per cent. of those which had had a double epididymitis were sterile. These figures suggest that chronic prostatitis and vesiculitis is an important cause of sterility and may be the active agent even in a case in which the sterility is attributed to double epididymitis.

Treatment.—Epididymitis may often be prevented by the wearing of a suspensory bandage by the patient during an acute gonorrhœa or while being treated for stricture. Observance of sexual hygiene and gentleness in urethral instrumentation work to the same end.

The treatment of an acute case consists in elevation of the testicle, local applications to it, brisk catharsis, rest, and a light diet. A patient with a sharp epididymitis is much better in bed than out of it. One may ordinarily promise that four days in bed will bring him nearer to a cure than eight days on his feet. But whether the patient will lie quiet or not, the testicle must be elevated as high as possible. With the patient in bed this is best accomplished by an adhesive plaster band across the two thighs with the testicles resting upon it (Fig. 4256), while, if the patient will be about, he can be made most comfortable by slinging his genitals up as high over his abdomen as possible in a T-bandage made with a towel, provision being made for the tenderness of the organ by a generous use of absorbent cotton padding.

Fig. 4256.—Strapping Testicle.

Curling's support consists of a bandage, a large silk handkerchief, and a piece of tape. The bandage is tied around the patient's waist, the tape is attached to the back of the bandage and to the centre of the handkerchief, which is folded once into a triangular shape, the tape being so arranged as to hold the central point opposite the perineum. The two long angles of the triangle are then tied snugly to the waistband in each groin, while the short right angle is carried up over the genitals supporting them high up on the abdomen.

Of local applications to the testicle guaiacol is much the best in the first forty eight hours of the inflammation. If applied pure before the swelling has reached its height it will often abort an attack. A mixture of equal parts of guaiacol and glycerin may be applied daily or twice a day during the first few days with marked benefit, and is far less irritating than the pure drug. If the patient is in bed it is advantageous to keep the testicle covered with hot poultices. The tobacco poultice is reputed an anæsthetic, but in this it falls far behind guaiacol, and, as the only real virtue of the poultice is its heat, the flaxseed poultice is adequate.

As the acute symptoms subside poultices may be replaced by a hot-water bag, and guaiacol is no longer useful.

As soon as it is bearable strapping is applied. The classic and dirty adhesive plaster strapping is obviously inferior to compression by a light rubber bandage held around the testicle by a single strap of adhesive plaster (Fig. 4256). This makes a light and comfortable dressing, the pressure of which can be varied at any moment without pain or discomfort to the patient. At first this dressing is changed every twenty four hours. As the testicle rapidly decreases in size and bears more and more pressure without irritation, the strap is reapplied at longer intervals. Finally, a suspensory bandage is all the patient needs, and this he may wear until the general swelling has entirely subsided.

The treatment for subacute cases need not be so energetic. Guaiacol may be applied in less strength and more frequently. A suspensory bandage is all the support required.

Relapsing epididymitis may often be relieved by attacking the prostatic or vesicular focus in which the disease centres, and every effort should be made to conquer this inflammation both by local treatment and by building up the patient's health before having recourse to any surgical procedure.

If these means fail—as they often do fail utterly—the patient is usually glad to submit to vasectomy, although this operation closes the canal forever; since by this means he can be absolutely assured against any further recurrence of the inflammation. Indeed, this operation performed in the midst of an attack will cut it short more quickly and more certainly than any other means I know.

The Operation of Vasectomy.—The operation of vasectomy may be performed under local anæsthesia. If the testicle is swollen the vas is most conveniently reached at the external inguinal ring. The technique of this operation is similar to that of the high, open operation for varicocele, which is described below. But if the testicle is not swollen, it is often a simpler matter to reach the duct through an incision in the back of the scrotum. The vas is identified as the thickest, most resisting member of the bundle of tissues making up the cord, and, as it is always behind and to the inner side of the large bundle of veins, it may be readily caught between two fingers and held close beneath the skin of the scrotum behind. The skin is infiltrated with cocaine; an incision through it and through the dartos permits the vas to be protruded. This is caught with a pair of forceps, freed from the surrounding fascial fibres, tied doubly and cut between the ligatures. If there is any suspicion of inflammation of the duct it is wiser to cauterize both ends before dropping them back into the scrotum. A single stitch closes the incision. The patient need remain in bed with his testicle supported for only three or four days.

XXIII. Orchitis.—The inflammations of the testicle to be described under this head are three: First, traumatic orchitis; second, subacute neuralgic or gouty orchitis; third, the orchitis of the exanthemata. The first two varieties may be dismissed with a word.

Traumatic Orchitis.—Traumatic orchitis, caused by a blow, a kick, a missile, or a fall, runs a course quite comparable to that of epididymitis; yet the excretory ducts are very rarely blocked, so that, even after a severe inflammation, sterility may not be anticipated; while, on the other hand, traumatic orchitis is far oftener followed by atrophy of the testicle than is the gonorrhœal inflammation. In the treatment of this form of orchitis poultices hold the first place.

Neuralgic or Gouty Orchitis.—Neuralgic or gouty orchitis is a mild inflammation with little swelling and tenderness, but with considerable neuralgia. It may result from sexual causes, or it may occur spontaneously in gouty or rheumatic individuals. The treatment is that of irritable or neuralgic testicle.

Orchitis of Infectious Diseases.—The orchitis of infectious diseases deserves more extended notice. It has been noted in the course of typhoid fever, influenza, smallpox, tonsillitis, and rheumatism, but it is commonly known as the orchitis of mumps on account of its frequency in this

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disease as compared with its great rarity in other infectious conditions.

Orchitis of Mumps.—The orchitis of mumps does not occur in children. In young adults orchitis complicates the parotid inflammation in at least five per cent. of all cases; indeed, Laveran encountered orchitis one hundred and fifty-six times in four hundred and thirty-two cases of mumps among soldiers. The inflammation of the testicle usually appears at the end of the first week of the parotitis; exceptionally, the testicle is inflamed before the parotid, and there are a few recorded cases of alleged mumps of the testicle without any inflammation of the parotid gland. The affection is habitually unilateral, runs a very acute course lasting but a week or ten days, and is followed by atrophy of the organ in one-half the cases; suppuration and gangrene are exceptional terminations, and, if the testis does not atrophy, its function is in no way impaired.

Symptoms.—The chief symptom of orchitis is pain. On account of the unyielding nature of the tunica vaginalis, the testicle swells but slowly, requiring several days to attain its full size. But the pain of the inflamed gland, tightly bound down by its fibrous envelope, is instant and excruciating. This pain has been compared to nephritic or hepatic colic. It cannot be relieved by position, and is greatly intensified by the slightest touch upon the inflamed organ. It is accompanied by marked general symptoms; chills, fever, vomiting, sleeplessness, etc. The testicle retains its ovoid shape, and the epididymis is not distinguishable from the rest of the tumor; the scrotum is often œdematous, swollen, and red.

The disease usually terminates by resolution, the pain subsiding gradually, the tumor disappearing more slowly, after which the testicle may or may not atrophy. Abscess may occur and may prolong the attack indefinitely, while the onset of gangrene is announced by sudden cessation of the pain without relief of the other symptoms.

Diagnosis.—Orchitis is distinguished from epididymitis by its cause, and by the great disparity between the severity of the general symptoms and the intensity of the pain on the one hand, and the slight degree of swelling on the other.

Treatment.—An adult with mumps should be kept in bed during the first days of the disease, with testicles well supported in order to prevent orchitis. When the attack is once on little can be done in the way of treatment, except to ameliorate symptoms and to prevent abscess or gangrene. For internal medication jaborandi is the only drug that bears any reputation. Locally, poultices and guaiacol should be employed as in epididymitis. If these fail to relieve pain the tunica albuginea should be divided subcutaneously. A sharp-pointed tenotome knife is introduced through the skin, and then made to cut the tense fibrous capsule, while the testicle is steadied in the other hand. From three to six short cuts should be made at different points in the tunic. This relieves the pain almost instantaneously. If abscess forms it should be incised and drained, while gangrene demands castration.

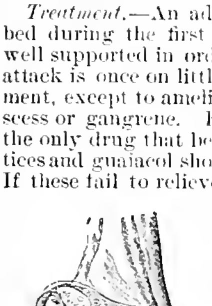

Fig. 4257.—Tuberculous Epididymitis.

XXIV. Tuberculosis of the Testicle.—Tuberculosis of the testicle occurs under two forms: diffuse, miliary tuberculosis, part of a general miliary tuberculosis, and circumscribed tuberculosis; only this latter concerns us here (Fig. 4257). It occurs as one or more tuberculous deposits, appearing usually in the epididymis and affecting the testicle only secondarily. It may or may not be accompanied by pyogenic infection.

Etiology.—The recognized causes of epididymal tuberculosis are the tuberculous predisposition, the existence of a tuberculous focus elsewhere in the body, and a local trauma or inflammation, precedent or persistent. Of these causes the first is ascertainable almost always, the second sometimes, and the third rarely. The efficient cause of the disease is the tubercle bacillus. The belief is gradually gaining ground that tuberculosis of the genital organs habitually begins in the epididymis, and thence extends in one direction to the testicle, in the other to the vesicle and prostate. The opposite view, that the inflammation begins in the prostate or in the vesicles, has the authority of Kocher, of Lancereaux, and of Guyon, and to this view I am inclined to adhere. For I have often seen tuberculous prostatitis and vesiculitis without tuberculous epididymitis, and yet, having examined the urine of every case of tuberculous epididymitis that has come under my observation, I have never failed to find urinary evidences of prostatic congestion. Moreover, I have often found manifestly tuberculous nodules in the internal genitals and sometimes tubercle bacilli in the urine; while, finally, the affection of the opposite testicle which so often follows not long after the primary inflammation, is explicable only on the theory of transmission through the internal seminal tract. Thus, while it is patent that in many cases tuberculous epididymitis is the only striking evidence of tuberculosis in the individual, the disease is none the less systemic, and patient investigation will usually disclose some lesion of the prostate and sometimes an unsuspected disease in the kidneys or in the lungs.

I do not believe that genital tuberculosis can be acquired in coitus. The inflammation is most common in the third decade of life, and very rare before the fifteenth and after the fiftieth year.

Morbid Anatomy.—The discrepancy of opinions as to whether the tuberculous deposit begins in the tubules of the epididymis or in the intertubular tissue apparently has some connection with the views of the pathologist as to the primary or the secondary nature of the epididymal lesion. However this may be, the disease, as seen by the clinician, appears in an acute and a chronic form.

Acute tuberculosis is manifested by general swelling of the testis and epididymis with an accompanying hydrocele, considerable tenderness, and the fever and night sweats that go with acute tuberculosis. These cases of so called galloping or fulminating tuberculosis of the testicle are apparently attributable to a mixed infection; they appear and extend rapidly and reach the stage of suppuration within a few weeks.

The chronic form of the disease may appear as such or may follow upon the subsidence of an acute tuberculosis. In this condition there is little or no hydrocele or inflammation of the testicle; while in the epididymis and in the vas are found rounded nodules of tuberculous inflammation, small, hard, and caseous, or fluctuating and purulent.

The urinary organs are often infected either primarily or secondarily, although the lungs are frequently spared. Thus even on autopsy Kocher found only ninety-five cases of pulmonary tuberculosis among four hundred and fifty-one autopsies on cases of urogenital tuberculosis.

Symptoms.—The patient, a young man with tuberculous antecedents, usually comes complaining of a spontaneous enlargement of one testicle. Exceptionally, the enlargement may be a persistence of an acute gonorrhœal epididymitis; more frequently it has appeared during the course of a chronic gleet of long duration, though often enough there is no obvious cause for the swelling.

The history may be acute, in which case the testicle will be found considerably enlarged, with much fluid in the tunica vaginalis, aspiration of which reveals an enlarged testicle surrounded by a lumpy, œdematous epididymis, the vas deferens of which is enlarged and perhaps nodular. All of the inflamed areas are rather tender to the touch.

On the other hand, if the attack is a chronic one, the general aspect of the organ is normal while in one or more parts of the epididymis or of the vas tuberculous

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nodules may be seen and felt. Further questioning usually reveals a history of rather frequent calls to urinate; while examination of urine, prostate, vesicles, and kidneys will often reveal some congestion or inflammation of the internal sexual organs and perhaps an inflammation of the kidneys as well.

Diagnosis.—See Diagnostic Table, on p. 185.

Prognosis.—The usual course of the disease is that of a local tuberculous trouble advancing slowly to a fatal termination. Innumerable castrations are performed in the hope of eradicating the disease while still confined to one testicle; but its recrudescence on the opposite side affords bitter confirmation of the belief that tuberculosis here as elsewhere is not a local but a systemic disorder. In fact, it has seemed to me that removal of one testis hastens the appearance of tuberculous nodules in its fellow.

The prognosis of the disease is quite as indefinite as is the prognosis of tuberculosis elsewhere in the body. If the testicular lesion is circumscribed and chronic, if there is no evidence of grave internal disease, and if the patient can and will put himself for a long period of time in proper hygienic surroundings, the prognosis is good. The sexual potency of the testicle is lost, but the potency of the individual is unimpaired, and probably the testicle will not atrophy. If the local foci go on to suppurate they may be drained, and climatic and tonic treatment may be expected to control the disease and to prolong the patient's life indefinitely, even in many cases to effect a cure.

On the other hand, the prognosis of fulminating tuberculosis is bad. If seen early and treated intelligently this condition may subside and become chronic; but the very occurrence of the hyperacute form of the disease is evidence that the patient's tissues form a good soil for the growth of the tubercle bacillus, and is a warning that the greatest care will be required to prevent generalization of the disease, if indeed this has not already occurred.

Treatment.—From what has been said in the preceding paragraphs it is evident that not much need be expected from the surgical treatment of testicular tuberculosis. A recent discussion of this subject before the Paris Surgical Society (*Annales des Maladies Génito-urinaires*, 1900, xviii., 961, 1066) is brilliantly expressive of the change of opinion upon this subject which has occurred in France during the past quarter of a century. The consensus of opinion now favors conservatism and the belief that, in most cases, castration is harmful. My own experience with acute tuberculosis of the testicle is that treatment by hygiene, cod-liver oil, creosote, and perhaps local applications of guaiacol, will sometimes cause resolution and will oftentimes be followed by localized suppuration and subsidence of the general acute inflammation; while any surgery, beyond drainage of the suppurating foci, will only start up new trouble in the testicle or, if this is removed, in other parts of the body.

In the more chronic forms of the disease incision and drainage of suppurating foci is always indicated, and, when the whole epididymis is involved in a suppurating indurated mass, it is undoubtedly advantageous to perform the operation of epididymectomy; but it is questionable whether any benefit is obtained by removal of discrete, uninflamed caseous lumps.

Castration is never indicated unless the whole organ is reduced to a suppurating cavity. Many surgeons prefer to castrate for fulminating tuberculosis, but my experience is against this.

XXV. Epididymectomy.—The operation of epididymectomy resembles orchidectomy, except that, instead of removing the whole testicle, the inflamed epididymis is shelled off from the gland and removed with the extrapelvic portion of the vas deferens. If the upper end of the vas is found inflamed or exuding pus, it should be stitched into the wound; otherwise it will cause deep suppuration. The removal of the whole vas and of the vesicle along with the epididymis is an operation required only in the most exceptional cases in which there is considerable inflammation of the vesicle itself. It will not give good results as a routine procedure. (See Tuberculosis of the Seminal Vesicle.)

XXVI. Syphilis of the Testicle.—The testicle may be involved by syphilis in its secondary and in its tertiary stages.

Secondary Epididymitis.—Secondary syphilis sometimes causes a slight painless enlargement of the epididymis. This occurs at the time of the secondary skin manifestations, and is insignificant.

Tertiary Lesions.—Tertiary syphilis attacks the testicle and the epididymis. The disease may show itself by the deposition of gummata or by a diffuse infiltration of the organ. In the former case the testicle is enlarged, painless, and nodular, and in the latter—a more common form—the testicle is enlarged, painless, and smooth. The most characteristic changes are found in the epididymis, which may be affected throughout or at one or the other extremity; the part involved is evenly enlarged in such a way as to cap the testicle, forming a sharp-edged, hard mass like a clam-shell in which the testicle lies. As hydrocele is a very common accompaniment of this inflammation, the clam-shell characteristics of the epididymis are often obscured by the vaginal effusion; but aspiration of the hydrocele will in fully seventy-five per cent. of all cases of syphilitic orchitis reveal the pathognomonic, insensitive clam-shell epididymis. The cord is habitually normal. I have never seen double syphilitic testicle.

Syphilitic testis rarely appears before the second year of the disease. The gland enlarges gradually and painlessly; it is never tender unless there is some complicating gonorrhœal inflammation. The progress of the disease is very slow. The sexual function is little impaired. Syphilitic testicle occurs as a hereditary manifestation.

For *diagnosis*, see Diagnostic Table.

The *prognosis* is good. The disease is sometimes quite rebellious to treatment; but, inasmuch as the seminal tubules are not immediately involved and perish only by atrophy from pressure, a testicle may be syphilitic for a long time without losing its function.

Local *treatment* is useless. Mixed treatment will generally conquer the lesion, and, if this fails, hypodermic injections once or twice a week of 1 gm. of a ten-per-cent. solution of mercuric salicylate in benzoinol will often effect a cure.

XXVII. Tumors of the Testicle. — Testicular tumors are so rare and so diverse and mixed in character that an entirely satisfactory classification of them has yet to be made. They may be roughly divided into benign tumors, cystic tumors, and malignant tumors.

Benign Tumors.—Enchondroma, fibroma, osteoma, and myoma have been observed, and in the tunica vaginalis, lipoma and fibroma. These if small are not discovered ante mortem; if large it is usually impossible to distinguish them from beginning malignant disease.

Cystic Tumors.—Teratoma, benign cystic disease, and malignant cystic disease (Fig. 4258) are recognized by the pathologist; but clinically they are often indistinguishable from one another. Dermoid cysts and teratoma both have a tendency to malignant degeneration, and it is impossible—given a cystic tumor of the testicle —to be sure that it is benign and will so remain. Therefore, from a therapeutic point of view, all such cystic growths must be classified as at least potentially malignant.

Malignant Tumors.—Kober has recently collected the records of one hundred and fourteen cases of sarcoma of the testicle. Seventy-one per cent. occurred between the ages of twenty and fifty with a history of trauma in forty-three per cent. The tumors were usually round-celled or spindle-celled, less frequently cystic and alveolar. Carcinoma, usually medullary, is rarer than sarcoma; cystic and chondrocarcinoma have been described. The occurrence of lymphadenoma is affirmed by the French and denied by the Germans. Jacobson has seen three

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cases of myxoma. Four cases of sarcoma of the tunica vaginalis have been reported.

The only symptom of testicular tumor is the presence of a growth. The patient comes complaining of an en-

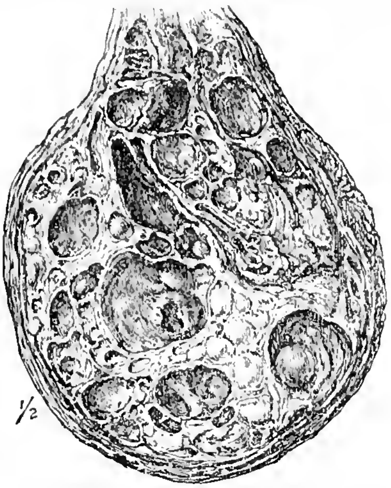

FIG. 4258.—Cystic Disease of the Testicle.

largement of the testicle which may have been present for many years without varying notably in size; or it may have suddenly taken on a more rapid enlargement after many years of quiescence; or it may have grown rapidly from the outset. In any event the tumor is usually found to be an irregular enlargement of the whole testicle, perhaps cystic in places, perhaps complicated by hydrocele. The pain is not severe and the general shape of the testicle is preserved, while testicular sensation is lost. If the disease has been present for some time enlarged iliac and lumbar glands may be felt by deep abdominal palpation. The inguinal glands are not involved until very late in the disease when the neoplasm has burst through the tunica albuginea and reached the scrotal tissue. The patient is usually seen before he has reached this stage, and, in the present surgical days, malignant fungus of the testicle (ulcerating neoplasm) is practically unheard of.

Diagnosis.—While it may be possible to state clinically that a tumor of the testicle shows no evidence of malignancy, one can never feel sure that it will not at some time undergo malignant degeneration. Therefore it is only necessary to be sure that the growth is a tumor in order to have recourse to immediate orchidectomy. To be sure, it is always necessary to employ mixed treatment and the aspirator; the one to rule out syphilis, the other to exclude hydrocele, spermatocele, and hæmatocele.

XXVIII. ORCHIDECTOMY.—Preparation.—The usual preparations for an aseptic operation are required. I prefer general to local anæsthesia.

The Incision.—Dr. White removes both testicles through an incision in the median raphé of the scrotum, but, since it is usually necessary to remove only one of these organs, the best incision is in the upper part of the scrotum just below the groin, an extension downward, as it were, of the ordinary incision for hernia.

The Actual Operation.—The cord is laid bare as in the operation for hernia and is divided between ligatures. The testicle is then drawn upward and out through the incision, and excised. If the skin is adherent the incision must be carried down far enough to remove the portion of skin involved.

Treatment of the Cord.—If the operation is performed for tubercle the end of the vas should be sutured to the skin in order to avoid deep suppuration. It is always safer to use one ligature for the vas and one for the bundle of veins in order to prevent hemorrhage.

Termination of the Operation.—The surface of the wound must be carefully scrutinized and every bleeding point caught and tied, for in the loose cellular tissue of the scrotum the slightest oozing may cause enormous hæmatoma. To guard against this still further it is convenient to apply an adhesive plaster dressing supporting the scrotum upon one strap running from thigh to thigh, and compressing it under a light aseptic dressing between other straps running criss-cross from the thighs to the abdomen. Weir and others have replaced testicles by celluloid and paraffine substitutes.

Complications.—Hemorrhage is the only complication to be feared; it may require reopening and repacking of the wound. The post-operative insanity alleged to result from castration for hypertrophy of the prostate has not been proven peculiar to this operation.

XXIX. SYMPTOMATIC HYDROCELE.—The hydrocele that so frequently complicates inflammatory diseases of the testicle is called symptomatic. The inflammation of the tunica vaginalis is secondary to the testicular disease, and, while the patient's comfort may be increased by the occasional tapping of such a hydrocele, no permanent relief may be expected in most cases unless the prime cause—the disease of the testicle—is removed.

XXX. IDIOPATHIC HYDROCELE.—An accumulation of serum in the tunica vaginalis occurring without any recognizable disease of the testicle is called idiopathic hydrocele. This disease is more common in the tropics than in temperate climes. It usually affects men who

DIAGNOSTIC TABLE.

	Simple chronic epididymitis.	Tuberculosis.	Syphilis.	Tumor.
History	Gonorrhœa, stricture, or hypertrophy of the prostate.	Tuberculosis, family or personal.	Syphilis, inherited or acquired.	Perhaps trauma.
Frequency	Uncommon	Frequent	Frequent	Rare.
Size	Small between attacks	Does not reach any great size.	Does not reach any great size.	May reach any size.
Sensitive	Yes	Yes	No	No.
Shape	Between attacks testis normal, epididymis nodular.	Epididymis nodular. Testis not involved unless acute or ancient.	Testis evenly enlarged, slightly nodular. "Clam-shell" epididymis as a rule.	Testis considerably enlarged; no characteristic involvement of epididymis.
Cord	May be slightly thickened	Usually enlarged and nodular	Free	Free; veins dilate in later stages.
Seminal vesicles	Usually distended	Tuberculous	Uninfluenced	Uninfluenced.
Prostate	Posterior urethra congested or inflamed.	Congested; may be tuberculous.	Uninfluenced	Uninfluenced.
Urine	Cloudy	Cloudy; may contain bacilli.	Clear	Clear.
Hydrocele	Unusual	Often	Nearly always	Unusual.
Onset	Usually acute	Usually chronic	Chronic	Chronic.
Course	Recurrent acute attacks	Usually chronic	Chronic	Fairly rapid.
Opposite testicle	Often involved simultaneously.	Usually involved subsequently.	Free	Free.
Abscess	Unusual	Common	Rare	None.
Potency	Unimpaired	Somewhat impaired	Somewhat impaired	Unimpaired.
Atrophy of testis	Rare	Rare	Common	Never.

At the end, as at the beginning, the iodides with mercury, and the aspirator.

have reached middle age, but may occur in youth and in infancy.

Varieties.—The commonest form of hydrocele as seen in the adult is confined to the tunica vaginalis (Fig. 4259). In infancy and less frequently in later life the fluid may be found to fill not only the tunica vaginalis but also the unobliterated processus funicularis up to and into the inguinal canal. This is *infantile hydrocele*. Another form of hydrocele met with in infants is called *congenital hydrocele*. In this condition the funicular process of peritoneum has never been closed off at all, and the hydrocele sac communicates directly with the abdominal cavity and is habitually complicated by congenital hernia.

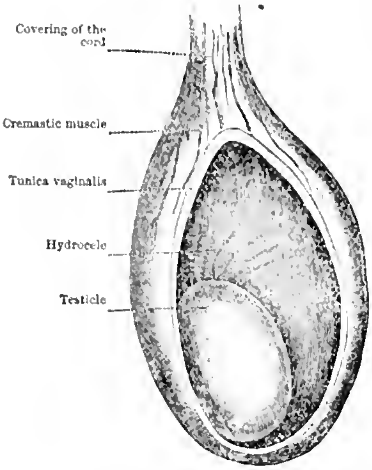

FIG. 4259. Hydrocele.

A fourth variety is *hydrocele of the cord* in which the funicular process, closed off from the abdominal cavity above and from the cavity of the tunica vaginalis below, is affected by hydrocele. Exceptionally, hydrocele occurs in the tunica vaginalis of a retained testicle; this is *inguinal hydrocele*. And again, hydrocele may occur in an old hernial sac the neck of which has been shut off by adhesions. These varieties are extremely rare. There are also certain cysts that develop in connection with the testicle, *i.e.*, *spermatocele* and multilocular hydrocele of the cord. Neglecting for the present all these more or less unusual varieties in intrascrotal cysts, we may consider at length idiopathic hydrocele of the tunica vaginalis.

Symptoms.—This condition presents itself as a fluctuating or elastic ovoid swelling somewhat pear-shaped, being larger below than above. Its surface is smooth, it is irreducible into the inguinal canal; indeed, the spermatic cord, normal in size and sensibility, can usually be grasped above the top of the tumor. There are almost no subjective symptoms; the patient complains only of the large tumor and of some dragging and pain due to its position and weight. The history is always chronic, the fluid accumulating by slow degrees.

Diagnosis.—In examining a hydrocele the two points to be determined are the fluid nature of the tumor and the position of the testicle in reference to the fluid. If the normal cord can be felt above the tumor, if fluctuation can be obtained in it, and if palpation reveals the testicle as a slight nodosity with testicular sensation, both of these questions are answered without further investigation. But the testicle may be impalpable, fluctuation may be unobtainable; and a large hydrocele extending into the inguinal canal exhibits a slight impulse on coughing, and so requires some test to distinguish it from irreducible hernia. For this purpose the so called light test is commonly employed.

The room is darkened and a tube is made by rolling a sheet of paper upon itself, and, while one end of this is applied to one side of the tumor, a match or a candle is lighted and held at the opposite side. If the tumor is fluid light will be transmitted through it, and a dull red glow may be seen by looking into the paper tube. The same effect may be more brilliantly obtained by the use of an electric light, by which means the whole tumor may often be made luminous without darkening the room and without the use of the paper tube. It is alleged that this reaction may be obtained in small hernias in infants; but with this possible exception its positive result is absolute evidence of the presence of hydrocele.

If there is no question of hernia in the diagnosis hydrocele may be distinguished from solid tumors of the testicle by aspiration. When this test is applied, the surgeon should be ready in the event of its success to attempt a radical cure by injection.

Complications.—Exceptional complications of hydrocele which may interfere with the diagnosis and treatment are great thickening of its walls, which may proceed even to calcification (and so frustrate the light test), multilocular hydrocele (resulting either from an adhesive inflammation or from the simultaneous existence of several varieties of hydrocele), fibrous bodies in the hydrocele sac (doubtless the result of previous attacks of inflammation), and, very exceptionally, suppuration of or hemorrhage into the hydrocele.

Treatment.—It is so easy to cure idiopathic hydrocele in children that a great number of palliative treatments have been devised by those whose chief experience is with young patients. Thus the application of various counter-irritants to the skin, multiple puncture with a sharp needle, and simple evacuation of the fluid will often prove curative in the young. But in adults such treatments are purely palliative, as is instanced by Curling's case, who had ruptured his hydrocele thirty times only to see it return within a few months. I have seen a similar case, the patient returning for tapping every six months for many years, but refusing to have any more radical procedure attempted, although the fluid reaccumulated with unvarying regularity.

Of the radical cures of hydrocele the one which I prefer is aspiration followed by the injection of pure carbolic acid. All simple hydroceles which are translucent, no matter how old or how large, are amenable to this treatment; and in such simple cases injection can boast a percentage of cures equal to that of any other operation. Injection will not cure symptomatic hydrocele, nor will it cure suppurating, hemorrhagic, or fibrotic hydrocele.

A great number of substances have been employed for injection into the tunica vaginalis, but for safety and comfort and assurance of success none equals pure carbolic acid. The method of operating is as follows: If the hydrocele contains more than six ounces of fluid it should be tapped and the patient told to return for the cure a week or two weeks later, when partial reaccumulation shall have occurred; otherwise the aspiration and injection may be performed at once. The instruments required are a large hypodermic syringe and an aspirator. The solutions are a bottle of carbolic-acid crystals deliquesced by heat, some pure alcohol, and some green soap to cleanse the skin. The needles are boiled; the surgeon cleanses his hands and the skin of the patient with green soap and alcohol. A hypodermic syringe is then filled with the pure carbolic acid, and its needle, unattached, is plunged into the front of the tumor, the drop of serum issuing through it proving that its point is in the cavity. The needle of the aspirator is then plunged into another point on the surface of the tumor (the position of the testicle having been previously ascertained by the light test), and immediately serum gushes from this. The aspirator is now set in action and the contents of the sac are drawn off, every effort being made to withdraw the fluid even to the last drop.

Only two precautions need be taken: (1) not to allow the hypodermic needle to slip from the sac; (2) not to wound the testicle. The sac being dry, the hypodermic syringe is attached to its needle and from five to thirty drops of the pure carbolic acid are injected. I have injected two drachms of pure carbolic acid without any serious reaction; but the use of such large quantities, while it does not cause carbolic-acid poisoning, may produce a good deal of inflammation, and is, I believe, quite unnecessary. Indeed, Dr. Coley has had excellent

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results from the injection of a single minim of the acid; but, inasmuch as it is impossible entirely to empty the sac, I always prefer to inject enough fluid to cover its surface thoroughly. Immediately after injection the needle is withdrawn, some alcohol poured over the skin to protect it from the carbolic acid, and the scrotum briskly rubbed in order to diffuse the fluid throughout the tunica vaginalis.

After this little operation the patient may often continue to go about, but as the reaction for the first forty-eight hours is often considerable, it is better that he should lie in bed during this time.

During the first week the sac usually refills, but thereafter this fluid is gradually absorbed, and at the end of six weeks the patient should be practically well, except for the presence of the hardened, thickened tunica vaginalis which gradually softens and disappears during the succeeding months. If the reaccumulated fluid does not disappear within a few weeks aspiration should again be performed, and a few drops more of carbolic acid may be injected at this time, although this is usually unnecessary.

Failure of the injection treatment may be attributed to three causes, namely:

1. Application of injection to cases incurable by this method—*i.e.*: (*a*) Most symptomatic hydroceles. (*b*) Some spermatoceles. (*c*) Hydroceles with inflamed, indurated, or calcareous walls. (*d*) Hæmatoceles and chyloceles.

2. Errors of technique, notably: (*a*) Endeavoring to cure too large a hydrocele. If the sac contains more than six ounces its contents must be reduced by one or more preliminary tappings. (*b*) Incomplete evacuation. This I believe to be the most frequent cause of failure; to insure success the last drop must be squeezed from the vaginalis. (*c*) Injection of the carbolic acid into the cellular tissue. I need scarcely insist upon this point. (*d*) Failure to perform the secondary aspiration which is sometimes part of the cure.

3. The use of iodine instead of carbolic acid. Iodine injection is painful and uncertain, while carbolic acid, being a local anæsthetic, produces only a momentary tingling and, at my hands, has been a certain cure.

The Open Operation.—For cases in which the diagnosis is not certain or in which, for one of the reasons stated above, the injection treatment is inapplicable or has failed, the open operation should be performed. This operation may be done in one of three ways:

FIG. 4260.—Hydrocele of the Cord Complicated by Hernia.

1. Volkmann's operation consists of simple incision and drainage. The sac is opened by one sweeping cut, its edges are sutured to the skin, its surface swabbed with pure carbolic, and a wick of gauze inserted into the wound. The convalescence from this operation is so prolonged that it has been generally discarded in favor of—

2. Von Bergmann's operation. Here an attempt is made to excise the sac; skin and fascia are divided down to the tunica vaginalis, and this is shelled out, opened and cut away up to the testicle. That part of the tunica which is adherent to the testicle is then swabbed with pure carbolic acid, and the skin incision is closed over a drainage-tube which is removed in a few days.

3. Eversion of the sac is an operation recently proposed to take the place of von Bergmann's operation, the advantages claimed for it being that it is more rapidly performed and that it requires no drainage. The sac is dissected out roughly and the greater part of its parietal layer cut away. The testicle is then extruded through the wound, and the remainder of the sac is inverted and sutured behind the testicle by a few strands of catgut. Testicle and sac are then replaced and the skin wound sutured.

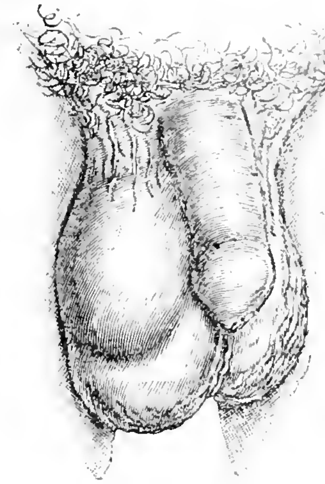


FIG. 4261.—Spermatocele.

I prefer this operation to any other open procedure, and expect to cure by it within ten days; yet there have been recurrences after this as after every one of the various operations advised for hydrocele.

Congenital Hydrocele.—Congenital hydrocele, in which the hydrocele sac communicates with the abdominal cavity, occurs in infancy.

Congenital hydrocele is often confused with hernia, since the tumor is continuous into the inguinal gland and is reducible into the abdomen. The distinction between the two conditions is not important, since with congenital hydrocele there is habitually hernia, and the treatment of the two conditions is the same—namely, a well-fitting truss, and if this fail, the operation for radical cure of hernia. Congenital hydrocele should never be injected.

Infantile Hydrocele.—Infantile hydrocele is far more common than the congenital variety. Thus Horwitz records one hundred and ten cases of hydrocele, of which twenty-two were infantile and only one congenital.

The diagnosis and treatment of this condition present no peculiarities.

Abdominal Hydrocele (Bilocular Hydrocele).—This is a very rare variety of infantile hydrocele, in which the sac fills the scrotum and also extends into the abdominal cavity, pushing the peritoneum before it, sometimes forming an enormous cyst in the latter. Some twenty cases have been recorded, cure having been accomplished by simple drainage and by injection.

XXXI. HYDROCELE OF THE SPERMATIC CORD.—Hydrocele of the cord (Fig. 4260) may be multilocular (diffuse) or encysted. Kocher classifies multilocular hydrocele under the following heads: (1) Echinococcus cysts, (2) spermatocele, (3) encysted hydrocele of the cord subdivided into loculi by adhesive inflammation, (4) cysts of Müller's duct of the Wolffian body or of the organ of Giraldes, (5) cystic lymphangioma.

The three conditions commonly classified as encysted hydrocele of the cord are: (1) Hydrocele of the processus funicularis, (2) spermatocele, and (3) hydrocele of an old hernial sac.

Whatever the true nature of the hydrocele, it is in appearance either a single cyst or a number of small cysts occupying the region of the spermatic cord. Habitually the cyst is either a hydrocele of the processus funicularis (the serous peritoneal prolongation surrounding the cord, which normally disappears during infancy, but which sometimes persists and is then liable to hydrocele) or spermatocele.

The treatment of hydrocele of the processus funicularis is by injection.

XXXII. SPERMATOCELE.—Spermatocele (Fig. 4261) (encysted hydrocele of the testicle, epididymal cyst) is a collection of fluid "contained in a cyst or in cysts distinct from but close to the cavity of the tunica vaginalis" (Jacobson).

Clinically, two classes of spermatocele may be recognized

1. Small cysts are very common about the head of the epididymis in old men They do not attain any notable size; they rarely contain spermatozoa, they produce no symptoms, and are usually discovered by accident.

2. Large cysts develop in the epididymis before the fiftieth year, as a rule; they are often multiple and usually contain spermatozoa. They form irregular fluid tumors about the top of the gland, the smaller tumors having a notch in the upper end, giving them a shape comparable to that of a heart. This heart shape is so common as to be considered a pathognomonic sign. These cysts rarely contain more than an ounce or two of fluid, although Curling drew thirty-two ounces from one individual and forty from another; while Jacobson mentions a case from whose right side forty nine ounces were drawn and fifty-eight from the left. Such large cysts as these are habitually mistaken for hydroceles, their true nature being disclosed by the milky fluid which, on examination, proves to be full of spermatozoa.

Hydrocele and spermatocele may coexist. Spermatocele is commonly attributed to dilatation and sacculation of the spermatic ducts behind a partial obstacle, just as the kidney dilates behind a partial obstruction but is not dilated by complete obstruction. The earlier authors held that spermatocele is due to cystic growth in various fœtal remains, and attributed the presence of spermatozoa to the bursting of the cyst into the epididymal canal. The communication between the cyst and the epididymis has several times been demonstrated.

Diagnosis.—The heart shape, though pathognomonic, is not always present. The diagnosis may usually be made upon the discovery of a small uninflamed tumor above the testicle. Large tumors can be diagnosed only by aspiration, without which they are commonly mistaken for hydrocele of the tunica vaginalis, hydrocele of the cord, or neoplasm.

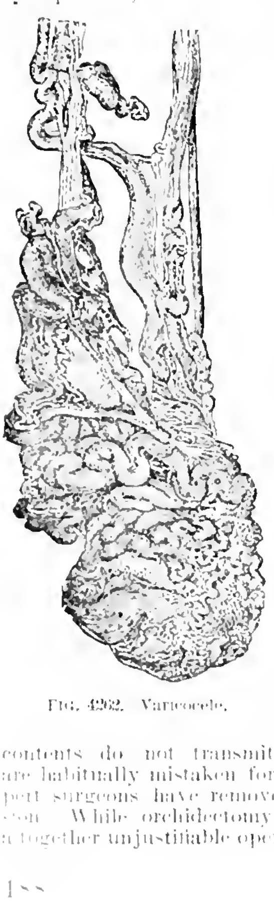


FIG. 4262. Varicocele.

Treatment.—The small spermatoceles of later life require no treatment. The larger growths may sometimes be cured by aspiration and injection of carbolic acid; a more certain method is excision of the entire sac.

XXXIII. HÆMATOCELE.—If a hæmatoma, whether of the testicle, of the tunica vaginalis, or of the scrotum, becomes encysted instead of being absorbed, the cyst is denominated hæmatocele (Fig. 4254). Scrotal hæmatocele and testicular hæmatocele are always traumatic in origin. Hæmatocele of the tunica vaginalis is sometimes spontaneous. I have seen a case of spontaneous hæmatospermatocele

The diagnosis of hæmatocele presents no difficulties, unless it be spontaneous or of such long duration that its traumatic cause has been forgotten. The tumor usually retains the pyriform shape of a hydrocele, but its thickened walls and dense contents do not transmit light. Such hæmatoceles are habitually mistaken for neoplasms and the most expert surgeons have removed them under this impression While orchidectomy in this condition is not an altogether unjustifiable operation, it is more satisfactory to the surgeon to make a correct diagnosis before operating and more pleasant to the patient to retain his testicle, if that be possible. The only sure means of diagnosis in these cases is aspiration or incision.

The treatment is incision and drainage, or, if the testicle is disintegrated, orchidectomy.

XXXIV. CHYLOCELE.—Chylocele (fatty, milky, chylous hydrocele, galactocele) is an accumulation of chyle or fatty lymph in the tunica vaginalis. It occurs in connection with elephantiasis; exceptionally it is due to the traumatic rupture of a lymphatic vessel into the tunica vaginalis. False chylocele is due to a fatty or cholesterin-producing degeneration in a hydrocele. The treatment is incision and drainage.

XXXV. SYMPTOMATIC VARICOCELE.—Symptomatic varicocele is rare. It is caused by obstruction of the spermatic veins. I have seen one case due to prolonged use of a truss. It is usually caused by the pressure of enlarged retroperitoneal glands upon the spermatic veins. This generally occurs in connection with malignant disease of the kidney and is an evil omen, since it indicates glandular involvement.

Diagnosis.—Symptomatic varicocele develops very rapidly, late in life, on either side. It is painless, attains a large size, and is always associated with an abdominal tumor or some other cause of obstruction.

XXXVI. SPONTANEOUS VARICOCELE.—The left testicle habitually hangs lower than its fellow, and the veins of the left spermatic cord are habitually somewhat more prominent than those upon the right side. Idiopathic varicocele is a spontaneous varicose enlargement of these veins (Fig. 4262). The proportion of adult males suffering from this disease is estimated as between seven per cent. (Bennett) and twenty-five per cent. (Senn), the discrepancy in these figures being evidence of how common are small varicoceles and how slight is their importance.

Varicocele always occurs on the left side; very rarely a large varicocele on the left side is associated with a small one on the right side. The disease occurs only in young adults. The cause of varicocele has been bitterly debated. It occurs in young adults on account of the sexual congestion to which they are so peculiarly liable. It is not known why it should always occur on the left side, although this has been attributed to the anatomical position of the left spermatic vein, which is longer than the right and enters the left renal vein at right angles, so that it is not so much affected by the venous suction as is the right vein, which enters the vena cava at an acute angle. Exceptionally, varicocele results from a sudden strain.

Symptoms.—The symptoms paraded by advertising charlatans as those of varicocele cover every neuralgic manifestation, and to this notoriety is attributable a large proportion of the symptoms complained of by these patients. Three sets of symptoms may be distinguished:

1. Neurotic symptoms, such as the failure of sexual desire and potency, and all kinds of reflex pain and weakness.

2. Neuralgic symptoms, of which the most notable is a continuous soreness or pain running from the testicle up through the groin into the loin, most marked in some one of these localities.

3. The only symptom may be the presence of venous tumor.

In a general way it will be found that patients with the smallest varicoceles, those in whom the enlargement of the veins is scarcely more than a fancy, encouraged by the weighty opinion of some quack, suffer most from the purely neurotic symptoms; while it is the medium-sized varicoceles that present the most marked neuralgic symptoms, leaving the largest growths to cause the least pain.

Diagnosis.—The sufferer habitually diagnoses his case by the fact that the left testicle hangs lower than the right, and that he has some real or imaginary sexual neurosis. The surgeon must not be misled into this opinion. The perverted sexual appetite, the morbid broodings over sexual matters, the swindling methods of the quack, are causes quite adequate to explain the neurotic symptoms of these patients, whose varicocele is only one evidence of general morbid sexuality. Cure of the varicocele can affect the neurotic symptoms only by its hypnotic influence upon the patient's mind.

The actual varicocele tumor manifests itself as a general swelling of the scrotum which, when palpated, is felt to be made up of a mass of varicose veins, which feel like earthworms, soft and convoluted. Veins of this description can almost always be felt in the left side of the scrotum, and it is fair to make the diagnosis of varicocele only when these veins make a considerable tumor and drag the testicle well below its fellow. Palpation may also reveal atrophy of the testicle from pressure. No other scrotal tumor is mistakable for varicocele.

Treatment.—The mild cases in whom sexual symptoms predominate are best treated by the application of a suspensory bandage, rigid sexual hygiene, and medication of the prostate, as for neuralgia of that organ. The patient may be reassured that his varicocele cannot influence life or potency, and that, with the lapse of years or by the sexual hygiene of matrimony, he may expect to be relieved from all his symptoms. Larger varicoceles require operation for their removal, in order to relieve the patient of his discomfort and to prevent atrophy of the testicle from pressure. When neuralgia is the prominent symptom, operation may be performed to relieve the disfigurement and with some prospect of relief to the neuralgia; but it is never possible to assure the patient absolutely that any operation for varicocele will relieve sexual or neuralgic symptoms. The constant failure of surgery to live up to its promises in this matter is an example of the futility of attempting to cure a reflex phenomenon without absolute assurance of the nature of the reflex. If operation is decided upon, whether for the purpose of relieving the patient's mind, or of attempting to cure his painful symptoms, or of removing a large mass of varicose veins, two methods of approach are open to the surgeon. Without stopping to consider the applicability of coagulating injections and of electricity to this condition, we may briefly describe the operations of subcutaneous ligature and of excision.

Subcutaneous Ligature.—The instruments required for this operation are the Keyes-Reverdin needle (Fig. 4263), a sufficient length of stout silk, and a pair of scissors. These are sterilized by boiling, the patient's skin is prepared as for any aseptic operation, and the surgeon cleanses himself with proper care. The operation may be performed with or without general anæsthesia. If the patient prefers he may take chloroform during the whole operation, or he can avoid this and at the same time have the pain greatly mitigated by the injection of cocaine into the points of puncture and the administration of a whiff of chloroform at the time the ligatures are tied. Under these circumstances he is made to stand during the insertion of the ligature, in order that the veins may be as full of blood as possible; while, if general anæsthesia is employed throughout, the operation must be performed with the patient recumbent.

To perform the operation the first and almost the only technical requisite is to separate the bundle of varicose veins from the vas deferens. In order to do this the contents of the left half of the scrotum are squeezed repeatedly between the thumb and index finger of the left hand and allowed to roll piecemeal from this grasp until the surgeon can be sure of distinguishing (1) the large, tortuous varicose pampiniform plexus; (2) the vas itself which stands out separately as the largest, hardest single cord in the whole mass; and (3) a few veins running to the inner side of the vas. These three sections having been distinguished, the thumb and finger are pressed between the vas deferens and the varicose veins at a point just below the junction of the scrotum with the trunk. Pressure is made until the surgeon feels sure that no vascular tissues lie between his fingers, all the while being careful not to allow the vas to slip outward or the veins to slip inward.

Now taking the needle threaded with a piece of silk fourteen inches long, the surgeon quickly plunges this into the space made by his pressure between the vas and the veins. Needle and thread enter the front of the scrotum, issuing behind. The eye of the needle is then opened, the silk loop extracted from it, the eye tightly closed, and the needle slowly withdrawn until its point is only just within the anterior puncture. One end of the silk loop is then pulled through to the back of the scrotum, the veins are allowed to slip back toward the vas, and the needle is reintroduced externally between the veins of the skin and made to issue accurately through the original posterior puncture. At this stage the varicose veins are encircled by a strand of silk to the inner side and the needle to the outer side. All that remains to be done is to open the eye of the needle once again, to insert in it the end of the piece of silk and to withdraw the needle, carrying the silk around the veins and out through the original anterior puncture. The veins are now held in a sling formed by the silk loop. The dartos at the point of posterior puncture is caught in the loop, and this must be freed by a sharp tug. The loop is now tied tightly. This operation squeezes certain nerve filaments, and is the only intensely painful part of the whole procedure. A second and a third knot are then tied for safety, the ends of the silk are cut off short, and another jerk frees the dartos at the point of anterior puncture, permitting the knot to slip out of sight into the scrotum.

FIG. 4263.—Keyes Varicocele Needle.

This little operation may be repeated just above the testicle and again just below it; while, in very exceptional instances, it may seem necessary to tie a few veins running to the inner side of the vas. I have never put more than three ligatures in any one case, and it is my routine custom to place one ligature high up in the scrotum and one just above the testicle. If general anæsthesia is not employed it is convenient to insert all the ligatures, then to give the chloroform and then to tie.

After the operation the points of puncture are sealed with collodion, the scrotum is slung up with a T-bandage, and an ice-cap is placed against it to minimize the painful and œdematous reaction. The patient remains in bed some three or four days, though this period may be cut short, and then goes about his business wearing a suspensory bandage. For a few months the points of ligature remain surrounded by hard nodes of induration, after which this gradually disappears. Thereafter the suture may be readily detected grasping the atrophied veins.

The Open Operation.—Excision of varicocele may be most conveniently done through an oblique incision over the spermatic cord at its point of exit from the inguinal canal. The tissues of the cord are laid bare and the veins separated from the vas and pulled out, drawing the testicle up to the lower end of the incision. When the whole pampiniform plexus has thus been extruded it is tied off by two stout ligatures, and excised between them; the ends of the ligatures are then tied together, thus supporting the testicle. A few stitches close the incision; the patient lies in bed for from four to six days.

In choosing the operation appropriate to a given individual case, it must be remembered that: (1) ligature avoids incision, while excision postulates it; the temperament of the patient may require one or other operation to be chosen on this account; (2) ligature in unskilful hands may injure the vas and the potency of the testicle, while the open operation in unskilful hands is commonly followed by prolonged suppuration. Suppuration is extremely rare with ligature, and either operation if skilfully and carefully done should avoid either complication; (3) atrophy of the testicle is as likely to occur after either operation. I have never seen it, nor have I seen relapse of the varicocele in any case upon which I have performed subcutaneous ligature; (4) subcutaneous ligature is a neater operation requiring shorter convalescence and involving less shock to the patient; therefore it is habitually to be preferred.

One other operation is frequently performed for the relief of varicocele—viz., *ablation of the scrotum*. If a large varicocele have stretched the scrotal skin, it is the custom of many operators to excise a portion of this, partly to obtain an æsthetic result, partly to support the testicle. This second hope is vain. The distensible scrotal skin cannot be employed to support anything, and for the same reason, if the pressure of the varicocele is removed, the skin may be left to contract of itself, unless it has been enormously stretched.

XXXVII. Tumors of the Cord.—The various hydroceles of the spermatic cord have already been dwelt upon. Of solid tumors the only one of any significance is the so-called fibrolipoma, a tumor which sometimes grows to enormous size simulating malignant disease of the testicle. In fact, so many of these tumors which have been pathologically passed upon as fibroma, fibrolipoma, or, fibromyoma, prove by their prompt recurrence to be malignant that it is more correct to group the whole class as sarcoma, the pathologist to the contrary notwithstanding.

XXXVIII. Diseases and Injuries of the Seminal Vesicles.—*Malformations.*—The malformations of the seminal vesicles are unimportant. There are never more than two vesicles, and if one is missing the testicle on that side is missing as well. The ejaculatory ducts may empty into the ureters or into the urethra at some point anterior to the triangular ligament, instead of on the edge of the prostatic utricle.

Wounds.—Guelliot recognizes only one case of undoubted accidental wound of the vesicle due to fracture of the ischium. Operative wounds of the ejaculatory ducts are doubtless frequent as the result of various perineal cystotomies, prostatotomies, and prostatectomies. Incision of one or both of the ducts is doubtless usually followed by obstruction which, if partial, causes dyspermia; if total and bilateral, sterility. Another result of such a wound is inflammation, showing itself as an acute vesiculitis and epididymitis. It is for these reasons that cystotomy performed upon a young adult should be suprapubic rather than perineal. Spermatic fistula has resulted from the old-fashioned lateral lithotomy operation. It heals kindly unless the parts are cancerous or tuberculous.

Acute Seminal Vesiculitis.—Acute inflammation of the seminal vesicle is a common complication of acute prostatitis. But the acutely inflamed vesicle gives no characteristic symptoms, and is not observed clinically except under three conditions: (1) acute epididymitis, with which there is always an inflammation of the vesicle; (2) chronic vesiculitis, the result of an acute attack; and (3) abscess of the vesicle.

Abscess of the Seminal Vesicle.—If the vesicular inflammation is so intense as to produce suppuration, the symptoms of prostatitis (for these patients always suffer first from an inflammation of the prostate) are intensified. The temperature is high, there may be chills, increased vesical irritability, and a sense of burning and discomfort deep in the perineum, oftentimes sufficiently irritating to cause sympathetic rectal tenesmus.

The pus accumulates either within or alongside of the vesicle and habitually points toward the rectum. Examination of such a case in its early stages reveals a hot, boggy, pulsating swelling above and to one side of the prostate, or perhaps extending down over that organ. Later, as the pus focalizes, the tenderness and heat are less, while fluctuation becomes apparent.

If the inflammation is discovered before abscess has developed, an attempt may be made to abort it by placing the patient in bed and irrigating the rectum twice a day with water as hot as he can bear. But after fluctuation becomes apparent, the only appropriate treatment is incision and drainage, preferably through the rectum (see below).

Chronic Seminal Vesiculitis.—Chronic inflammation of the vesicle may result from an acute inflammation, or may come on insidiously as a result of sexual intemperance or with no obvious cause. Many cases show no symptoms to distinguish them from chronic prostatitis. The surface prostatitis causes pyuria and chronic gleet, and there may well be no subjective elements of any deeper trouble; but the vesicular focus can be felt by rectal touch as a hard, irregular mass just above one horn of the prostate, and, unless this vesicular mass is dissipated by local treatment, it is impossible to cure the gleet. In other cases, however, there are subjective evidences of the inflammation of the vesicle, and all cases of chronic seminal vesiculitis may be classified as follows:

1. Cases (as noted above) in which there are no subjective symptoms of the vesicular inflammation, but only chronic gleet.
2. Cases of relapsing urethritis, the recurrence being occasioned by sexual excitement and due to a smouldering focus in the vesicle.
3. Cases of gleet complicated by painful or hemorrhagic emissions.
4. Cases of relapsing pyuria. These cases differ pathologically from all the others, in that the vesicle is a dilated pus sac, filling up and emptying at more or less regular intervals, so that the urine is at one time entirely free from pus and at another loaded down with it.
5. Neuralgic cases. These may be subdivided into cases of neuralgia about the perineum and along the urethra, and cases of neuralgia of the back and of the testicles. In the former class the indurated vesicle is usually very tender and local treatment immediately efficacious; while in the latter class there may be only a little enlargement of the vesicle with scarcely any tenderness, although the reflex neuralgia in the testicle, the rectum, or the loin be intense. Such cases are slower to improve under treatment.

Diagnosis.—The diagnosis of chronic seminal vesiculitis is made by rectal touch. The prostate may or may not be inflamed; it may be large and congested, or it may contain foci of induration; but above and at the outer angle of the prostate is always felt a lumpy mass; this is the inflamed vesicle. In some cases it is soft and massage upon it for a few minutes will greatly decrease its size, while drops of pus exude from the meatus, and the urine next passed will be extremely purulent. In other cases the mass is harder and less affected by massage.

Treatment.—The treatment of chronic seminal vesiculitis may be local or hygienic. Hygienic treatment consists in abstention from excessive sexual intercourse, and, in severe cases, from all sexual matters whatever. An improvement in the surroundings of the patient, a vacation in the country, will often entirely relieve the mild neuralgic and gleety cases. But in the majority of instances hygiene should be employed only as an accessory to local treatment in order to keep the patient in a condition in which local measures can effect a cure.

The local methods of treatment are: (1) Mechanical, (2) thermic, (3) chemical, (4) electric.

1. The mechanical treatment consists in massage, a manipulation which is performed by the finger introduced into the rectum. The vesicular induration is palpated and then gently rubbed in all directions with a to-and-fro and spiral motion, and the pressure is gradually increased until it is quite firm; but severe manipulation is to be avoided for fear of lighting up an epididymitis.

Various metal implements have been devised for massage but it is so difficult to employ them with sufficient

Sexual Organs.

gentleness that the surgeon's finger is the instrument to be preferred.

2. Thermic treatment is applied by means of the double-current rectal tube. The tube I prefer is that devised by Dr. Chetwood (Fig. 4264). This is inserted into the patient's rectum, as shown in Fig. 4265, and two quarts of water at the temperature of 105° F. are run

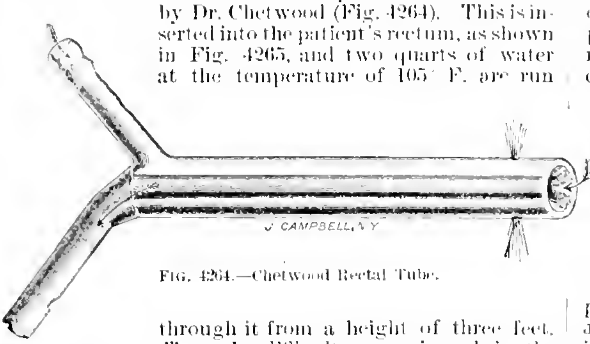


FIG. 4264.—Chetwood Rectal Tube.

through it from a height of three feet. The only difficulty experienced in the use of such a tube is in getting the water out. It runs in easily enough, but some experience is required before it can be made to flow out through the tube without running up the bowel and causing colic and an evacuation.

3 and 4. Chemical and electrical applications to the prostate have been generally employed without any great success. Ichthyol suppositories are well spoken of.

In choosing the treatment appropriate to a given case it is best to place one's chief reliance upon the hot-water irrigations. These may be used once or twice a day, and it is my custom to employ them for two weeks out of three. Except in hyperacute cases the patient experiences little or no immediate relief from this treatment, but under it the indurations slowly disappear. In some neuralgic cases cold water is more efficacious than hot. At the same time it is well to massage the vesicle once or, in severe cases, twice a week. Rectal irrigation must be kept up for from eight to twelve weeks, as a rule, though it is not necessary to employ massage during the latter part of this time.

Tuberculosis.—Genital tuberculosis often begins in the seminal vesicles (see above). It seems always to begin as a unilateral disease; indeed, it often involves the vesicle, the epididymis, and even the kidney of one side, with one-half of the prostate, before making any incursion upon the other side. But it is apparently through tuberculosis of the vesicle and of the prostate that the disease passes from one testicle to the other.

There are commonly no symptoms directly referable to the vesicle. Hæmosperm, abscess, fistula, and irritation or apathy of the sexual appetite are very exceptional manifestations. In most cases the disease is discovered only by rectal examination and manifested only by symptoms of the associated inflammation in the prostate and in the epididymis.

Diagnosis.—The diagnosis depends upon the discovery in a patient with prostatic or epididymal tuberculosis of hard nodules, boggy, inflamed areas, or large fluctuating masses in the region of one or both vesicles. Primary vesicular tuberculosis without prostatic or epididymal disease is not diagnosed.

Treatment.—The treatment appropriate to most cases is systemic. Local applications or massage can only do harm by increasing the epididymal inflammation. The tuberculous vesicle should rarely be examined, never massaged.

Operations.—A suppurating vesicle, whether tuberculous or simply inflamed, may require incision. This for simple inflammation may be carried through the anterior rectal wall where the abscess points. Such incision, though theoretically subjecting the patient to grave danger from sepsis, is practically followed by the happiest results. It may be performed without anæsthesia by means of a thin bladed knife introduced on the finger, and it results in evacuation of the abscess without untoward complications.

Incision of the tuberculous vesicle is always followed by fistula, and must therefore be carried from the perineum. It is convenient to make a circular incision beginning at one ischial tuberosity and encircling the front of the anus about one inch from it, carried past the opposite tuberosity and back to the median line, thus surrounding the anus by three-fourths of a circle. This incision is carried upward through the deep fascia and the levator ani muscle; blunt dissection and retraction of the rectum then expose the prostate and the vesicle. Through this incision the vesicle may be incised, scraped, or excised. Excision of the organ is a difficult and tedious operation on account of the depth at which one must work. Although the apex of the vesicle rests against the peritoneum, it is usually easy to shell it away, and rupture of the peritoneum is a complication of this operation which has not been recorded. The real dangers of the operation are puncture of the urethra or of the rectum. These are avoided by introducing a sound into the former, a finger into the latter.

The vesicle may also be excised by a Kraske or Rydgier excision of the sacrum and lateral displacement of the bowel; while Young, of Baltimore, has reintroduced Villeneuve's operation of excising the vesicle as a complement to castration, employin. the oblique inguinal incision.

Vesicular Cysts.—Prolonged inflammation of the vesicle may leave it greatly dilated. Such cysts are not uncommon in the aged. Occlusion of the ejaculatory duct

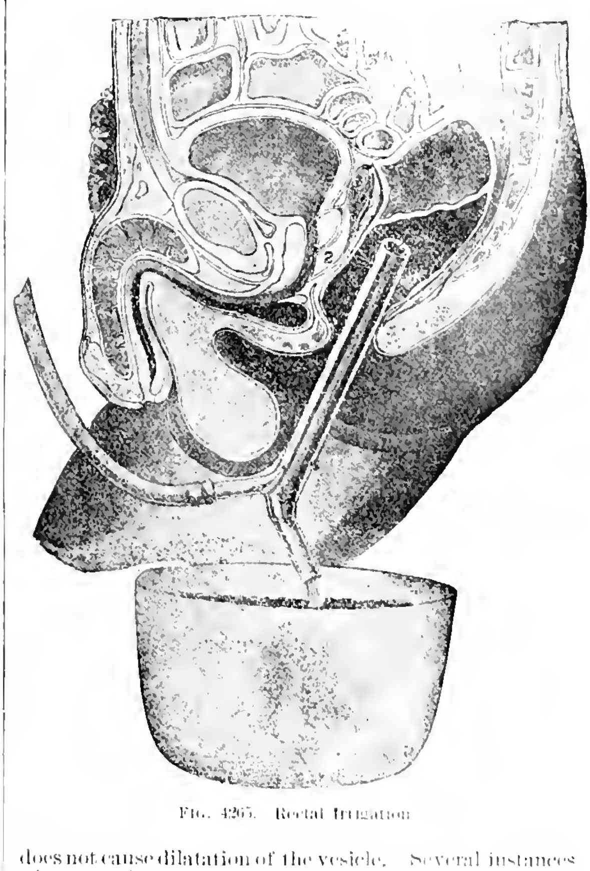


FIG. 4265. Rectal Irrigation

does not cause dilatation of the vesicle. Several instances of retrovesical echinococcus cysts have been attributed without convincing proof to the vesicle.

Concretions and Calculi.—Vesicular concretions formed of starchy matter, epithelia, and phosphatic salts are common in the aged; exceptionally they give rise to *spermatic colic.* This pain occurs spontaneously or at the moment of ejaculation, and is sharp, colicky, and nauseating. It is most intense at a point about an inch up the anterior rectal wall or at the neck of the bladder; thence radiating to the testicle and the loin. The pain is caused by the impaction of a concretion in the ejaculatory duct. It may cause painful or deficient emission or hæmosperm. It may be long-continued or of brief duration.

The treatment of a mild case consists in introducing a finger into the rectum and gently massaging the painful spot. This usually dislodges the concretion and relieves the patient. Recurrent colic seems to be relieved by the hot rectal douche. If the attack is severe, prostate and vesicle may be massaged against a full-sized sound introduced into the urethra; this failing, incision may be considered.

Malignant Growths.—Guelliot records one case of primary carcinoma of the vesicle; secondary involvement occurs from the prostate, the bladder, or the rectum.

XXXIX. Seminal Incontinence or Spermatorrhœa.—Seminal incontinence or spermatorrhœa may be defined as the involuntary and unconscious loss of seminal fluid. It may show itself in one of two ways: either the semen leaks away quite continuously, in which case a few spermatozoa may be found in the centrifuged urine, or else the semen is squeezed out by muscular exertion or by defecation, in which case it appears as a pearly drop at the meatus. Both conditions are fairly common, and neither involves any symptoms or threatens impotence. The lesion to which the seminal leakage is attributable is a weakness of the prostatic muscle encircling the orifices of the ejaculatory ducts. This weakness may be due to antecedent gonorrhœa or to perineal section, or it may result from sexual causes (habitual masturbation).

Thus the condition of spermatorrhœa presents itself clinically in three types:

1. Spermatorrhœa without Symptoms. This I am confident is a large if not the largest class of cases.

2. Spermatorrhœa without any Symptom except Exudation from the Meatus. The pearly drop of mucus which is so commonly extruded by a constipated movement of the bowels habitually contains no spermatozoa and has no connection with the seminal vesicles or their contents. In most cases it consists entirely of prostatic secretion and is evidence of a prostatic congestion. It is quite exceptional to find spermatozoa in this discharge.

3. Spermatorrhœa with Neurotic Symptoms. Lallemand's huge tome upon spermatorrhœa is the text-book from which modern charlatanism draws the elements of the lurid pictures with which it deludes and depraves young men suffering from sexual weakness. Lallemand attributed practically every urinary and genital disorder to the loss of seminal fluid, and inasmuch as any man who is worried about his sexual capacity rates that fluid as his most valuable possession, it is an easy matter to persuade him that its loss entails many and dire evils.

As a matter of fact, spermatozoa are elaborated in the testicle and are merely stored in the seminal vesicle, and there is no evidence to show that leakage of the seminal elements from the vesicle has any more effect upon the potency or nervous tone of a man than has sexual intercourse or the nocturnal emissions which take its place. On the contrary, the frequency with which spermatozoa are found in the urine of men sexually normal proves that this dribbling is entirely harmless. The only connection which can be established between spermatorrhœa and sexual incapacity is that of a common cause. For the sexual debility which causes impotence may equally well cause spermatorrhœa, and the lymphatic, neurotic individuals who are most subject to sexual weakness are equally subject to the muscular weakness and the gonorrhœal inflammations which cause spermatorrhœa.

The treatment of spermatorrhœa is a matter of hygiene, local, general, and mental. The tone of the urethra and of the prostatic muscles should be strengthened by counter irritation with sounds, with the cold water rectal douche, or with mild electrical currents. The general health may be built up by muscular outdoor exercise to replace the lounging, smoking, and drinking with which these men are prone to occupy their leisure hours. While above all and most difficult of all it is the physician's duty to elevate the patient's moral tone, to discourage his pruriency, and to set his mind upon a clean, decent basis. It is not always possible to insist that the loss of seminal fluid has no connection with the sexual disorder, since the conviction of these patients that such is the case is often absolute. It is better to try to lessen the symptoms while paying little attention to the theory of their cause, though, as a matter of fact, probably seventy-five per cent. of those who complain of sexual weakness due to seminal incontinence possess the sexual weakness, but have not and never have had any spermatorrhœa.

XL. Impotence.—Impotence is inability to perform the sexual act. It is not to be confounded with sterility, which is inability to beget children. Impotence may exist without sterility and sterility without impotence. Three varieties of impotence may be recognized: the organic, the symptomatic, and the neurotic.

Organic Impotence.—This may be caused in six ways:

1. Abnormal size of the penis. If the penis is absent or so small as to make intromission impossible, the patient is relatively impotent. The same is true of an overdeveloped penis.

2. Hypospadias and epispadias involve impotence, inasmuch as the semen is not thrown into the vagina; thus the more marked the urethral deformity the more likely the impotence. In the same way tight stricture causes impotence, whether by forcing the ejaculated semen back into the bladder or by permitting it to flow out through fistulous openings in the perineum.

3. Imperfect, irregular, or bent erections, whether due to congenital deformity, to injury, or to inflammation, may prevent direct ejaculation.

4. Various external agencies may have the same effect; among these may be mentioned tumors about the genitals, ankylosis of the hip, excessive abdominal fat, etc.

5. Eunuchs and persons with atrophy of both testicles are always sterile and usually impotent.

6. Faulty erection or ejaculation from disease of the brain or of the spinal cord is an exceptional cause of impotence.

Symptomatic Impotence.—Impotence is symptomatic of youth and of old age, as also of many acute and chronic diseases, of debility from sexual excess, from drugs or alcohol, or from any other cause that lowers the patient's tone. Chief among the troubles of which impotence is a symptom may be placed congestion, neuralgia, and inflammation about the prostate and the seminal vesicles.

Nervous Impotence.—Nervous impotence is a state of mind rather than a state of body, and a person with entirely adequate sexual capacity and no organic disease may become temporarily or permanently impotent through some purely functional cause. As subsidiary causes of impotence are ranged chronic prostatitis and vesiculitis and various forms of sexual excess, in particular the solitary vice. That these causes are secondary is obvious from the fact that, of the great number of men who have chronic prostatitis and vesiculitis, and of the still larger number who masturbate habitually, only a very small proportion fall victims to nervous impotence. Such being the case and the essentially neurotic nature of the sexual act being obvious, it is evident that when a patient complains of lost manhood his trouble is mental, although it may have some underlying physical basis. In passing it is to be noted that neither obstruction of both vasa deferentia, nor prostatectomy, nor castration in adult life, necessarily results in impotence.

The nervously impotent may be divided into three classes: (1) Those whose potency, whether normal or congenitally slight, is not up to the mark they would set for it; (2) those who having been adequately potent have lost their powers through sexual excess or other cause; (3) those who have suddenly become impotent as the result of shock or fright.

1. If it can be determined that the patient is setting

himself a sexual pace of which he is incapable relief obviously consists in making him recognize his own sexual coefficient and in impressing upon him that, if he persists in trying to put a quart into a pint measure, he will inevitably reach the far more grave condition of permanently debilitated potency.

2. When the patient, as the result of excessive sexual indulgence, of prolonged gonorrhœa, or of quack doctoring, complains of loss of manhood, and tells the routine sad story of a debauched youth, it is necessary not only to discover his sexual coefficient, as in the first class of cases, but also to encourage him to look for a return of his sexual powers and to make him recognize that this return will come only as a result of total abstinence from all sexual excitement. For in these cases, even though there be no history of overworked passions, the long months and years during which the patient has moped over his sexual incapacity have had a like effect. All this must be dropped as far as the patient can drop it, and to assist him in this it is necessary to ply him with drugs of which damiana, strychnine, belladonna, and monobromated camphor are among the best, as much for the reason of making him feel that he is being treated, as for the rather dubious end of actually stimulating the sexual nerve centres. Yohimbin has been recently advocated for the treatment of these cases, but I cannot say that I have seen any good results from its use. Finally, it is often a great help if some physical cause can be found for the disorder. The cure of a chronic vesiculitis is of all things the most likely to set such a patient sexually straight. And if this can be once accomplished, if the physician recognizes that his patient has reached about as high a plane of sexual capacity as can be expected, he should immediately insist that this can be retained only by absolute sexual regularity. Celibacy is quite beyond the aspirations of such a patient; matrimony is an ideal state for him if he can muster the courage to attempt it and can develop sufficient moral sense to look upon the marriage state from a decent point of view. But sexual relations outside of marriage are inevitably harmful and, in the end, pull him down to his lowest plane, both morally and physically.

3. Of the cases coming under this head by far the greatest number occur among the newly wed. For one reason or another the young husband fails in his first attempt at sexual intercourse, and the result is so deep a discouragement that subsequent success is temporarily impossible. To handle such a case successfully it is only necessary to separate the couple at night, to administer some light stimulant to the man, and to bid him make no attempt whatever at sexual intercourse until a morning erection, which will sooner or later occur, gives him the opportunity of hurriedly proving his capacity, and this once done the disease is cured.

XLI. Sterility in the Male.—*Definition.*—Sterility in the male is inability to produce healthy spermatozoa or to discharge them from the urethra; conversely, in order to be fertile, a man must be able to discharge semen containing healthy spermatozoa.

Etiology.—Thus the causes of sterility are interference with the production of spermatozoa, interference with their health, and interference with their discharge. These causes may be tabulated as follows:

Interference with production. (Azoöspermia.)	Physiological—youth and extreme age. Local—atrophy, or disease of testes. General—Systemic disease. Excess of any kind. Congenital deficiency.
Interference with health. (Oligozoöspermia or azoöspermia.)	Testicular—excess of any kind especially sexual. Prostatic and vesicular / Urethral or deferential } inflammation.
Interference with discharge.	Organic { Stricture of vas (azoöspermia). Stricture of urethra (aspermia). Functional—(oligospermia or aspermia).

The seminal fluid is made up of the spermatozoa, which are the transformed epithelial cells of the testicular seminal tubules, combined with the secretions of the prostate and the seminal vesicles. The production of spermatozoa by the testicle begins at puberty and continues until old age is reached; and the sexual age of a man depends primarily upon heredity, secondarily upon surroundings. Recorded instances of fertility at the age of eighty and of ninety contrast with the accepted sterility after the seventieth year.

Of the causes interfering with the production of spermatozoa, the local ones require no comment. Of the general causes systemic disease is the most common. Such wasting diseases as tuberculosis and diabetes commonly check testicular activity, the system withdrawing this function in favor of more vital ones. Similarly, excess of any kind, be it excessive debauchery, alcoholism, even excessive exercise, worry, and nervous tension, equally result in azoöspermia (absence of spermatozoa from the semen). Thus a finely trained athlete often keeps himself in a condition of temporary sterility, while the overworked business man, the drunkard, and the victim of sexual excess suffer in the same way. Finally, there are a certain few who suffer what is apparently a congenital absence of spermatozoa; in all respects healthy, except that they are usually the neurotic products of over-civilization, their seminal fluid never contains any spermatozoa.

The health of the spermatozoa may be interfered with in their production, and this is the common result of sexual excess. Repeated ejaculations empty the seminal vesicles and call upon the testicles for renewed supplies, which are elaborated hurriedly and imperfectly; yet this condition is commonly an ephemeral one. An exceptional cause of interference with the health of the spermatozoa is inflammation of the canals through which the semen passes—*i.e.*, the vas deferens and the urethra, whose acrid discharges interfere with the vitality of the organisms. But prostatitis and vesiculitis are the usual causes of reduced spermatic vitality; for the vitality of the spermatozoa depends primarily upon the normal alkalinity and consistence of the prostatic and vesicular secretion in which they abide. It has been frequently observed that acidulation of the semen promptly kills the spermatozoa, and concentration seems temporarily to paralyze them; while the addition of a drop of warm water to a specimen of such concentrated semen under the microscope has the immediate effect of reviving the still organisms.

Gonorrhœal occlusion of the epididymis, following acute epididymitis, is probably the commonest cause of sterility in the male. Urethral stricture causes sterility but rarely. Functional derangements of ejaculation are most uncommon. Certain neurotic individuals are unable to effect ejaculation in sexual intercourse no matter how long this be continued, although they may have frequent and copious nocturnal emissions.

According to the estimates of good authorities, one-third of matrimonial sterility is due to the male.

Symptoms and Diagnosis.—The evidence of sterility is absence of ejaculation, lessened vitality of the spermatozoa, or absence of spermatozoa from the semen. Absence of ejaculation and absence of spermatozoa are readily determined. Malformation of the spermatozoa shows itself as oligozoöspermia, in which condition the spermatozoa, instead of swarming throughout the microscopic field, are very few, generally immobile and frequently deformed. Such a condition suggests either malproduction of the semen or interference with their health by prostatitis or vesiculitis. The diagnosis of sterility is therefore not difficult, though the diagnosis of its cause is not so easy. The usual causes of sterility are gonorrhœal epididymitis (double), vesiculitis, and prostatitis; most other cases are due to dissipation, to overwork, etc., or to a congenital weak sexuality.

Treatment.—The treatment of sterility consists in the removal of its cause. Many cases tend to spontaneous cure. Others are by their nature incurable; but in a large proportion of cases, whether due to prostato vesiculitis or to a run-down general condition, a cure may be expected to result from intelligent treatment. One of the latest triumphs of surgery is the operation of Dr. Edward Martin, of Philadelphia, of suturing the vas deferens into the globus major of an epididymis having an obstructed globus minor. The result of this operation was the appearance of spermatozoa in the expressed secretion of the seminal vesicles, from which they had previously been absent. *Edward L. Keyes, Jr.*

SHADOW TEST.*—"Keratoscopy," "Retinoscopy," "Retinoskiascopy," "Korescopy," and other names. An objective method of determining the refraction of the eye.

When, from a certain distance, an observer throws light into an eye by means of a perforated mirror, on looking through the hole in the mirror he sees the entire pupil illuminated with a reddish light. If, now, the mirror is slightly rotated, a dark segment ("shadow") comes into view and, increasing as the mirror is rotated, presently extends over and darkens the entire pupil. The direction in which the "shadow" grows—*i.e.*, the direction in which the border of the shadow moves, whether in the same or in the opposite direction to that in which the mirror is rotated—depends, with certain limitations, on the refraction (hypermetropia, emmetropia, or myopia) of the observed eye, and affords a means, when the necessary conditions are fulfilled, of measuring its refraction.

The perforated mirror used in the shadow test may be either plane or concave.

1. We will assume that a plane mirror is used, and that the observer's eye, which is immediately behind the perforation, is stationed at a distance of one metre from the observed eye. The mirror is now adjusted to reflect light, preferably from an Argand burner, directly upon the observed eye, whose pupil is seen filled with a uniform red light. On rotating the mirror to the right (*i.e.*, turning the left side of the mirror forward) a dark "shadow" appears at the left side (*i.e.*, to the observer's left) of the pupil and passes over it, increasing from left to right, until the entire pupil is darkened. Similarly, on rotating the mirror to the left, the shadow appears at the right side of the pupil and passes over it from right to left.

This movement of the border of the shadow in the direction of the rotation of the mirror occurs whenever the focus of the observed eye for pencils originating at its fundus (*i.e.*, the far-point of the observed eye) falls elsewhere than between the observer's and the observed eye. When, as we have assumed, the observer's eye is stationed at a distance of one metre, the observed eye may be either hypermetropic, emmetropic, or myopic in any degree less than 1 D.

2. On rotating the (plane) mirror to the right the "shadow" appears at the right side of the pupil and passes over it from right to left; or, on rotating the mirror to the left, the shadow appears at the left side of the pupil and passes over it from left to right.

This movement of the border of the shadow in a direction opposite to that of the rotation of the mirror occurs when the focus of the observed eye for pencils originating at its fundus (*i.e.*, the far-point of the observed eye) falls within the distance at which the observer's eye is stationed. In our assumed case this distance is taken equal to one metre; the observed eye is therefore myopic in some degree greater than 1 D.

3. On rotating the (plane) mirror in any direction, no "shadow" is seen, but the illumination of the pupil fades gradually into darkness. This fading out of the illumination of the pupil in its totality, without any appearance of a moving shadow, occurs only in the case in which the focus of the observed eye for pencils originating at its fundus (*i.e.*, the far point of the observed eye) falls at the exact distance at which the observer's eye is stationed, which in our assumed case has been taken equal to one metre; the observed eye is therefore myopic, and its myopia is equal to 1 D.

4. If a concave mirror of short focus is substituted for the plane mirror, in which case a real image of the flame is formed between the observer's and the observed eye, the "shadow" is seen to move in a direction opposite to that in which it moves when the plane mirror is used.

These facts have been utilized for the practical determination of the refraction in several different ways, two of which have been especially cultivated.

I. The observer, stationed at a distance of one metre, and using a concave mirror preferably of about 20 cm. focus, throws light from an Argand burner placed beside or above the patient's head, into the eye whose refraction is to be investigated. If on rotating the (concave) mirror in any direction, he sees the "shadow" moving in the opposite direction, he concludes that the eye is either hypermetropic, emmetropic, or myopic in some degree less than 1 D. Convex glasses, of progressively increasing strength, are then placed, one after another, in a trial frame before the observed eye, until a glass is found through which no shadow movement is discernible in the transition from the illuminated to the darkened state of the pupil. The combination of the observed eye and this convex glass represents myopia of 1 D., and the subtraction of 1 D. from the value of the glass gives the refraction of the eye. For example, if the convex glass measures 3.5 D., the refraction is H = 2.5 D.; if the convex glass measures just 1 D., the eye is emmetropic; if without a glass no moving shadow is seen, the refraction is M = 1 D.

If, on rotating the (concave) mirror, the shadow is seen moving in the same direction, the presence of myopia of a higher grade than 1 D. is established; concave glasses, of progressively increasing strength, are then placed, one after another, in front of the observed eye, until a glass is found through which no shadow movement is seen. The combination of the observed eye and this concave glass represents myopia of 1 D., and the addition of 1 D. to the value of the glass gives the actual myopia.

This is the method advocated by Cuignet, Parent, and others.

II. The observer uses a plain mirror, and does not keep at a fixed distance from the observed eye. We will suppose that he first stations himself at a distance of one-half metre, and sees the "shadow" moving in the same direction as that in which the mirror is rotated, thus establishing the fact that the eye is either hypermetropic, emmetropic, or myopic in some degree less than 2 D. A convex glass of sufficient strength to render the observed eye myopic in excess of 2 D. is then placed before it in a trial frame, thus causing an image of its fundus to be formed in front of the eye of the observer. The observer next approaches the observed eye until he reaches a point at which no moving shadow is discernible—*point of reversal*. The observer's eye is now at the far-point of the observed eye as modified by the convex glass, and the distance from eye to eye is measured by means of a rule or a tape measure. The reciprocal of the fractional part of a metre thus measured represents, in dioptries, the refraction of the observed eye plus the convex glass, and the subtraction of the value of this glass gives the refraction of the eye.

When the observed eye is myopic in excess of 2 D., so that its far-point lies within the distance of one-half metre at which the eye of the observer is stationed, the movement of the shadow is in the direction opposite to that in which the mirror is rotated, and the distance of the point of reversal from the observed eye gives the measure of the myopia.

When the myopia of the observed eye is in excess of 4 D. or 5 D., the point of reversal falls too near the eye for an entirely trustworthy measurement of its distance. In such a case a concave glass, of sufficient strength to carry the far point back to a distance of from one-quarter metre to one-half metre, is placed before the observed eye, and the value of this (concave) glass must be added to that obtained by measuring the distance of the point of reversal

This is the method advocated by Chibret, Schweigger, and others.

* The writer desires again to acknowledge his indebtedness to Dr. John Green, of St. Louis, for assistance most kindly rendered in revising the present article for the press.

Shadow Test.

In emmetropia, and in simple ametropia (hypermetropia and myopia), the movement of the mirrored image of the flame, whether virtual or real, and that of the "shadow" are always in one and the same plane passing through the observer's and the observed eye. The same is true also in astigmatism whenever the plane in which the image moves, as determined by the direction in which the mirror is rotated, passes through either of the two principal meridians of the observed eye. The shadow test is, therefore, perfectly adapted to the measurement of the refraction of an astigmatic eye in each of its two principal meridians. If, however, the shadow is seen to move in a plane other than that determined by the direction of the rotation of the mirror (see Fig. 4266), it is certain both that the observed eye is astigmatic, and that the plane in which the mirrored image moves does not pass through either of its principal meridians. To find a principal meridian, whether of greatest or least refraction, it is then only necessary to vary the direction in which the mirror is rotated, until the shadow is seen to move in the same or in the opposite direction. The statement made by different writers, that the direction of the obliquely moving shadow corresponds to that of one or the other of the two principal meridians, is erroneous.

The idea of utilizing the direction of the movement of the "shadow" in the pupil for the practical determination of the refraction originated with Cuignet (1873), but he gave a wrong explanation of the phenomenon and so was led to give to the procedure the very unsuitable name "keratoscopy." Landolt (1878) was the first to propose a nearly correct theory, and his and Parent's descriptions have contributed largely to the popularization of the method. Credit must also be given to Chibret (1882) for the important modification of the procedure in which the plane mirror is used at a varying distance. Leroy and Monoyer have further developed the theory, which, strange to say, had been erroneously, or at best inadequately, stated during a number of years.

The theory of the shadow test will be best understood if we consider a few special cases:

I. We will assume that the observed eye is emmetropic, and that the test is made with a plane mirror at a distance of one-half metre. An image of the source of light (Argand burner) is formed at the fundus of the observed eye, which, within the limits of this image, is strongly illuminated so that every point gives out rays of light as if it were self-luminous. The details of this illuminated area at the fundus are, however, indistinguishable, or at best imperfectly distinguishable, inasmuch as, by the conditions of the test, the observer's eye is accommodated, not for the fundus, but for the pupil of the observed eye. The illuminated area is seen, therefore, in circles of confusion, consequently as a more or less diffuse red light shining through the pupil.

How much of the illuminated area is, in any case, visible to the observer, is determined in part by the diameter of the pupil of the observed eye, and in part also by the size of the hole in the mirror, or, if this is rather large, by the diameter of the pupil of the observer's eye. Let $a\,a'$ (Fig. 4267, *I*) represent a portion of the illuminated area (image of the flame) at the fundus of the observed eye, which we assume to be directed upon the hole in the mirror, consequently upon the pupil of the eye of the observer. Let $a\ P\ p\ \pi$ represent a limiting ray passing out of the pupil of the observed eye to enter the pupil of the observer's eye; similarly, let a' represent the origin of another limiting ray, as determined by the points P' and p', meeting the retina of the observer's eye at π'. Now $P\ P'$ and $p'\ p$ represent, respectively, the diameters of the two (circular) pupils, consequently $a\ a'$ and $\pi\ \pi'$ must also represent diameters of circles. We will call the circular area $a\ a'$ the *visible circle*. Inasmuch as the illuminated area (image of an Argand burner when the distance of the mirror is taken anywhere between the limits of one metre and one-quarter metre) is considerably larger than that of the visible circle, the entire pupil $P\ P'$ will be lighted up, and the visible circle $a\ a'$ will coincide throughout with the two pupils, $P\ P'$ and $p p'$, and with the circle $\pi\ \pi'$ at the fundus of the eye of the observer. But we have already seen that the visible circle $a\ a'$ is pictured at $\pi\ \pi'$ in circles of confusion; hence the impression made on the observer is rather that of the illuminated pupil $P\ P'$ than of the circle $a\ a'$.

To explain the phenomenon of the moving "shadow" we will suppose that the observer, whose attention is

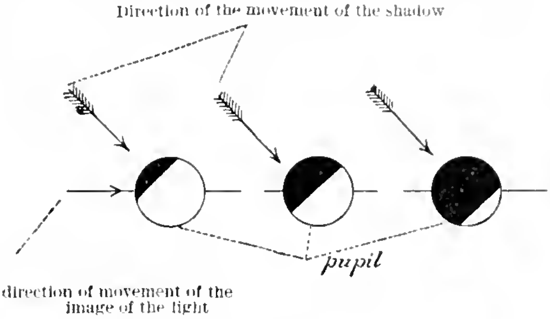


Fig. 4266.

fixed on the illuminating pupil $P\ P'$ of the observed eye, now rotates the mirror a little to the right (see Fig. 4268), thus displacing the mirrored (virtual) image of the flame to the left, consequently displacing the real image of the flame at the fundus of the observed eye to the right. The displaced image of the flame, as it passes over the visible circle, presently leaves a segment of the latter without illumination, consequently a segment of the pupil $P\ P'$ darkened (see Fig. 4269). As already explained, the border of this dark segment is seen somewhat imperfectly defined, thus suggesting a shadow with its penumbra, and accounting, in a way, for the name "shadow test."

It will be observed that in this case (emmetropia of the observed eye) the growth of the darkened segment of the pupil (movement of the shadow) is in the same direction as that in which the (plane) mirror is rotated, the reversed movement at π, or at π', being perceived as a direct movement at a or at a', consequently at P or at P'.

II. We will now assume that the observed eye is hypermetropic, the other conditions remaining as before (see Fig. 4267, *II*). Comparing *I* and *II*, Fig. 4267, it is evident that nothing essential has been changed, as regards either the formation of the "shadow" or the direction of its movement. The illuminated area (image of the flame) is, however, smaller, and the visible circle larger, than in the case of emmetropia of the observed eye. The dark border of the illuminated area will therefore pass the limit of the visible circle more quickly (the rate of rotation of the mirror being assumed to be unchanged), but more time will be required for its transit. We have seen that the apparent diameter of the visible circle is the same as that of the pupil; the rate of passage of the shadow across the pupil is therefore slower in hypermetropia than in emmetropia.

In hypermetropia of the observed eye the conditions for obtaining a clearer view of the details of the fundus, when the eye of the observer is accommodated for its pupil, are more favorable than in emmetropia, and the higher the grade of the hypermetropia (*i.e.*, the less the distance at which the virtual image, $h\ h'$, of the visible circle lies behind the plane of the pupil) the more clearly will the retinal vessels, etc., be seen. On the other hand, hypermetropia of the observed eye is unfavorable for the accurate focusing of the image of the flame on its retina, and for this reason the outlines of this image are less sharply defined than in emmetropia. The advantage, to the observer, of the clearer view which he obtains of the image of the flame is, however, greater than the disadvantage resulting from its less perfect definition; hence the free border of the shadow, as it traverses the pupil, appears more sharply defined in hypermetropia than in emmetropia, and the higher the grade of the hypermetropia, the more distinct, on the whole, does the shadow appear.

III. The observed eye is assumed to be myopic in some degree less than 2 D., the observer being stationed, as

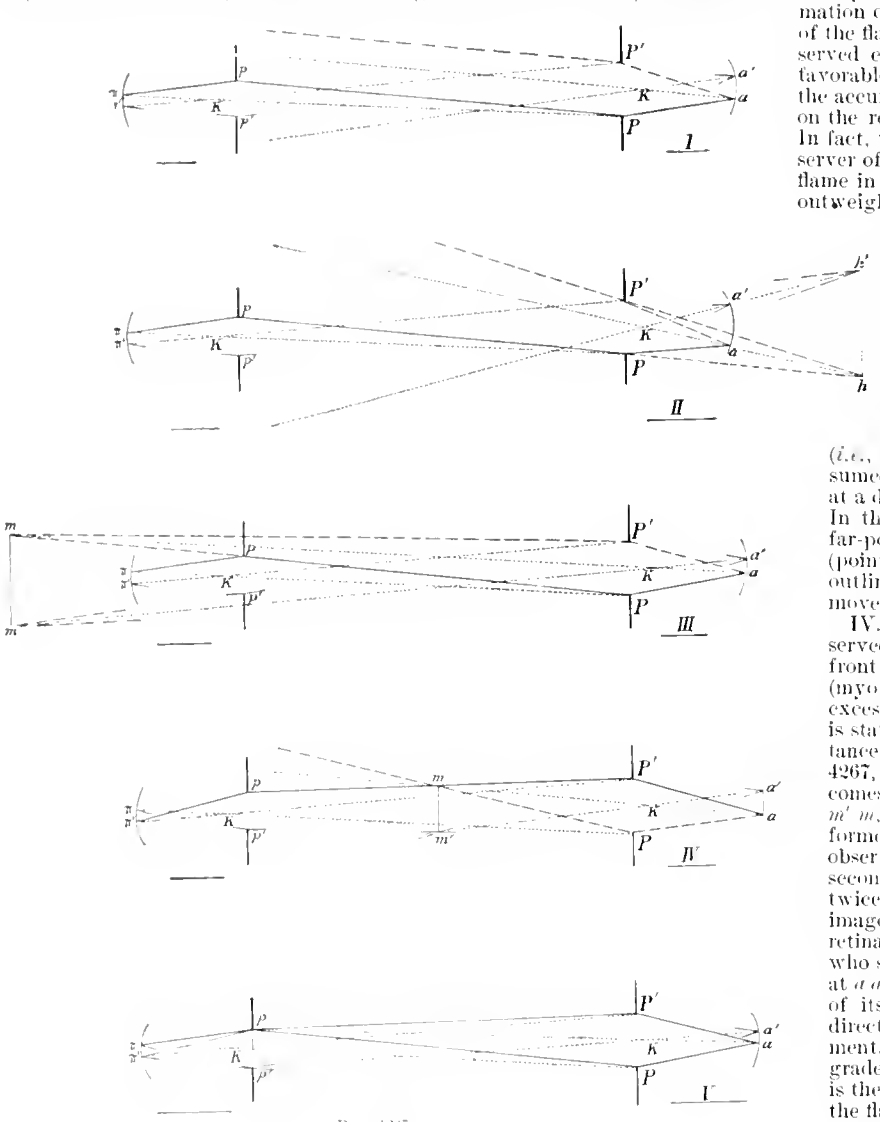


FIG. 4267.

before, at a distance of one-half metre (see Fig. 4267, *III*). Comparing *III* with *I* and *II*, Fig. 4267, we see by inspection that the conditions which determine the forma-

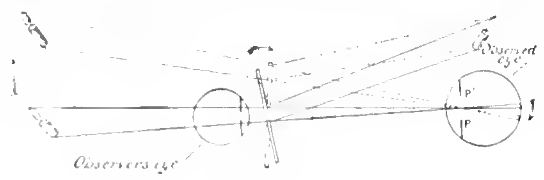


FIG. 4268.

tion and the direction of movement of the "shadow" still remain unchanged. The illuminated area (image of the flame) is, however, somewhat larger, and the visible circle smaller than in emmetropia. The appearance of the shadow will therefore be somewhat retarded, but its transit across the pupil will be accomplished in less time, consequently at a more rapid rate of movement.

In the case under consideration (myopia of less than 2 D.) the conditions are especially favorable for the formation of a sharply defined image of the flame on the retina of the observed eye, but they are even less favorable than in emmetropia for the accurate picturing of this image on the retina of the observer's eye. In fact, the disadvantage to the observer of viewing the image of the flame in larger circles of confusion outweighs any advantage accruing from the more perfect definition of this image, and this preponderance of disadvantage increases, in a progressively augmenting ratio, as the grade of myopia approaches the limit in which the far-point of the observed eye lies exactly at the distance of the pupil of the observer's eye (*i.e.*, 2 D., when, as we have assumed, the observer is stationed at a distance of one-half metre). In this limiting position of the far-point of the observed eye (point of reversal) no shadow outline, consequently no shadow movement, is discernible.

IV. The far-point of the observed eye is assumed to lie in front of the eye of the observer (myopia of the observed eye in excess of 2 D., when the observer is stationed at the assumed distance of one-half metre—see Fig. 4267, *IV*). A new condition now comes into play. A real image, m' m, of the visible circle a a' is formed at the far-point of the observed eye. Of this image a second image π π' (which is a twice inverted, therefore an erect image of a a') is pictured on the retina of the eye of the observer, who sees the image of the flame at a a inverted, and the direction of its motion, consequently the direction of the shadow movement, reversed. The higher the grade of the myopia, the larger is the illuminated area (image of the flame), and the larger also is the visible circle, the latter increasing, however, at a greater rate than the former. Conversely, the lower the grade of the myopia within the assumed limit of 2 D. (*i.e.*, the nearer to the plane p' p of the pupil of the observer's eye the real image m' m falls), the smaller is the portion

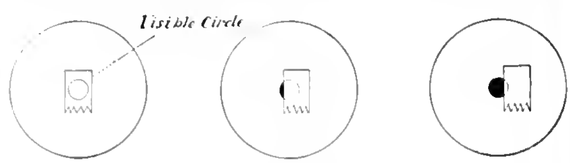


FIG. 4269.

of the fundus at a a'—*i.e.*, the visible circle—from which rays of light can enter the eye of the observer. Again, the higher the grade of the myopia (*i.e.*, the nearer to the plane P P of the pupil of the observed eye the real image $m' m$ falls), the sharper will be the definition of the shadow outline. Conversely, the lower the grade of the myopia (*i.e.*, the nearer to $p' p$ the real image $m' m$ falls), the less advantageous will be the conditions for seeing it distinctly; consequently the more imperfect will be the definition of the shadow outline, until, in the assumed limit of 2 D., no shadow outline, consequently no shadow movement, will be seen.

V. The far-point of the observed eye is assumed to lie at the exact distance of the pupil of the observer's eye (myopia of 2 D., when the observer is stationed at the assumed distance of one-half metre—see Fig. 4267, *V*). In this case the real image of the visible circle (*cf. V.*, with *III* and *IV*, Fig. 4267) is formed at and fills the pupil, $p\ p'$, of the eye of the observer, the point p corresponding to a, and p' to a'. Now the outermost rays, $a\ P\ p$ and $a\ P'\ p$, of the limiting pencil originating at a to pass out of the pupil of the observed eye and enter the pupil of the observer's eye, are refracted to π and π', respectively, at the retina of the observer; and, in like manner, all intermediate rays belonging to the same pencil are refracted each to its own point intermediate between π and π'; hence every point in the circle $\pi\ \pi'$ is faintly illuminated by rays emanating from a. Similarly, the limiting pencil originating at a', likewise all pencils originating at points lying between a and a', contribute each its own share to the general illumination of the circle $\pi\ \pi'$, consequently to the illumination of $P\ P$, the pupil of the observed eye, in its totality. The effect of the rotation of the mirror is manifested, therefore, by a gradual fading out of the light in the pupil, and not, as in Cases I. to IV, by the appearance of a moving "shadow." It will be further observed (*cf. I, II, III, IV*, and *V*, Fig. 4267) that in this case the diameter of the visible circle (*i.e.*, of the area at the fundus of the observed eye from which rays of light can pass out through its pupil to enter the pupil of the observer's eye) is as its minimum.

Comparing these several cases, we draw the following deductions:

(*a*) Appearance and direction of movement of the shadow. Whenever a "shadow," appearing at the side of the pupil of the observed eye, is seen to move in the same direction as that in which the (plane) mirror is rotated, the eye is either hypermetropic, emmetropic, or myopic in such (lower) degree that its far-point lies behind the eye of the observer—Cases I. to III.

When the "shadow" is seen to move in the direction opposite to that in which the (plane) mirror is rotated, the eye is myopic in such (higher) degree that its far-point lies in front of the eye of the observer—Case IV.

When no shadow outline is discernible, the illumination of the entire pupil fading gradually into darkness whatever may be the direction in which the mirror is rotated, the eye is myopic in such degree that its far-point lies at the distance of the eye of the observer—Case V.

(*b*) Distinctness of the shadow outline. The definition of the shadow outline is always less perfect than that of the image of the flame at the fundus of the observed eye, for the reason that the (virtual or real) image of this image, which we may regard as the object actually viewed by the observer, is formed either at an infinite distance from the pupil of the observed eye (in emmetropia), at a finite and always considerable distance behind the pupil (in hypermetropia), or at a finite and always considerable distance in front of the pupil (in myopia). In no case, therefore, can this image be perfectly focused by the eye of the observer, when, in accordance with the requirements of the test, the latter is accommodated for the pupil of the observed eye. Nevertheless, in high grades both of hypermetropia and of myopia, the difference in the distance (from the observer) of the pupil and the image is not so great as to prevent a fairly distinct view of both at the same time. In hypermetropia (Case II.) of decreasing grade, passing through emmetropia (Case I.) and myopia of relatively low grade (Case III.), to the limiting grade of myopia (Case V.), in which the image of the visible circle at the fundus of the observed eye lies at and fills the pupil of the eye of the observer; likewise in myopia of relatively high grade (Case IV.), decreasing to approach the same limit (Case V.), the distinctness of the shadow outline diminishes at a rapidly increasing rate, until, in the limiting case (Case V.), the shadow outline and the shadow movement vanish together.

Again, the image of the flame at the fundus of the observed eye is itself imperfectly defined, except in the particular case in which the far-point of the observed eye lies exactly at the distance of the (virtual or real) image of the flame as formed by the mirror. When the test is made with a plane mirror (see Fig. 4268) this particular case implies myopia of low grade, which, as already stated, is a condition unfavorable for obtaining a distinct view of the image of the flame at the fundus of the observed eye. When, on the other hand, the test is made with a concave mirror, the higher grades of myopia offer the most favorable conditions both for the sharp definition of the image of the flame at the fundus and for seeing the outlines of the real image of this image, consequently for good definition of the shadow outline.

Narrowness of the pupil, whether of the observed eye or of the eye of the observer, is favorable to the definition both of the image of the flame, at the fundus of the former, and of the image of this image, as pictured on the retina of the latter. But narrowness of either pupil, and still more of both pupils, involves a notable limitation of the area of the visible circle (see Fig. 4267) and narrowness of the pupil of the observed eye involves also a diminution (in the ratio of the square of its diameter) of the brightness of the image of the flame at its fundus. Furthermore, a narrow pupil is unfavorable for observing the passage of the shadow. For these reasons, it will readily be comprehended that the preponderance of advantage may be greatly on the side of a large and well-lighted pupil, and this is in practice found to be the case. To this end the diameter of the hole in the mirror should be somewhat greater than that of the pupil of the observer's eye, and the pupil of the observed eye, unless naturally rather wide, should be dilated by instilling a solution of one of the weaker-acting mydriatics.

(*c*) Brightness of the pupil. We have given the name "visible circle" to the circular area, at the fundus, from which alone any ray of light can both pass out of the observed eye and enter the eye of the observer. Under the conditions of the shadow test the visible circle is simply that portion of a larger illuminated area (image of the flame) which, seen always in circles of confusion, is visible through the pupil of the observed eye. The image formed on the retina of the observer's eye is, therefore, an indistinct image of the visible circle, but by reason of its indistinctness, together with the fact that its outline is the same as that of the pupil of the observed eye, the impression made on the observer is rather that of an illuminated pupil than of the portion of the fundus behind it. As the size of the image on the observer's retina is independent of the actual size of the visible circle it follows that the larger the visible circle (its brightness being assumed to be constant), or the brighter the image of the flame (the size of the visible circle being assumed to be constant), the stronger will be the illumination of the pupil.

The area of the visible circle is larger, (α) the wider the pupil of the observed eye, (β) the wider the pupil of the observer's eye, (γ) the greater the myopia of the observed eye in excess of the critical grade (Case V.), in which the far-point of the eye lies at the distance of the pupil of the observer's eye, (δ) the less the refraction of the observed eye measured from the same critical grade of myopia, and (ε) the less the distance of the observer's from the observed eye.

The brightness of the image of the flame at the fundus of the observed eye is greater (α) the wider the pupil of the observed eye; and, when the test is made with the concave mirror, the greater the apparent area of the mirror, that is, (ε) the less the distance of the observer's eye (looking through the hole in the mirror) from the observed eye, or (ζ) the larger the concave mirror.

The conditions favorable to a strong illumination of the pupil of the observed eye are then, (α) wideness of its pupil, (β) a fairly large pupil on the part of the observer, (γ) a high grade of myopia of the observed eye, (δ) a high grade of hypermetropia of the observed eye, (ε) a short observing distance, and (ζ) the use of a large concave mirror. Of these conditions, the first (α) may be secured when necessary by resorting to artificial mydriasis; the second (β) is best attained by observing with relaxed accommodation, the observer correcting the far-point of his own eye for the distance of the pupil of the observed eye by means of a suitable lens mounted behind the hole in the mirror. A short observing distance (ε) may be tried whenever the condition of the observed eye (*e.g.*, exceptionally dark pigmentation of the fundus, narrowness of the pupil from extensive synechiæ, imperfect transparency of the media, etc.) is unfavorable to good illumination of its pupil. The use of a concave mirror of large diameter (ζ) is also a possible resource in cases of exceptional difficulty.

(*d*) The rapidity of the shadow movement (other things being equal) varies inversely with the diameter of the visible circle, over which the image of the flame passes as the mirror is rotated; the smaller the visible circle, the less will be the time occupied in this passage, consequently the more rapid will be the movement of the shadow across the pupil. The darkening of the pupil occurs most quickly in myopia of the particular grade in which the far-point of the observed eye lies at the distance of the pupil of the observer's eye—Case V.; the passage of the "shadow" is progressively slower in higher grades of myopia, also in lower grades of myopia passing through emmetropia and the lower and medium grades of hypermetropia to hypermetropia of high grade.

(*e*) The form of the "shadow" is determined by the form of the image of the source of light. If this is approximately circular the shadow outline will be correspondingly curvilinear, and the shadow will have the form of a crescent. When an Argand burner is used the shadow outline appears as a somewhat ill defined straight line (see Fig. 4269.)

When the shadow test is made with the concave mirror, the direction of the shadow movement is in every case the opposite of that observed when the plane mirror is used. But with this exception there is no essential change in the reactions. When the observer is stationed at a fixed distance, of say one metre, the concave mirror has the advantage of affording a stronger illumination; when the test is made at a shorter and varying distauce, the plane mirror is to be preferred.

The complete theory of the shadow test as applied to the investigation of astigmatism is too complicated to be adequately presented in an elementary paper.

The shadow test is, on the whole, the most exact method which we possess for the objective determination of the refraction of the eye. As compared with the determination of the refraction with the ophthalmoscope by the direct method, it is both more accurate and easier of execution; and this is especially true in the higher grades of myopia, in which measurements made with the ophthalmoscope are always very unsatisfactory. In the measurement of astigmatism it has an advantage over the ophthalmometer of Javal Schiötz, in that it reveals the total astigmatism of the eye and not merely the corneal asymmetry. On the other hand, the shadow test affords almost no information regarding the condition of the fundus of the eye under examination, and none as regards its acuteness of vision. The true value of the shadow test is therefore as supplementing, not as superseding, other methods of examination.

The technique of the shadow test is comparatively easy to acquire, and it calls for almost no special apparatus; an ophthalmoscope furnished with a concave and a plane mirror and a Rekoss disc, or a clip for holding a correcting glass, and a short tape measure graduated to fractional parts ($\frac{1}{5}$, $\frac{1}{4}$, $\frac{1}{2}$, etc.) of a metre, make up the list of essentials.
Carl Koller.

SHANNONDALE SPRINGS.—Jefferson County, West Virginia.

Post-Office.—Charlestown. Hotel.

Access.—Viâ Baltimore and Ohio or Norfolk and Western Railroad to Charlestown, thence five miles by carriage to springs.

This delightful old summer resort is situated in the bend of the Shenandoah River, at the foot of the Blue Ridge Mountains. Shannondale was formerly one of the most noted of the Virginia watering-places. The large hotel was burned during the war, and no other was built for a number of years. The present hotel has accommodations for upward of one hundred guests. It is pleasantly located and overlooks the Shenandoah River, where excellent boating and fishing may be had. The place is much frequented during the summer by visitors from Washington, Baltimore, Philadelphia, and other localities. It is highly esteemed for its fine scenery and for the beneficial character of the mineral waters. The springs are three in number. An analysis by Dr. Stewart showed the presence of two hundred and forty grains of solid ingredients to the United States gallon. They consisted chiefly of the sulphate and carbonate of calcium and the sulphate of magnesium. There is also a small proportion of the sulphate and the carbonate of iron, and an undetermined quantity of carbonic acid and sulphureted hydrogen gas. The water has laxative, diuretic, and tonic effects. It may be classed as a saline-calcic-chalybeate. There are several bath-houses at the resort.
James K. Crook.

SHARON SPRINGS.—Schoharie County, New York.

Post-Office.—Sharon Springs. Hotels, boarding-houses, and cottages.

Access.—Viâ Albany and Susquehanna Railroad direct to the springs; also viâ New York Central Railroad to Palatine Bridge, and thence by stage nine miles to springs.

The village of Sharon Springs is situated in a valley about eleven hundred feet above the sea-level; the streets are provided with good sidewalks, and are well shaded with maple-trees. The air is pure and bracing and free from malarial influences. Even in the warmest of summer weather the nights are cool and pleasant for sleeping. The springs are easy of access within the village limits on the edge of a natural forest abounding in pleasant walks. The surrounding country is hilly and affords interesting drives and pleasant scenery. Excellent accommodations, conformable to any taste or grade of expenditure, may be obtained in the village. Sharon is one of the well-established old resorts of New York State, its waters having been used for medicinal purposes since early in the last century. The old bathing buildings were destroyed by fire a few years ago and have been replaced by the present spacious establishment, believed to be unexcelled for its purposes anywhere in the country. There are several valuable springs at Sharon, the most important being the White Sulphur, the Magnesia, and the so-called Eye-water Spring. The waters of the White Sulphur Spring are used both internally and for bathing purposes. The water is clear and bright as it issues from the spring, of an agreeable temperature for drinking (48° F.), and free of the roughness and acerbity which so often characterize sulphur waters. It is conducted to the bath-house and heated to any desired temperature for bathing. This spring yields fourteen hundred or fifteen hundred gallons of water per hour, so that the supply is always fresh and abundant. The Magnesia Spring is also valuable for drinking purposes. The third spring is used extensively as a lotion for inflammatory conditions of the eye, which fact has led to the designation of the Eye-water Spring. A chalybeate spring is also found within the village limits. The following analyses of three of the springs were made a number of years ago:

One United States Gallon Contains:

Solids.	White Sulphur Spring. (Lawrence Reid.) Grains.	Gardner Magnesia Spring. (J. G. Pohll.) Grains.	Eye-water Spring. (Lawrence Reid.) Grains.
Sodium bicarbonate	......	0.54	......
Calcium bicarbonate	......	9.70	......
Magnesium bicarbonate	24.00	1.36	32.00
Calcium sulphate	85.40	93.50	77.50
Magnesium sulphate	34.00	19.68	7.50
Sodium chloride } Magnesium chloride }	2.70	1.23 / .41	2.50
Calcium chloride	......	.16	......
Calcium sulphide } Magnesium sulphide }	3.00	.63	......
Silica	.....	.40	......
Total	149.10	127.61	119.50
Gases.	**Cu. in.**	**Cu. in.**	**Cu. in.**
Sulphureted hydrogen	20.50	6.00	......
Carbonic acid	......	2.22	......
Atmospheric air	......	3.00	......

The sulphur baths here have a wide reputation in the treatment of gout, rheumatism, and certain forms of paralysis. They are also serviceable in cases in which exudations are to be absorbed, *e.g.*, in old gunshot wounds, stiff joints, glandular enlargements, etc. It is said that many of the consequences of high living, such as congestion of the liver, abdominal plethora, and hemorrhoids, are quite certain to be benefited by a course of the Sharon waters. They are useful also in metallic poisoning and in ridding the system of chronic syphilitic infection, etc. The methods of employing sulphur waters at the well-known French spas, Aix-les-Bains, Challes, and Allevard, were adopted at Sharon Springs in 1884, and have been in successful operation since that time. The sulphur water of Sharon is also used commercially.

James K. Crook.

SHEBOYGAN MINERAL WELL.—Sheboygan County, Wisconsin.

Post-Office.—Sheboygan. Hotels.

Access.—Viâ the Ashland division and also the Fond du Lac division of the Chicago and Northwestern Railroad; also viâ steamers on Lake Michigan. The city of Sheboygan is beautifully located at the entrance of the Sheboygan River into Lake Michigan, at an elevation of about 650 feet above the level of the Atlantic Ocean. The mineral well is located in Fountain Park, and is 1,475 feet in depth. It was bored in 1875, and extends down to the granite bed-rock. Abundant water was discovered, the pressure, as indicated by the gauge, being 52.5 pounds to the square inch, or sufficient to raise a column of water to the height of 115 feet. The well was carefully tubed. The water is pure, bright, and sparkling, and entirely free from all surface contamination. The following analysis was made by Prof. Charles F. Chandler, of New York, in 1876:

One United States gallon contains (solids): Sodium chloride, gr. 306.94; potassium chloride, gr. 14.48; lithium chloride, gr. 0.11; magnesium chloride, gr. 54.91; calcium chloride, gr. 27.82; sodium bromide, gr. 0.19; calcium sulphate, gr. 16.98; calcium bicarbonate, gr. 13.66; iron bicarbonate, gr. 0.59; manganese bicarbonate, gr. 0.17; calcium phosphate, gr. 0.04; alumina, gr. 0.13; silica, gr. 0.47; organic matter, sodium iodide, baryta sulphate, and sodium biborate, traces. Total, 436.49 grains.

This water is seen to be very highly mineralized, and is closely allied to those of Kissingen and Kreutznach, in Germany. It contains, however, in addition to all the mineral constituents of those waters (except the nitrate of soda in Kissingen), traces of sulphate of baryta and biborate of soda, and a small quantity of bicarbonate of manganese. It has practically the same therapeutic properties as those waters, and is applicable to the same conditions. The most pronounced effects are laxative, diuretic, and tonic. It seems to act as a stimulant to the mucous membrane generally, and promotes the secretions. It is highly recommended as a remedy in chronic constipation. It is further applicable to a large class of morbid conditions depending upon a deranged circulation and defective secretion, such as dyspepsia, functional disturbances of the liver, hemorrhoids, anæmia and chlorosis, rheumatism, etc. The water is bottled and sold all over the country.

James K. Crook.

SHELDON SPRINGS.—Franklin County, Vermont.

Post-Office.—Sheldon. Hotels.

Access.—Viâ Vermont Central Railroad to St. Albans; thence viâ Missisquoi Valley Railroad to Sheldon.

Persons going to Sheldon Spring, one of the group, should buy tickets for Congress Hall Station, eight miles east of St. Albans. These springs are charmingly situated along the banks of the Missisquoi River, at an elevation of about two thousand feet above the sea-level. Within sight are Mount Mansfield and others of the Green Mountains. The springs are four in number—the "Central," within the village; the "Vermont," half a mile from the village; the "Missisquoi," one mile and a half northward; and the "Sheldon," two miles from the village. So far as I have been able to ascertain, the "Sheldon" is the only spring of which the water has been analyzed; and this analysis shows it to be very feebly mineralized. Notwithstanding this fact, the "Sheldon" water has been found to possess a very useful action in uric-acid gravel, gout, and catarrhal states of the bladder. The waters of the Missisquoi Spring are found on the market.

James K. Crook.

SHOCK. (SURGICAL.)—Shock may be defined as a condition of general vital depression or a state of general exhaustion of the nervous system coupled with a dilatation of the peripheral arterioles and a loss of the normal blood pressure.

Shock may be the result of an accidental injury, an operation, a profound emotion, or an overpowering fear. It is a condition in which the motor, sensory, and sympathetic nervous systems as well as the cerebral cortex are profoundly affected, and their action, for the time being at least, more or less arrested or destroyed.

Shock the result of an injury, an emotion, or of fear, follows very closely upon the action of its cause. When the result of an operation it may become manifest during any of its stages or only at its close. Shock may make its appearance suddenly, or it may come on gradually and be slowly progressive in character.

Symptoms.—The symptoms of shock will depend upon its severity. There may be as the result of some trivial injury a slight faintness, a pallor of the face, and a feeling of nausea which pass off in a moment, or the traumatism may be so severe and so sudden that the heart's action is arrested and the patient succumbs at once. In a well developed case of shock the patient's sensibilities are lessened and his mental faculties held more or less in abeyance. The pulse will be quickened, feeble, thready, and perhaps irregular. The respirations are increased in frequency, labored, and often irregular. The face and visible mucous membranes are pale, the eyes sunken and listless. The face, hands, and often the entire body are bedewed with a cold, clammy perspiration. The patient is usually torpid and indifferent to his surroundings, the mental faculties are depressed, and occasionally there is complete unconsciousness. The tone of the muscular system is so lessened that it is capable of only feeble contraction, the patient manifesting little disposition to move hand or foot. The sphincter muscles are at times completely relaxed. The temperature of the body may be reduced one, two, or even three degrees. Nausea and vomiting occur in many cases. In the so-called erethistic form the patients are excitable, restless, often incoherent, and even delirious.

DIAGNOSIS.—Shock must be differentiated from fat embolism, from hemorrhage, and from the effects of ether or chloroform. With each or all of these it may, however, be associated. Fat embolism most frequently occurs in injuries to the skeleton, and makes its appearance as a rule about thirty-six to seventy-two hours after the injury, while shock occurs at once. In fat embolism there are restlessness, anxiety, dyspnœa, accelerated respiration, and a quickened heart action with fat globules upon the surface of the urine. Hemorrhage is very frequently an associated factor with shock and aggravates the latter condition, but the two may be, and often are, entirely separate. Shock presupposes an injury. A patient may die from hemorrhage without suffering in any degree whatsoever from shock, while, on the other hand, a patient may receive a blow on the epigastrium, upon the head, or have his limbs crushed off and suffer the loss of scarcely a drop of blood and still die almost instantly or within a few hours from shock. Loss of blood when external is readily to be seen. When it occurs within closed cavities, as the abdomen, thorax, or skull, it will have to be diagnosed by the symptoms produced. These will be accompanied by those characteristic of the sudden or more or less gradual loss of blood. The symptoms of hemorrhage are not always those which are most typical of shock, in that in the former there is more of restlessness and nervous excitement, more acuteness of intellect, far greater pallor of the skin and visible mucous membranes, greater dilatation of the pupils and alæ nasi, and often a decided rise in temperature. There will also be a lowering of the hæmoglobin. It will be impossible, at least as a rule, to separate the effects of chloroform and ether from those of shock. Either of these substances when given incautiously or to excess interferes with respiration, lowers blood pressure, and materially aggravates the condition of shock.

PROGNOSIS.—This will depend upon the degree of shock, upon the organ or organs injured, and also upon the presence or absence of sources of irritation which will maintain or aggravate the existing condition. The prognosis will also depend very largely upon the treatment. It may be said that if shock be not immediately fatal, if the traumatism has not produced irreparable injury to vital organs or exhausted the vaso-motor nervous system, and the conditions are such that shock is not constantly added to, the prognosis will be good. The injury may be to the brain, heart, or some other organ of vital importance, and be of such a character or produce such an exhaustion of the nervous system that recovery is an impossibility.

Reaction from Shock.—With proper treatment and under ordinary conditions reaction will become manifest in a few hours. The patient then becomes restless and changes his position. The cold perspiration disappears, slight color comes to the lips and cheeks, the eyes seem less sunken and the face less pinched. The pulse gains in volume and loses something in its frequency, the respiration is deeper, more regular, and less frequent. The patient now seems to realize his injuries. He is less drowsy and perhaps asks questions concerning his condition. This state may progress uniformly until the temperature has reached a point above normal, when the pulse becomes full and strong, a flush comes to the cheeks, restlessness is increased, and reaction is fully established. If the injury has been such that the irritation is maintained for a time reaction may be delayed or prevented, or the condition may oscillate between reaction with improvement and an aggravation of the condition or shock.

The Pathology of Shock; the Mechanism of Blood Pressure.—The condition of vital depression known as shock seems inseparably connected with three pronounced conditions. One of these, and perhaps the most important, is the decrease of blood pressure, the second is the loss of muscular force, and the third a lessening of the mental phenomena of the patient, including the intellectual, emotional, and volitional. For the proper circulation of the blood, a condition which is essential in the maintenance of the functions and health of the individual, a certain degree of blood pressure must be maintained. If this fall to any considerable degree the capillary lake and venous system are flushed, the pulse becomes weak and thready, the arterial system is depleted, the venous system congested, and the functions of the body disturbed or even arrested. The blood pressure is maintained in part by the vaso-motor system of nerves whose centre is in the gray matter of the floor of the fourth ventricle. There are also certain subsidiary centres in the spinal cord. In health these nerves acting upon the muscular tissue in the walls of the blood-vessels and especially upon that in the arterioles, maintains an equable and constant tonic contraction, in consequence of which the heart is able to maintain the blood pressure throughout the general arterial system at a certain definite standard. A stimulus imparted to the vaso-motor system, either directly through the splanchnic area or indirectly through a sensory nerve, increases the action of the vaso-motor system, the contraction of the peripheral arterioles, and augments the blood pressure. If this stimulus is continued for an indefinite period or is excessive in character, then and in that case the vaso-motor system becomes exhausted, the peripheral arterioles dilate, and the blood pressure is lowered. There are three factors, however, which are responsible for the maintenance of a normal blood pressure. One of these is the forceful rhythmic action of the heart, another a suitable quantity of fluid in the vascular system, and a third a proper tonic contraction of the peripheral arterioles. If any one of these three conditions is disturbed the blood pressure will be effected. A diminution in the force, with an increased frequency of the heart's action, a lessening in the amount of circulating fluid within the vessels or a dilatation of the arterioles, each and all will lessen the blood pressure. That the blood pressure is very markedly lessened in cases of serious shock is the testimony of all observers.

The mechanism of the lessening of blood pressure in shock is the following: An injury to a peripheral sensitive nerve, if of mild degree, acts as a stimulus which is conveyed to the brain and transmitted reflexly to the bulb in the floor of the fourth ventricle, the centre for the vaso-motor nerves. Acting upon this centre this impulse is transmitted through the vaso-motor system, producing contraction of the arterioles and consequently increasing the blood pressure. After the abdomen has been opened slight handling of the intestines or stomach causes, in consequence of the stimulus being applied directly to the splanchnic area, a rise in blood pressure. If the stimulus be excessive or often repeated the vaso-motor centre becomes partially or totally exhausted, the peripheral arterioles dilate, and a great lessening in the blood pressure occurs. That a severe traumatism, whether it be peripheral, intraabdominal, intrathoracic, or intracranial, exhausts or paralyzes the vaso-motor system of nerves, is well established by experimental research.

By kymographic and sphygmographic tracings it has been shown in every case of long-continued operation and in cases of severe injury that there is a lessening of the blood pressure. This is due, in operations or injuries without the loss of blood, to the exhaustion of the vaso-motor system and a loss of tone in the heart's muscular contractions. In cases in which there has been hemorrhage it is also due to the diminution of the volume of fluid in the vascular system. It is well to inquire if in shock there is not something more than a weakened heart's action, a lessening of the peripheral resistance by the dilatation of the arterioles, and consequently a lowering in the blood pressure. In every case of severe shock there is a decided lessening or weakening of the mental phenomena. The intellect is inactive, the emotions are suppressed, and volition is at a standstill. There is also a muscular powerlessness. The patient is not only unable to exert his mind, but his muscles have also gone out of action. In severe shock there has been such an injury or stimulus to the nerves as practically to put out of action the mental faculties, the motor and sensory nerves, and the sympathetic system. It seems to me that this condition is scarcely due in its entirety to the loss of blood pressure, but that the same crushing force which overstimulated the vaso-motor centres and produced their practical paralysis has overstimulated the cortex of the brain, suspending in a large measure the action of the intellect, the force of the will, the play of the emotions, and the function of the motor nerves. It is often stated, following the teaching of Goltz, that patients dying of shock bleed to death in their own veins. This is supposed to occur in the splanchnic areas, but the condition is simply one of vaso-motor paralysis in which the peripheral vessels have lost their tone, and in consequence of which the blood rushes through the arterioles into the capillary lake and venous channels. While this condition perhaps occurs with greater force in the abdominal region than elsewhere, it does occur wherever there are arterioles and vaso-motor nerves which may be acted upon by overstimulation.

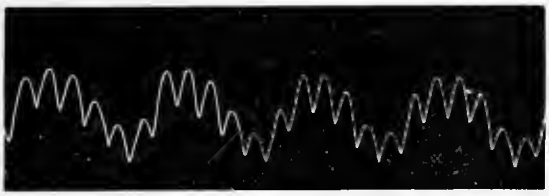


FIG. 4270.

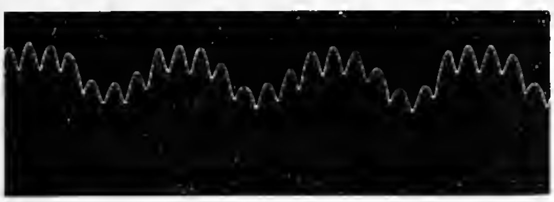


FIG. 4271.

Prophylaxis.—In the prevention of shock one must place his patient, both physically and mentally, in the best possible condition. Just before the administration of the anæsthetic, gr. $\frac{1}{40}$ of strychine with gr. $\frac{1}{8}$ or gr. $\frac{1}{4}$ of morphine may be given hypodermically with decided advantage, as both assist in supporting the heart's action and in maintaining the blood pressure, while the latter lessens to some degree the amount of anæsthetic required. In the choice of an anæsthetic if there is fear of shock, or if it be already present, ether should be administered, in preference to chloroform, as chloroform lessens very decidedly the blood pressure and favors the production of shock.

Fig. 4270 represents a kymographic tracing from the femoral artery of a dog while under the influence of ether, the dog having undergone a resection of a portion of the intestines and a gastro-enterostomy. The blood pressure had fallen at this time from 14.1 cm. to 13.2 cm. Upon substituting chloroform for ether for three and one-half minutes the pressure fell to 11.8 cm. as represented in Fig. 4271. In another experiment the blood pressure under ether stood at 14 cm. After a change had been made to chloroform it fell in one-fourth of a minute 0.2 cm.; in one minute and a half it had fallen 0.4 cm., and in two minutes 0.5 cm. Upon going back to ether the blood pressure lost was quickly regained. It has been the writer's experience that the use of chloroform will reduce the blood pressure present under ether anæsthesia 0.5, 1, or even 1.5 cm. It would seem reasonable, then, that where shock is present or is to be feared, and consequently where blood pressure is low, chloroform should not be used. The heat of the body should also be as far as possible preserved; consequently the temperature of the room, at the time of the operation, and the covering of the patient are matters of importance. The water used in the immediate preparations for the operation should be of such temperature as to abstract nothing of heat from the patient. Evaporating liquids, such as alcohol, must be used with care, and the towels about the field of operation and the sponges should be dry.

In the prevention of shock during an operation or following an accident it is of the greatest importance to limit the loss of blood to the least possible amount, as the blood pressure depends as much upon the amount of fluid within the vessels as it does upon the contraction of the peripheral arterioles or the action of the heart. The loss of only a small amount of blood will lessen at once the pressure. It is also essential, in order to limit the amount of anæsthetic used and the exposure of the patient, that the operation be done as quickly as is compatible with the performance of good surgical work. Cocainizing the main branches of the peripheral nerves before division has been recommended by Crile and Harvey Cushing for the purpose of blocking these nerves and preventing stimulating impulses being carried to the brain. The few experiments of this character which I have undertaken have seemed to show that the cocainization of a nerve causes about as much stimulation of the vaso-motor centres as would its section. It is a fact which may be easily established that the handling, stretching, manipulating, or cocainization of a sensitive nerve will, in consequence of the irritation, at once raise the blood pressure. The same is also true of the section of such a nerve. Of course, this rise is followed by a subsequent fall. It is only a question as to which is the greater evil. When a patient is under the influence of an anæsthetic, it would seem as though all of his sensitive nerves were in a sense blocked, and that not much more could be accomplished by their cocainization.

Fig. 4272 represents Dudgeon's sphygmograph which the writer has been using before, during, and after operations and before and after the administration of certain drugs which are ordinarily used in the treatment of shock. This instrument, while perhaps open to objections, is nevertheless of great value, when carefully used, in determining the height and character of the wave, which conditions correspond reasonably with blood pressure. During the past few months, for the purpose of more accurately testing the blood pressure and its relationship to shock, I have been experimenting with Ludwig's kymograph, represented in Figs. 4273 and 4274. Twenty-two dogs were used for this purpose,

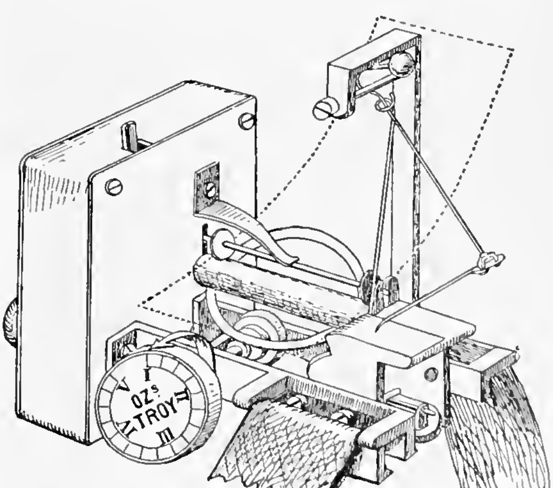


FIG. 4272. Dudgeon's Sphygmograph. The dotted outline represents the piece of blackened paper on which the sphygmogram is written.

the tube of the manometer being in the majority of cases inserted into the femoral artery, in three in the external iliac, and in a few in the common carotid. The dogs were maintained under full surgical anæsthesia by ether, a change being made for a short time, in some cases, to chloroform for the purpose of observation. The blood pressure was taken at the time of the connection of the instrument with the vessel and then its variations were recorded as different operations were being performed, until pronounced shock with loss of blood pressure was present. Various drugs were then administered subcutaneously and the effect upon the blood pressure recorded. The cannula connecting with the vessel was occasionally opened for the purpose of noting the effect of hemorrhage. While it must be admitted that the instrument is delicate and easily disturbed, it unquestionably, when working properly, records accurately the blood pressure. With the sphygmograph one must judge of the blood pressure by the height of the stroke, and with this instrument this is reasonably correct, but in the case of the kymograph the height of the stroke and the blood pressure are not at all synonymous. While the height of the

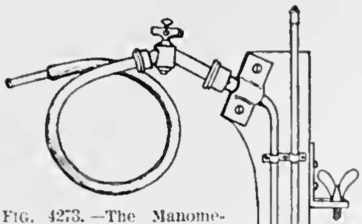


FIG. 4273.—The Manometer of Ludwig's Kymograph. It is also shown in Fig. 4274, *D*, *C*, *E*. The mercury which partially fills the tube supports a float, in form of a piston, nearly filling the tube; a wire is fixed to the float, and the writing style or pen is guided by passing through the brass cap of the tube fixed to the wire; the pressure is communicated to the mercury by means of a flexible metal tube filled with fluid.

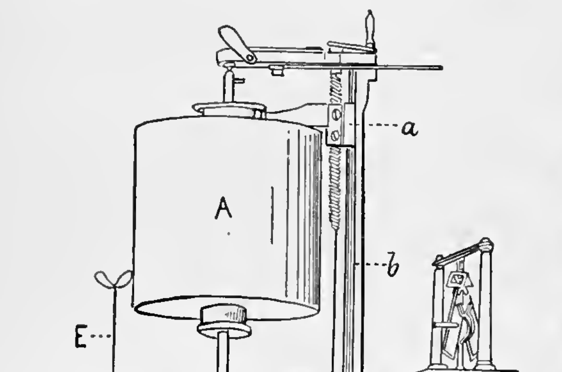


FIG. 4274.—Diagram of Ludwig's Mercurial Kymograph. *A*, Revolving cylinder, worked by a clockwork arrangement contained in the box (*B*), the speed being regulated by a fan above the box; cylinder supported by an upright (*b*), and capable of being raised or lowered by a screw (*a*), by a handle attached to it: *D*, *C*, *E*, represent mercurial manometer.

stroke depends in the kymograph in a measure upon the blood pressure, it also is influenced by the size of the artery with which the instrument is connected, its nearness to the heart, and the size of the cannula used. These conditions always being the same, as they are with the sphygmograph, the height of the stroke in a reasonable degree corresponds with the blood pressure.

Treatment of the Actual Shock.—The treatment of shock may be considered under three heads: (1) The recovery

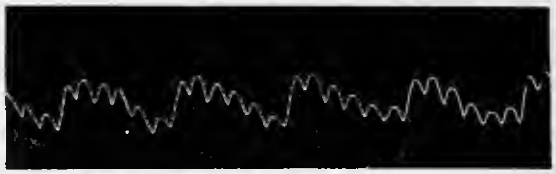


FIG. 4275.

of the normal blood pressure. (2) The re-establishment of the muscular tone; and (3) the restoration of the mental phenomena. The restoration of the blood pressure is at times more quickly affected by an intravenous infusion of the normal salt solution than by any other method, and in cases in which the condition is largely the result of hemorrhage this is the most scientific and satisfactory

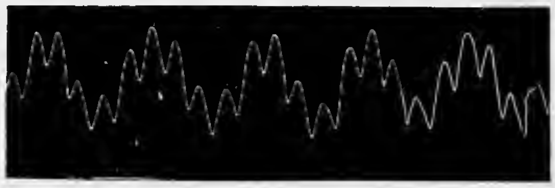


FIG. 4276.

method of treatment. The tracing in Fig. 4275 is from the femoral artery of a dog that had undergone a resection of a portion of the intestine and a gastro-enterostomy. The dog had also lost a large amount of blood. Pressure in the femoral at the time tracing in Fig. 4275 was taken was 13.2 cm. The tracing in Fig. 4276 was taken after one quart of normal salt solution had been infused into a

FIG. 4277.

vein, the pressure now having risen 2.6 cm. Fig. 4277 shows a sphygmographic tracing of a weak pulse during an operation, and Fig. 4278 a tracing of the same pulse after the injection of one pint of normal salt solution beneath the breast.

Hypodermoclysis.—In the writer's clinic at St. Joseph's and Milwaukee County hospitals, as well as in his pri-

FIG. 4278.

vate practice, it is the rule, when a pulse shows weakness, and especially if this be largely from loss of blood, to inject beneath a breast, at the border of the scapula, in the lumbar or gluteal regions, a pint of normal salt solution, and to repeat this injection in half an hour upon the opposite side if necessary. The apparatus required is an aseptic fountain syringe attached to a large surgically clean aspirating needle. While this method does not act as quickly as the intravenous infusion, it acts promptly enough for ordinary cases and is extremely simple. In cases in which the blood pressure is lowered in consequence of exhaustion of the nervous system from gross injury this treatment may still to a certain extent be advantageous, in that it produces some slight vascular stimulation and also adds to the volume of fluid circulating, and thus assists to a certain extent in compensating for the dilatation of the peripheral vessels. It is, however,

FIG. 4279.

a matter of frequent observation in cases of profound shock with great weakness of the pulse that the introduction into a vein of a quart of normal salt solution does not materially improve the patient's condition. The volume of the pulse in these cases may be restored for a few minutes, but this volume is without tension and soon disappears. This is in consequence of the fact that the vaso-motor system has become partially or completely exhausted. What is desired in these cases is the strengthening of the heart and the restoration of the functions of the vaso-motor system, and of the cerebral cortex. It is,

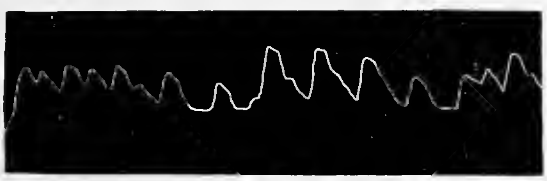


FIG. 4280.

nevertheless, true in some cases of gross injury or of prolonged operation that the exhaustion of the nervous system is so complete that no treatment which we are able to institute will be effectual.

In my experience with shock there is nothing which meets the condition and which sustains the nervous system and holds the ground gained so well as strychnine. Kymographic tracings show that strychnine increases the blood pressure in practically every instance. This pressure is often increased by a single hypodermic injection from 0.5 to 1 or even 1.5 cm. In the administration of strychnine for a serious condition of shock one-fourth of

FIG. 4281.—Before Whiskey.

a grain may be given in divided doses during the course of one hour, and, following this, one-thirtieth of a grain administered every two hours for one or two days, or until the muscles show the influence of the drug.

Nitroglycerin.—The use of nitroglycerin in shock has been criticised by many writers upon the ground that it dilated the superficial capillaries and thereby reduced blood pressure. In my experimental and clinical work nitroglycerin has always increased the height of the stroke and lessened the frequency of a rapid pulse. Gr. $\frac{1}{100}$–$\frac{1}{50}$ of nitroglycerin, injected subcutaneously, has always increased the blood pressure from 0.5 to 1 cm. Its effect, although manifested almost at once and reaching perhaps the same height as that from strychnine, is not so long sustained. The tracing in Fig. 4279 was taken from the femoral artery of a dog where the pulse was scarcely perceptible in consequence of numerous sections of both sciatic nerves, resection of a considerable portion of the small intestine, and of the entire stomach. The tracing in Fig. 4280 was taken one-half a minute after the injection of gr. $\frac{1}{50}$ of nitroglycerin. In four and one-half minutes the blood pressure had risen 1.8 cm.

Caffeine.—Caffeine acts almost as promptly and effectually in restoring blood pressure as does strychnine. Five grains injected subcutaneously in a dog raised the blood pressure from 12.6 cm. to 13.6 cm. This effect is also well sustained.

Adrenalin.—In the writer's experience adrenalin in gr. $\frac{1}{100}$–$\frac{1}{50}$ acts promptly in increasing blood pressure.

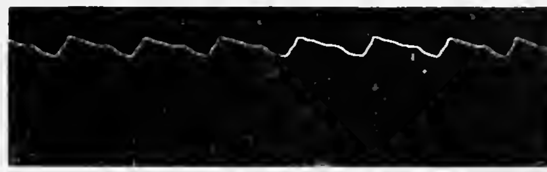


FIG. 4282.—Twenty Minutes after Whiskey.

This action seemingly, however, is not well sustained. Adrenalin is certainly deserving of further consideration in the treatment of shock.

Digitalis and Strophanthus.—Both of these substances were used repeatedly. Their immediate action, however, upon blood pressure is not pronounced. With a rapid pulse their use is indicated, as they will assist in controlling this factor and in maintaining blood pressure.

Whiskey.—The advocacy of whiskey or brandy in shock has occasioned more dispute and acrimonious de-

FIG. 4283.—Three-quarters of an Hour after Whiskey.

bate than that of all the other remedies combined. That they are capable of raising the blood pressure when injected subcutaneously or taken into the stomach there can be absolutely no doubt. A dog whose sciatic had been sectioned half a dozen times was subjected to an intestinal anastomosis and then to a complete resection of the stomach. During these procedures, which occupied one hour and twenty minutes, the blood pressure fell from 14.2 cm. to 12 cm. At 10:25, 25 c.c. of whiskey in water was injected subcutaneously, and in twelve minutes the blood pressure had risen to 13.3 cm., at 10:39 to

FIG. 4284.—One Hour after Whiskey.

13.6 cm., and at 10:40 to 13.8 cm., at which point it remained until 10:44, when it fell to 13.1 cm., where it stood for a very considerable time. The sphygmographic tracing in Fig. 4281 was taken from a weak patient's radial before giving whiskey, the tracing in Fig.

4282 twenty minutes after one ounce by stomach, that in Fig. 4283 forty-five minutes after, that in Fig. 4284 one hour after, that in Fig. 4285 one and one-half hours after, and that in Fig. 4286 two and one-half hours after.

In the treatment of shock there are conditions to be met besides those of blood pressure. One of these is the loss of muscular tone, and another the practical suspension of the mental faculties. It is probably true that anything which assists in restoring blood pressure will

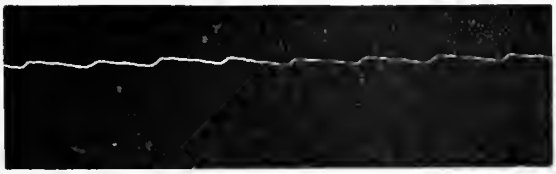


FIG. 4285.—One Hour and a Half after Whiskey.

also assist in re-establishing muscular tone and the vigor of the mental faculties. The normal salt solution, when infused into a vein, acts only mechanically, and is often without decided effect upon the profound depression of the vital functions. Remedies are wanted in shock which will restore not only blood pressure but also all of the vital functions. These conditions are met more perfectly in shock without hemorrhage by the use of strychnine, caffeine, nitroglycerin, whiskey, adrenalin, and normal salt solution than by any other remedies. In

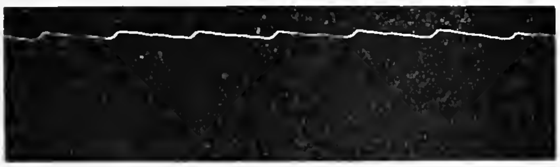


FIG. 4286.—Two Hours and a Quarter after Whiskey.

cases in which hemorrhage has been a prominent factor the normal salt solution should take precedence of all other remedies. *A. H. Levings.*

SHOULDER, THE SURGICAL ANATOMY OF.—The region of the shoulder comprises the bones forming the joint, viz., the scapula and the upper part of the humerus, the clavicle and acromio-clavicular articulation, also the upper and outer part of the thorax, which takes part in forming the axilla. These bony structures, with the softer tissues enveloping them, would be included in the term *shoulder.*

Surface Anatomy.—Beneath the skin can be easily felt the outer end of the clavicle, the acromion process, and the coracoid. Where the clavicle joins the acromion there is a distinct elevation which can be without difficulty detected by running the finger nail over it. The line of this articulation would correspond to a vertical line running up the middle of the front part of the arm. The acromion in the stoutest person may easily be made out by following the spine of the scapula, and the coracoid process is just inside the shoulder joint and below the clavicle. Between the coracoid and the acromion processes is the rounded prominence of the shoulder; this is formed partly by the thick deltoid muscle, but also in part by the upper end of the humerus which lies below it. As the arm is rotated the tuberosities can easily be felt beneath the muscles. In dislocation of the humerus, instead of a prominence there is a flattening, and in pressing with the fingers a well-marked depression is found where the head of the bone is normally felt. If in suspected dislocation the thumb be placed on the coracoid process and one of the fingers of the same hand on the acromion, the space will be found wanting in roundness and the finger can be easily pushed into a hollow; the upper end of the bone can be no more felt on rotation. The portion of the humerus which in normal joints is felt beneath the deltoid is not the head, but the tuberosities. The head can be felt through the axilla if the fingers be well pushed up and the arm be strongly abducted. The head of the humerus faces in the direc-

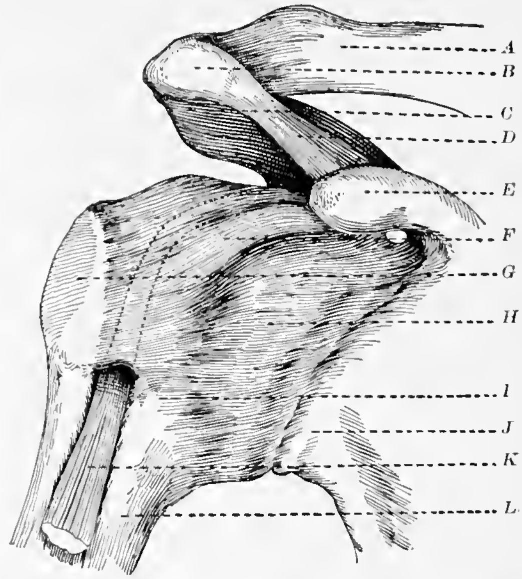


FIG. 4287.—*A*, Clavicle; *B*, *C*, acromion; *D*, coraco-acromial ligament; *E*, coracoid; *F*, coraco-humeral ligament; *G*, great tuberosity of humerus; *H*, capsular ligament; *I*, lesser tuberosity; *J*, scapular neck; *K*, long tendon of biceps; *L*, humerus.

tion of the internal condyle, this latter being always a good guide to the position of the upper end of the humerus.

The adjacent margins of the deltoid and pectoralis muscles cannot be felt below, but above there is a considerable triangular interval which forms the infraclavicular fossa below the clavicle. This fossa is well seen in thin persons, but is obliterated in subcoracoid dislocations, in fracture of the clavicle, and by inflammatory tumors and new growths. In subclavicular dislocations the depression is replaced by an eminence. The space between the two muscles lodges the cephalic vein (Fig. 4288).

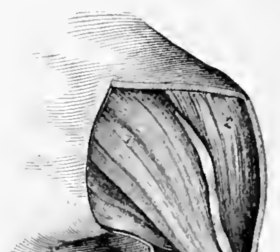


FIG. 4288.—Skin and fascia have been removed. 1, Pectoralis major; 2, deltoid; between these muscles is seen the cephalic vein; 3, biceps; 4, coracobrachialis, close to which lies the brachial artery and the median nerve drawn to one side. (After Roser.)

The back of the shoulder is comparatively flat; here the deltoid muscle is thinner. By abducting the arm the deltoid becomes prominent and various vertical elevations appear which correspond to the muscular tissue between the various tendinous intersections which run down from the acromion through the muscle. The axillary border of the scapula and inferior angle may be brought out by placing the forearm behind the back; to bring the vertebral border and superior angle into evidence, the hand should be placed over the opposite shoulder.

Surface Marking of Axillary Artery.—At a point internal to the coracoid process and below the most convex portion of the clavicle the axillary artery may be compressed against the second rib. The course of this artery can be easily marked out by drawing a line from the most convex portion of the clavicle to the inner border of the elevation formed by the coracobrachialis muscle.

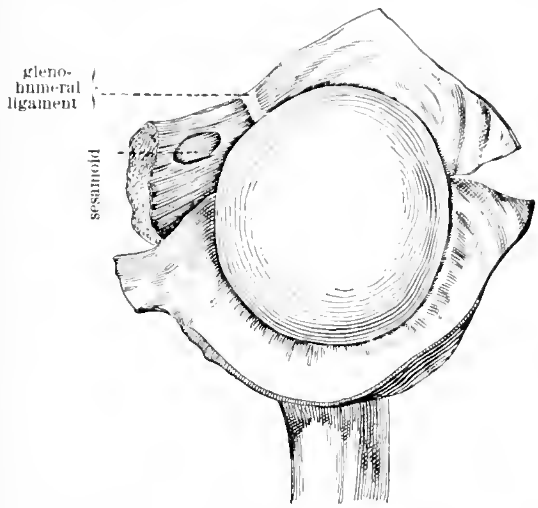


FIG. 4289.—Head of Humerus, with Part of Capsule Attached. (Morris.)

If the arm be raised from the side, the third part of the axillary artery may be felt pulsating as it passes into the arm beneath the anterior fold of the axilla, and in a line corresponding to the outer border of the axillary hair, that is, at the junction of the anterior with the middle third of the space between the axillary folds. At the junction of the upper with the middle third of the deltoid muscle the posterior circumflex vessels and nerves wind round to the back of the humerus under the muscle.

The *deltoid region* comprises the point of the shoulder and is confined to the limits of the deltoid muscles which cover the shoulder-joint and upper end of the humerus. Between the deltoid muscle and the joint is a large bursa, the subdeltoid or subacromion bursa. Owing to the exposed position of the shoulder-joint it is liable to

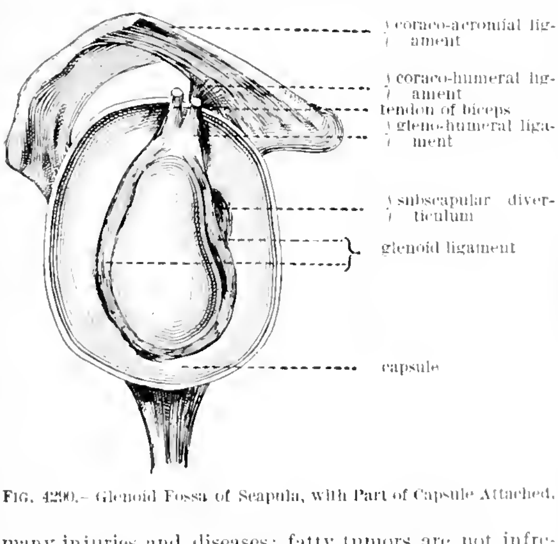


FIG. 4290.—Glenoid Fossa of Scapula, with Part of Capsule Attached.

many injuries and diseases; fatty tumors are not infrequently seen here and may attain to a large size.

The shoulder-joint is of the ball-and-socket variety (enarthrodial), and so is very freely movable; the socket in the scapula is very shallow but is deepened by the glenoid ligament, to which the long head of the biceps is attached. It is small in size compared with the large articular surface of the head of the humerus. This disparity gives greater freedom of movement with lessened security and more liability to displacement in extreme movements.

The circumflex nerve supplies the deltoid, shoulder-joint, and skin over the lower two-thirds of the shoulder and upper part of the triceps. In injuries to the shoulder this nerve is frequently damaged, and paralysis with atrophy of the deltoid may result; marked flattening of the shoulder may as a consequence ensue.

Relations of the Joint.—Muscles of great strength surround the shoulder except inferiorly; above we have the deltoid and supraspinatus, internally and in front the subscapularis, and externally and behind the infraspinatus, both these latter separated from the capsule by a bursa. The capsule of the joint, though strengthened by these muscles, is very loose, so that when the muscles

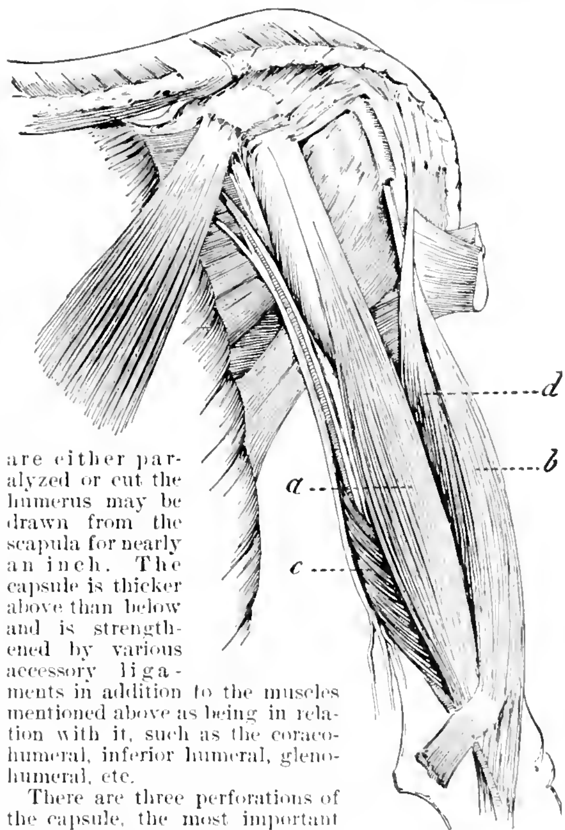


FIG. 4291.—Abnormal Arrangement of the Biceps. *a*, Coracoid head; *b*, glenoid head; *c*, humeral head; *d*, capsular head.

are either paralyzed or cut the humerus may be drawn from the scapula for nearly an inch. The capsule is thicker above than below and is strengthened by various accessory ligaments in addition to the muscles mentioned above as being in relation with it, such as the coraco-humeral, inferior humeral, gleno-humeral, etc.

There are three perforations of the capsule, the most important being that for the long head of the biceps at its lower part; it is also perforated by the supraspinatus and not infrequently by the infraspinatus. *The tendon of the long head of the biceps* has synovial membrane prolonged along it and surrounding it. This tendon keeps the head of the humerus against the glenoid cavity and prevents the bone rising up toward the acromion. This tendon is sometimes ruptured, thus causing weakening of the upper limb and a drawing up of the humerus forward and inward against the coraco-acromial arch. The tendon may be dislocated—that is, it may slip out of its groove to one side or the other. In such cases the head is prominent and drawn up under the acromion; owing to the higher position of the greater tuberosity, abduction is not so free.

Rupture of the tendon is more apt to occur in persons the subjects of rheumatic disease; in them the joint is dry and perhaps the tendon is partially worn. In old cases it is not uncommon to see the long tendon of the biceps attached to the upper end of the humerus, the head of the bone having worn through the tendon and the capsule, and entered the subacromion bursæ. In very old cases

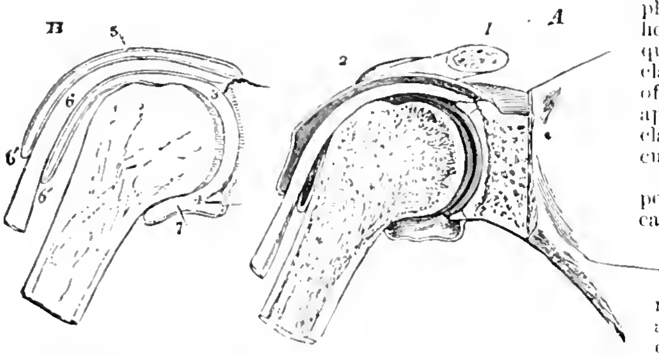


FIG. 4292.—A, Section showing the Relation of the Long Tendon of the Biceps to the Shoulder-joint. B is an outline showing the arrangement of the synovial membrane. (Allen Thomson in "Quain's Anatomy.")

the under surface of the acromion process will be eburnated as well as the surface of the humerus which has been in contact with it. As a rule the joint is well protected above by the acromion and coracoid processes, and the ligaments between these.

THE EPIPHYSES.—There are a number of epiphyses about the shoulder-joint, some of which are of importance. It is of importance to know that the epiphyseal end of the acromion, which articulates with the clavicle, may sometimes remain separated throughout life and may be mistaken for a fracture; in fact, Sir Astley Cooper described it as such. The coracoid process is also formed by a separate ossific centre, and the head of the humerus forms a single epiphysis in the fifth year; this is composed of no less than three fused secondary centres and it is limited by the surgical neck. Separation of the upper epiphysis of the humerus may be mistaken for dislocation, but the easy reduction and the fact that the glenoid cavity is always full should prevent one from falling into this error.

BURSÆ.—The bursæ about the shoulder are many, for besides the subdeltoid or subacromion bursa and the ones between the subscapularis and infraspinatus muscles, and the capsule of the joint (which was frequently continuous with the cavity of the joint), we have the bursa between the insertion of the latissimus dorsi and teres major muscles and between the teres muscle and the bone. Any one of these may become inflamed and distended with fluid as the results of strain or direct injury. Very often the inflammation is tuberculous, the subacromion is most often the seat of disease, for it is more exposed than the other neighboring bursæ.

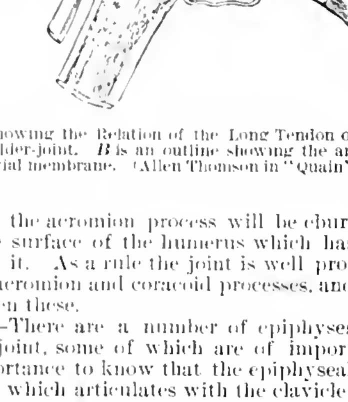


FIG. 4293. Frontal Sections of the Shoulder-joint while the Arm is Hanging. (Henle.) +, Clavicle; *ac*, acromio-coracoid ligament; *D*, deltoid muscle; *B*, tendon of long head of biceps; *Ss*, subscapularis; *Ss*[1], supraspinatus; *Al*, triceps; *Tmj*, teres major; *, posterior circumflex artery; **, trace of epiphysial union.

THE CLAVICLE.—The skin over this bone is very loose and easily rolled on the bone. Cutting down on the subclavian artery and pulling the skin firmly over the clavicle, the surgeon cuts freely on the bone, and when the skin is released the incision is well above the clavicle, and the external jugular vein, which it was intended to avoid, comes into view. Passing over the clavicle are seen the clavicular branches of the superficial cervical plexus, and these nerves may be easily injured here. In disease of the cervical spine there is frequently pain over the collar bone. Beneath the clavicle and subclavian artery, the vein and cords of the brachial plexus rest on the first rib. The apex of the lung passes up into the neck behind the clavicle, encircled by the first rib, and can be percussed in the supraclavicular fossa.

The sternal end of the clavicle is near very important structures, such as the innominate and left carotid artery, the pneumogastric and recurrent nerves, and the large venous trunks. The acromio-clavicular joint is sometimes dislocated and is hard to retain in place when reduced; the sternal end also may be displaced and this joint may be attacked by tuberculous disease.

AXILLA.—The axilla (*ala*, a wing) is the space which exists between the upper arm and side of the thorax. It is of a pyramidal shape, and is bounded in front by the pectoral muscles, behind by the subscapularis, teres major, and latissimus dorsi, on the inner side by the serratus magnus, intercostal muscles and ribs, and on the outer side by the upper part of the arm and shoulder-joint. The base is formed by the skin stretching between the anterior and posterior boundaries. The hollow between the anterior and posterior folds is commonly known as the armpit, but anatomically we imply more by the term axilla than this depression; we include all the deeper space which reaches up to between the scalene muscles, and contains the axillary vessels, brachial plexus of nerves, and lymphatics. This deeper space is surgically continuous with the neck.

Superficial Anatomy.—The skin of the armpit proper, which is very thin, sensitive, attached to the fascia beneath, and of a darkish color, is supplied with glands which secrete an odorous sweat. In some cases this sweat is of a peculiar color, and stains the linen; it may be large in amount and cause great discomfort to the individual and his friends from the disagreeable odor emitted.

The skin of the armpit is abundantly provided with hairs which never grow to any great length; their limit is generally well defined, the outer border furnishing a good surface mark for the axillary artery in the third

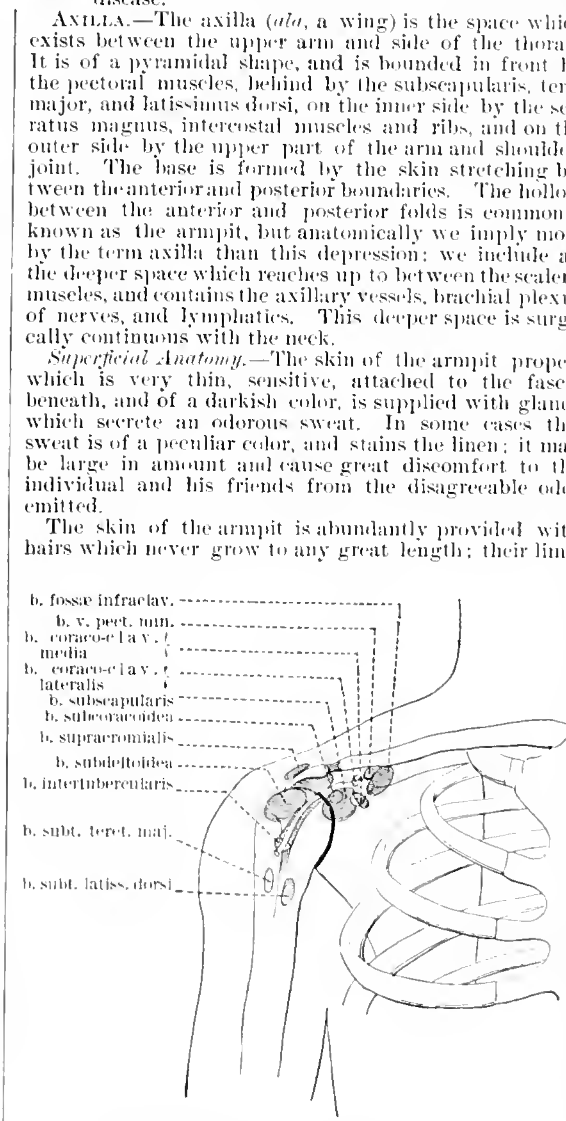


FIG. 4294. The Principal Bursæ about the Shoulder.

part of its course.* The armpit is of different depths in different individuals; in women and children it is not so well marked as in men, chiefly because in them we have less muscular development and more adipose tissue. When the arm is lifted above the head the depression almost disappears and the skin is put so much on the stretch that nothing can be felt of the deeper part; the depression deepens as the arm is lowered to the side, the skin being relaxed and thrown into folds. The fingers can now be pushed high enough to feel the head of the humerus. When it is necessary to examine the deeper structures, the arm ought only to be slightly drawn away from the side. In operations on the axilla the arm should always be abducted and raised to lessen the depression.

It is not uncommon to see suppuration of the follicles in this region; these small follicular abscesses, owing to the sensitiveness of the skin, are very painful and should be opened early.

The skin covering the anterior fold is thick, not closely adherent to the deeper structures, and free from hairs. Close below the clavicle and internal to the shoulder, the coracoid process can be felt.

The lower border of the great pectoral muscle follows the line of the fifth rib; the first visible serration of the serratus magnus on the inner side of the space is the sixth. The posterior fold is thicker than the anterior on account of the great thickness of the teres major muscle. When the arm is raised from the side the axillary artery can be felt pulsating as it passes into the arm, and may be easily compressed.

Fascia.—On removing the skin from the axilla we come upon a strong fascia, the disposition of which it is important to know because of its influence on the course of abscesses, which not infrequently form in the neighborhood. The strong fascia which covers the great pectoral muscle and is attached to all the subcutaneous bony prominences, winds round its lower border and splits into two portions, one of which continues to ensheath the pectoralis muscle on its inner surface, while the other forms the floor of the axilla and, after covering the latissimus dorsi and teres major muscles, passes upward and backward and is lost in the strong deltoid aponeurosis. The portion of this fascia which covers the pectoralis major muscle externally sends a process between it and the deltoid muscle, and this process becomes continuous with the costo-coracoid membrane.

The costo-coracoid membrane (Fig. 4295) is a strong aponeurosis which is continuous with the deep cervical fascia; it splits to enclose the subclavius muscle, is attached to the clavicle and to the coracoid process, and is continued to the capsule of the shoulder. It is also attached to the cartilages of the first and second ribs, and is continuous with the aponeurosis over the serratus magnus muscle. This fascia is the costo-coracoid membrane proper, and covers the first part of the axillary vessels and nerves. When it reaches the edge of the small pectoral muscle it again divides to enclose it; reuniting again, it passes down to the base of the axilla, and becomes attached to the skin and the fascia covering the great pectoral; externally it is continuous with the brachial aponeurosis. Gerdy calls this process the *ligamentum suspensorium*, because he says it is the ligament of the skin of the armpit, which it pulls upward. This suspensory ligament, then, divides the axilla into an anterior and a posterior compartment, the posterior containing blood-vessels and nerves, and the anterior the loose cellular tissue which separates the two pectoral muscles and intervenes between the lower part of the fascia and the great pectoral. Now, when an abscess forms in front of the suspensory ligament—that is, below the small pectoral or between the two pectorals—it would tend to point at the lower border of the anterior axillary fold, or in the interspace between the deltoid and the great pectoral muscle; but if pus forms behind the suspensory ligament and is not evacuated early, it may burrow into the neck and thence find its way, through the upper opening of the thorax, into the mediastina; it may also find its way beneath the latissimus dorsi and point in the back, or it may burrow into the subscapular fossa and thence get into the shoulder-joint.

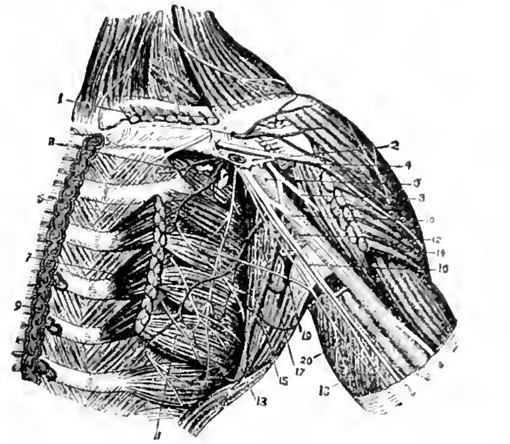


FIG. 4295.—Brachial Plexus and Axillary Artery. 2, Costo-coracoid membrane; 3, superior thoracic and ulnar arteries; 5, long thoracic artery; 6, axillary artery; 8, musculocutaneous nerve; 10, median nerve; 15, subscapular artery; 16, ulnar nerve; 18, internal cutaneous nerve; 19, circumflex nerve; 20, nerve of Wrisberg, joined by intercosto-humeral.

Abscesses in the axilla should be opened early and after the manner of the late Mr. Hilton. He advised that the skin alone should be cut with a knife, that a grooved director should then be pushed into the deeper structures till pus wells out. The deeper parts may be still further opened up by introducing a pair of dressing forceps, opening them widely in the abscess and withdrawing them open. If axillary abscesses are opened in this way, there is no danger of wounding any of the displaced vessels in the neighborhood, as they are pushed aside by the director. The finger answers often quite as well as a director.

Boundaries of the Axilla.—The *anterior boundary* (Fig. 4288) is formed by the two pectoral muscles, the great pectoral alone forming the lower border of the anterior fold. It is important, surgically, to remember that the fibres of the large pectoral go downward and outward, and those of the lesser upward and outward. The interspace between the great pectoral and the deltoid may be often very small or wanting, and the division between the two muscles can be made out only by the position of the cephalic vein and a branch of the acromial thoracic artery.

Owing to the pectoralis major muscle having an origin from the clavicle, it is necessary, in fracture of that bone, that the arm should be placed close to the side to prevent the muscle pulling down the inner fragment, and so delaying union. In females the lower edge of the anterior border of the axilla, owing to the presence of the mammary gland, is not so easily seen as in the male. In the female the mammary gland moves freely on the great pectoral muscle, there being an abundance of cellular tissue between the muscle and the gland; but in advanced cases of cancerous disease of the breast every movement of the pectoral muscle is painful because of the gluing together of the breast and the muscle by infiltrated tissue.

The acromial thoracic vessels and the internal and external thoracic nerves are seen on the inner surface of

* According to Mr. A. W. Martin (Edin. Med. Journal, June, 1884): "The presence of hair in the pubic region is sufficient, by the law of correlation of growth, to account for the presence of hair in the corresponding part of the fore-limb, the axilla." He also says that the hair of the axilla has a fixed ratio to that of the pubes and also corresponds closely in color; he regards sexual selection as sufficient to account for it on the pubes, and also remarks that its quantity in both sexes will be in proportion to the sexual passion. With this last statement I certainly am not prepared to agree.

the pectoral muscle. The long thoracic artery generally runs along the lower border of the lesser pectoral.

In rare cases the great pectoral muscle is wanting altogether, or the clavicular portion alone may be wanting. The lesser pectoral may be attached to as many as five

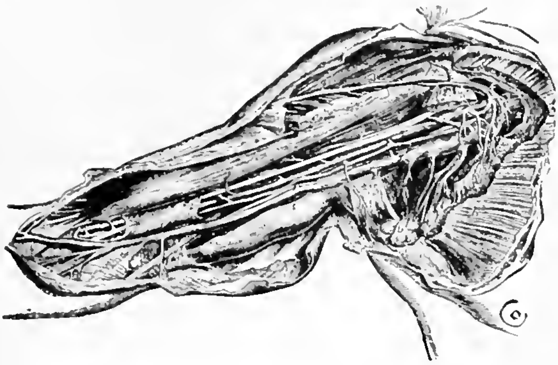


FIG. 4296.—Dissection of Axilla, showing the Axillary Vein (2, 2) and Parts in Relation with it. 1, 1, Axillary artery; 2, 2, axillary vein; 3, 3, basilic vein; 4, cephalic vein; 5, 5, pectoralis minor; 6, axillary glands.

ribs or as few as one. Its insertion may be transferred from the coracoid process to the coracobrachialis muscle or humerus itself.

The *posterior boundary* of the axilla is formed by three muscles which are supplied by the same set of nerves, viz., the three subscapular, and all three muscles are internal rotators of the humerus. The tendon of the latissimus dorsi, with the teres major, forms the lower edge of the posterior fold, the posterior wall of the deeper portion being principally formed by the subscapularis. The axillary vessels rest on this posterior wall, held together by a dense cellular sheath, and separated from the rest of the axilla by the above-described suspensory fascia.

The *internal boundary* of the axilla is formed by the ribs, intercostal muscles, and the upper digitations of the serratus magnus. On this wall, which is somewhat convex, a large nerve is seen running down in a vertical direction, to be distributed to the serratus magnus muscle. This nerve is a branch of the brachial plexus, and is called the long thoracic. We also find here branches of the posterior and long thoracic vessels. Abscesses and tumors, as a rule, lie along this wall, and are fortunately well away from the axillary vessels; in removing tumors we always dissect toward the inner wall.

The *external boundary* of the axilla is formed by the upper part of the humerus and coracobrachialis muscle; along this boundary, and on the inner side of the coracobrachialis are seen the axillary vessels and nerves closely bound down by their fascial covering.

The *inferior boundary* or *base* of the axilla, which is formed by the skin and fascia stretching between the anterior and posterior folds, has already been described.

The apex of this cone-shaped space may be said to be continuous with the posterior triangle of the neck, as vessels, nerves, lymphatics, cellular tissue, and fascia reach the axilla from the neck through this apex. It is the space between the upper edge of the scapula, clavicle, and first rib. Abscesses of the neck have been seen passing through this opening and pointing in the axilla.

Contents of the Axilla.—The axillary vessels, with the lymphatic glands, fat, and loose cellular tissue, are the principal contents of the axilla. The loose cellular tissue permits of free movements of the arm to and from the body, but it also permits of the collection of large quantities of blood and pus. The vessels and nerves are bound together by a sheath of thick cellular tissue; they lie on the outer wall of the space internal to the coracobrachialis.

Axillary Vein (Fig. 4296).—This is the most superficial of the contents of the axilla. In the upper part of its course it is so fixed by fascia connecting it with the coracoid process and pectoralis minor muscle, that if wounded it tends to gape, and air is apt to enter. The vein is formed by the junction of the venæ comites with the basilic vein. This union may occur low down or high up; the normal point of union is at the lower edge of the subscapularis muscle, though the junction not infrequently takes place higher up, sometimes as high as the clavicle. It is always shorter than the artery, measuring about 7.5 cm. (3 in.) in length. Union occurring high up complicates operations upon the artery, owing to the numerous transverse communicating branches which cross the artery. The vein lies to the inner side of the artery, and generally overlaps it. When the arm is drawn away from the side it almost altogether covers the artery. In the course through the axilla, this vein receives many tributary branches, the largest of which is the subscapular. It receives the cephalic vein immediately above the lesser pectoral muscle. In operations on the axilla, the vein and its branches are frequently wounded—more often than the artery—but it is rarely injured by external violence. In reducing dislocations of the shoulder, and using extreme traction, the artery is much more frequently injured than the vein, owing to its proximity to the heart and its fixed position; the vein, when wounded, bleeds freely, and there is great danger of air entering it. This accident has many times occurred, especially in operations for removing diseased glands, and not a few fatal cases are on record. It is always well before dividing the veins, especially about the neck and axilla, to tie them with a double ligature and cut between.

In almost all diseases of the axilla there is swelling of the arm caused by pressure on the veins and absorbents.

Axillary Artery (Fig. 4295).—This vessel, which is the continuation of the subclavian, extends from the lower border of the first rib to the lower border of the teres major muscle; it measures about 15 cm. (6 in.) in length, and its direction is altered with the position of the arm. When the arm is close to the side, it forms a curve having its convexity upward and outward; when the arm is held at right angles to the body, the artery is in almost a straight line; and again, when the arm is held above the head, the slight curve thus formed has its concavity upward. Its upper portion lies close to the chest and rests on the upper serrations of the serratus magnus; the long thoracic nerve is behind it, and in front is the costo-coracoid membrane. Its lower part lies principally on the subscapular muscle. The vein is superficial to the artery above, and the nerves of the brachial plexus lie to its upper and outer side; lower down the vein becomes more internal and the nerves surround the vessel, the two heads of the median embracing it. For convenience of description the axillary artery is divided surgically into three portions—the part above,

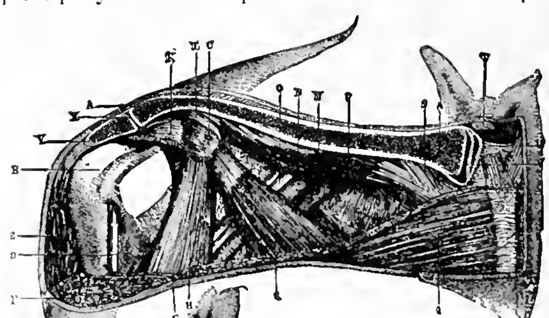


FIG. 4297.—Portion of Clavicle and Acromion Process removed with Pectoralis Major and Deltoid Muscles. Pectoralis minor muscle (*R*) crossing the space; relation of axilla to the shoulder shown, and also contents of axilla; *M*, axillary vein; *N*, axillary artery; *O*, brachial plexus; *P*, subclavius muscle. (From Anger's "Anatomie Chirurgicale.")

that beneath, and that below the pectoralis minor muscle. It lies deepest above this muscle and is most superficial below it. The large thoracico-acromial branch is given off immediately above the pectoralis minor, and might be wounded in the operation of tying the axillary in its first part. A number of small branches are given off which are not surgically important. The subscapular artery, given off near the lower edge of the subscapular muscle, is a large branch, which runs to the side of the chest and near its origin gives off the dorsalis scapulæ. The external mammary is given off below the lesser pectoral, and is sometimes of large size; it is always cut in the operation of excision of the breast, and may give rise to slight hemorrhage. The circumflex arteries closely embrace the neck of the humerus, and should be looked for and avoided in excision of the head of the humerus. In wounds of the first part of the axillary artery the vein is so closely in relation with it that it rarely escapes; lower down the artery may be wounded and the vein remain intact. Wounds of the axillary artery may result from stabs, fracture of the neck of the humerus (Fenwick), violence during the reduction of old dislocations. Hemorrhages may be slight or severe, according to the size of the wound. The loose tissues of the axilla admit of great and rapid distention by bleeding from either vein or artery. The treatment is first to compress or temporarily ligature the third part of the subclavian and then cut down on the artery in the axilla, turn out the clots, and ligature above and below the wound in the vessels. It is well to remember that in reduction of an old dislocation the artery has been torn when simple manipulation was practised, owing to the adhesions which had formed between the capsule and the vessel. The artery is usually tied in the third part of its course, where it is most superficial. It has been tied on the first part, but owing to its depth and the thick covering of muscle, and also its close connection with the vein, ligature of the third part of the subclavian is preferred, as being the safer and simpler operation. The third part of the subclavian is more easily compressed than the first part of the axillary.

Aneurism not infrequently affects the axillary artery; this is, perhaps, owing to its nearness to the heart and to the curve the artery makes at its upper part. It has been occasionally ruptured in reducing dislocation of the shoulder.

Nerves of the Brachial Plexus (Fig. 4295).—These nerves are derived from the lower four cervical and first dorsal. They are to the outer side of the artery in the first part of its course, but lower down they surround it. When the axillary artery divides into two trunks, one of which gives off all the branches, this latter is, as a rule, embraced by the two heads of the median. The axillary nerves are rarely torn by traction on the limb; when forcibly stretched they may be torn away from their attachment to the cord in the cervical region, as in a case recorded by Flaubert, where this accident happened in endeavoring to reduce a dislocated shoulder. The median is the nerve most frequently injured in wounds of the axilla, the musculospiral, from its very deep and protected position, always escaping. The axillary nerves are occasionally injured in fracture of the neck of the humerus, and may be compressed in dislocation of the shoulder.

Lymphatics (Fig. 4298).—The axilla is richly supplied with lymphatic vessels and glands. The glands, which are ten or twelve in number, are mostly placed along the axillary vessels and form a continuous chain with the cervical glands. They receive the lymphatics of the arm, and are often much enlarged in inflammatory affections of the hand and arm. A few glands are situated on the serratus magnus muscle and near the lower edge of the pectoral muscles. When enlarged these glands may be felt under the axillary border of the pectoralis major. The lymphatics from the pectoral group of glands drain into the axillary glands as do the lymphatics from the subscapular group. They receive most of the lymphatics from the side of the chest and mamma, and also the superficial lymphatics of the abdomen as

low down as the umbilicus (Treves). These are the glands which are first enlarged in certain affections of the breast, *e.g.*, cancer, and also when the chest or abdomen is inflamed superficially, as from blistering, etc. Their efferent vessels join the axillary glands. There are some glands situated at the back of the axilla along the subscapular vessels; these receive the lymphatics from the back. In the interspace between the great pectoral and deltoid muscles near the clavicle, one or two small glands are found; they receive the lymphatics of the shoulder and outer side of the arm; above, they are connected with the lower cervical, and below with the axillary glands. The efferent vessels of the axillary glands pass up with the subclavian vein and join the thoracic duct on the left side, and on the right the lymphatic duct of that side. Sometimes they open separately into the subclavian vein. The axillary lymphatics which pass upward under the clavicle anastomose freely with the subclavian lymphatics and the lymphatics of the deep cervical glands.

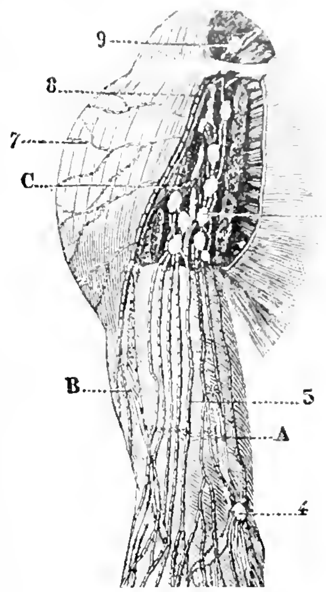


FIG. 4298.—Lymphatics of the Axilla. (From Testut.) 4, Epitrochlear gland; 5, superficial lymphatics of arm; 6, axillary glands; 7, lymphatic of shoulder; 8, lymphatic trunk accompanying the cephalic vein; 9, glands of neck; *A*, basilic vein; *B*, cephalic vein; *C*, axillary vein.

The glands of the axilla are frequently enlarged from sympathy with disease or inflammation of neighboring parts, and not infrequently run on to suppuration. They may be the subject of cancerous infiltration when the breast is affected with malignant disease; occasionally, malignant disease first affects these glands. Scrofulous enlargement of the axillary glands is not uncommon, and their removal is sometimes called for. Professor Verneuil (*Gazette des Hôpitaux*, October 10th, 1879) recommends linear division of the pectoral muscles previous to excision of deeply seated glands. As these glands lie chiefly along the vessels, there is great danger of hemorrhage, and even if the main vein itself is not wounded, some of the large veins going to it may be easily nicked and give rise to free hemorrhage.

In excision of the breast, when the axillary glands are affected they must always be removed, and this is often a difficult operation. The glands are very apt to become adherent to the vessels, especially the vein, which has often been wounded during removal of glandular tumors. When clearing the axilla of diseased glands the fingers will be found more serviceable than any cutting instrument, and infinitely safer. The deep lymphatics of the breast anastomose freely with the lymphatics of the fascia covering the great pectoral muscle and unite with the trunk of the deep lymphatics which go to the axilla. The lymphatics of the pectoral fascia do not anastomose freely with those of the muscle beneath, for the direction of the lymphatic flow is from the muscle to the fascia. Abscess of the axilla, originating in the glands, is not uncommon, the glands most liable to suppurative inflammation being those under the edge of the great pectoral muscle. The course which pus takes when it forms in the axilla has already been described with the fascia. Strumous glands in the axilla frequently break down and suppurate, leaving sinuses which are very difficult to heal.

Supernumerary mammæ have been frequently reported as occurring in the axilla. Dr. Garland (*Edin. Med. Jour.*, 1877) reports cases in which there were swellings in the axilla during pregnancy and suckling; and Dr. Sharpe (*Med. Times and Gazette*, 1855) mentions a case in which a supplementary mamma, which enlarged greatly during pregnancy, occurred in each axilla, and milk could be squeezed out apparently through pores in the skin; there was no appearance of nipples.

Mr. Birkett (*Med. Times and Gazette*, vol. ii., 1868) describes several cases of cystic tumors occurring in early life in the axilla and extending into the neck. He strongly advocates excision in these cases.

Fatty tumors frequently develop in this region; they can be removed without much difficulty.

Francis J. Shepherd.

SIALAGOGUES.—This term is applied to remedies that increase the secretion of saliva. In the normal state of the organism the secretion of saliva is a reflex process excited by chemical and mechanical stimuli. These affect the gustatory nerves and the sensory filaments of the trigeminal and glossopharyngeal nerves of the whole buccal cavity. Such stimuli are all foods and drinks that have a perceptible taste and the mechanical movements necessary in masticating. The stimulating impressions upon the sensory nerves are conveyed by them to the salivary centres, especially to the centre in the medulla oblongata; from these centres impulses are transmitted through the efferent nerves to the salivary glands, and as a result of these impulses there are an increased flow of blood to the glands and an abundant secretion of saliva. Hence it is observed that the saliva is most abundant when food has a very decided and agreeable taste and the process of mastication is slowly and thoroughly performed. In abnormal states of the buccal cavity, especially in the various forms of stomatitis, in consequence of the irritation of the sensory nerves, a more or less abundant flow of saliva takes place reflexly. (See also the article on *Saliva*.)

Most sialagogues act in the same manner as the normal stimuli of the secretion, that is, reflexly; by notably impressing the sensory nerves of the buccal cavity they excite the salivary centres and these transmit impulses to the salivary glands. Hence the greater the stimulating effect of sialagogues upon the sensory nerves of the mouth, the more abundant the salivary secretion. Very pungent substances, such as pellitory, mezereum, cubeb, capsicum, mustard, and ginger, if kept in contact with the buccal mucous membranes for some time, cause a free flow of saliva. Numerous other remedies having a decided action upon the sensory nerves of the buccal cavity, such as vegetable and mineral acids, alkalies, simple bitters and aromatics, ether, chloroform, and alcoholics, reflexly increase the flow of saliva.

Some sialagogues, however, do not act reflexly; they cause a very free flow of saliva when they are injected into the subcutaneous tissue or when they enter the blood by other routes. They act directly upon the peripheral ends of the secretory nerves of the salivary glands, and hence are called remote or specific sialagogues. The principal one of them, and the only one used therapeutically, is pilocarpine; others are physostigmine, muscarine, and nicotine. The preparations of mercury also act specifically; but when they have produced stomatitis the local irritation is necessarily followed by reflex salivation. The preparations of iodine and chlorate of potassium also increase the secretion of saliva by acting upon the secretory nerves.

Sialagogues are used when the salivary secretion is insufficient. This occurs in some persons who eat very rapidly; it is also frequently observed in prolonged febrile diseases, and it is one of the results of poisoning with certain alkaloids and ptomaïnes.

In the dyspepsia of persons eating too hastily sialagogues are probably of little or no benefit; but the adoption of correct habits in eating is generally soon followed by normal digestion. Such patients should be advised to masticate very slowly and at each meal to eat a sufficient amount of hard and dry food, such as stale bread, dry toast, crackers, to excite an abundant flow of saliva. When the teeth have become so defective that food cannot be thoroughly masticated, the patient should be advised to consult a dentist.

The salivary secretion is always diminished in high fevers, and it is sometimes almost completely arrested. When the patient constantly breathes through his mouth, the buccal mucous membrane sometimes becomes so dry that the movements of the tongue, articulation, and deglutition become difficult. In consequence of the dryness, the mucous membrane becomes fissured and abraded, thus presenting numerous openings for the entrance of micro-organisms. Various annoying and dangerous morbid conditions may result, such as soreness, ulceration, and bleeding of the gums, caries of the teeth, fœtor of the breath, glossitis, inflammation of the glands of the neck, of the Eustachian tube and the middle ear. Hence, while sialagogues are used to maintain the secretion of the saliva, all other appropriate means should be employed to prevent the dryness of the mucous membrane. The air of the patient's apartment should be kept moist; the patient should frequently drink water, at least every hour; a piece of wet wide-meshed fabric should be laid over his open mouth; and every three or four hours the entire buccal cavity should be moistened by means of a large camel-hair brush with a mixture of one part of glycerin and two parts of peppermint water. The only sialagogues appropriate in fevers are the acids; of these the most agreeable one is citric acid as contained in lemonade, which has been used from time immemorial as a pleasant drink to quench thirst in high fevers. The other acids that may be used are tartaric, acetic, phosphoric, and hydrochloric, very much diluted and given at short intervals. Some authors hold that only vegetable acids should be given, because they do not, like the mineral acids, diminish the alkalinity of the blood, which, according to some researches, always becomes diminished in prolonged fevers; others are of the opinion that the mineral acids deserve preference because they do not increase oxidation.

The buccal mucous membrane becomes intensely dry from arrested secretion of saliva and mucus in poisoning with belladonna, hyoscyamus, and stramonium, and to a somewhat less degree in poisoning with decayed meat, fish, and cheese. The arrested salivary secretion is, of course, only one of the symptoms; but it may be abated and some of the other symptoms allayed by the cautious administration of pilocarpine.

Pungent sialagogues have been used to allay toothache, earache, and other congestive and inflammatory affections of the nose, ear, and other parts of the head. During the profuse flow of saliva excited by their mastication, the salivary glands are very abundantly supplied with blood, and doubtless this hyperæmia may lessen the flow of blood to adjacent parts of the head and be of some benefit. For this purpose pyrethrum was generally preferred.

Samuel Nickles.

SIDE-CHAIN THEORY OF PAUL EHRLICH.—(Synonyms: Lateral-chain theory; Receptor theory. German, *Seitenkettentheorie*; French *Théorie des chaînes latérales*.)

Definition.—An hypothesis which attempts to explain according to chemical laws the mechanism of the processes of infection and immunity.

The side-chain theory first appeared as an explanation of the mechanism of the assimilation of foods (Ehrlich, Paul: "Das Sauerstoffbedürfniss des Organismus," 1885). According to this hypothesis a food must become chemically bound to a cell in order to be assimilated. Union of food and cell depends upon chemical structure. No matter what may be the chemical structure of a food, it must at least contain a chemical group which allows it to unite with a cell. This chemical group in a food is its "binding group" or "haptophorous group" (from the

Greek ἅπτειν, to bind to). The cell also must contain a binding group or haptophorous group with chemical affinity for the corresponding group of the food. When a food in the circulation passes near the cell, the chemical affinity between the haptophorous group of the cell and that of the food leads to the withdrawal of the food from the circulation and to the chemical union of the food and cell by means of their mutually attractive haptophorous groups. When thus chemically bound to the cell the food can be elaborated into an integral part of the cell, or it can be used up and thrown off as waste products. That portion of the cell which contains the haptophorous group is called by Ehrlich the "side chain" or "lateral chain" or "receptor" of the cell.

Side chain or lateral chain is a term used in chemistry to designate certain substitution products of the benzene ring. The term is used by Ehrlich to suggest an analogous condition in the cell. Receptor simply indicates that this portion of the cell "receives" the food or other material to be mentioned later.

Ehrlich supposes that a cell is composed of two parts: the side chains and the "Leistungskern" or "Central Group." The central group consists of a great number of complicated molecules whose interaction upon each other and upon the foodstuffs is the chemical basis for all vital phenomena manifested by the cell. The special function of the side chain is to bring food to the cell. Each cell possesses a number of different side chains with affinities for different foods, and, furthermore, at least some of the side chains of one cell differ from the side chains of other cells.

This theory of assimilation was first adopted by Ehrlich in 1897 as an explanation of the mechanism of infection by soluble toxins, such as diphtheria and tetanus, and of antitoxin formation (Ehrlich, Paul: "Die Werthbemessung des Diphtherieheilserums," etc. "Klinisches Jahrbuch," 1897). A little later he extended the theory to explain the mechanism of bactericidal immunity and also to account for all those reaction products which are known as cytotoxins, cytolysins, agglutinins, precipitins, coagulins, etc.

The explanation of infection and immunity is simple if one remembers Ehrlich's assimilation theory. If a toxin such as tetanus toxin is injected into an animal the toxin causes no injury unless it becomes chemically united to some vital cells of the animal. If such union does occur it means that the toxin chances to possess a binding group or haptophorous group with affinity for a corresponding haptophorous group or side chain of the cell. Only after union between the cell and toxin by means of their corresponding groups can the specific action of the toxin be directed against the cell.

Ehrlich assumes that the toxin consists of two parts. One, the haptophorous or binding group, happens to resemble the haptophorous group of some normal foodstuff so closely that it can unite with the side chain of some of the body cells. The second part of the toxin is the specific functioning part. This Ehrlich calls the "toxophorous group" of the toxin. These groups may be independent of each other. Either group may be injured without affecting the other. Ehrlich obtained evidence that the toxophorous group is actually less stable than the haptophorous group. Under various conditions a toxin may lose its power of producing the symptoms of poisoning, while it still possesses its power of uniting. Such a toxin Ehrlich called a "toxoid," that is, a "toxin-like" body. A toxoid is a toxin whose toxophorous group is destroyed while its haptophorous group remains intact.

If a dose of toxin is injected into a naturally immune animal the result is negative, for the toxin finds no side chains with affinity for its haptophorous group. In other words, the toxin is unable to unite with any cells of the experimental animal and one fundamental prerequisite of intoxication is absent.

If, however, the toxin is injected into a susceptible animal, the toxin molecules become bound by the haptophorous groups to the corresponding side chains of the cell, and thereupon the toxophorous group of the toxin acts upon the central group of the cell to produce the phenomena of the specific disease. If the virulence of the toxin is great the animal dies; that is to say, if the chemical energy of the toxophorous group is great, the central groups of the cells of vital organs are injured and thrown out of function and the death of the animal results.

But the toxin may be less virulent. The toxophorous group may have such little energy that the central groups of the cells of the animal are not thrown out of function. In this case the toxin is anchored to the side chain of the cell by means of the haptophorous group, and the toxophorous group causes little injury to the cell. The cell then functions normally except that the side chain occupied by toxin is not free to pick up food. The toxin remains attached to the side chain, for not being a food stuff it cannot be digested and thus removed from the side chain. The side chain thus occupied by toxin is a useless encumbrance to the cell and is accordingly removed as if it were a foreign body, the combined toxin and side chain being thrown off as a waste product.

But the cell requires just such a side chain for the normal process of assimilation. Therefore the cell repairs the defect caused by the loss of its side chain by forming a new side chain whose properties are identical with those of the one that was thrown off.

According to a law formulated by Weigert, tissue formed to repair a defect tends to be formed in excess of the original tissue lost. Ehrlich applies this law to the repair of the side chains and supposes that whereas possibly one side chain is lost, several or many side chains are formed to replace it.

But the cell requires only one such side chain under normal conditions, and all more than one are superfluous. The superfluous side chains are really encumbrances to the cell and are thrown off as waste products.

It is seen that these side chains arise to repair the defect caused by the loss of a pre-existing side chain. The pre-existing side chain was distinguished by having a chemical affinity for a certain foodstuff, and chanced to have the same affinity for a toxin. The newly formed side chains being identical with the ones which pre-existed must, therefore, have the same chemical affinity for the same foodstuff and same toxin.

Such side chains, formed as reaction products of the cell to the toxin and thrown off into the circulation, are the antitoxins. Of course the side chains thrown off into the circulation still retain their affinity for the foodstuff and for the toxin. Enormous amounts of such free side chains or antitoxins may accumulate in the plasma of an animal which then possesses a high degree of antitoxin immunity. If toxin is injected into such an animal, it is picked up at once by the circulating free side chains or antitoxins, union occurring between the mutually attractive haptophorous groups of the toxin and antitoxin. The toxin is thus rendered innocuous, for the means is removed by which it could otherwise unite with the body cells. It is seen that the antitoxin does not necessarily destroy the toxin, but simply neutralizes it by blocking its haptophorous group.

Serum taken from such an immune animal and injected into a susceptible animal confers a temporary immunity (passive immunity) upon the second animal, the mode of action being the same that has just been described. The antitoxic serum must be injected before the toxin has become anchored to the body cells. Otherwise enormous doses of antitoxin are needed and the result is even then uncertain.

Evidently the affinity between the side chain of the cell and the haptophorous group of the toxin is specific, and specific in a chemical, not a biological sense. That is to say, the side chain will not unite with any substance which has not an affinity for the haptophorous group of the side chain, but will unite with any substance possessing such an affinity, whether it be foodstuff, toxin, or other material.

Each cell contains a number of different side chains with affinities for different food materials in the circulation. While one or two side chains of a cell are concerned in the process of intoxication and antitoxin formation, the rest continue to function normally.

Ehrlich's theory explains readily the origin and mode of action of the cytolysins, agglutinins, etc.

If an animal be treated with inoculations of bacteria in doses less than fatal, the serum of the animal acquires several new properties.

If a few drops of the serum are added to a few drops of suspension of bacteria of the species injected, the bacteria lose their motility and collect in clumps and balls, that is to say, they become "agglutinated." Those substances in the serum which produce agglutination are termed "agglutinins."

The serum of the inoculated animal frequently shows another new property. If a few drops of the serum are added to a culture of the bacterium in fluid medium some products of bacterial action dissolved in the liquid are precipitated from solution. These substances in the serum which cause such a precipitation are called "precipitins."

Frequently the serum of the inoculated animal acquires the power of completely dissolving the bacteria. Such a serum is called a "bacteriolytic" serum. The substances in the serum which cause the dissolution of the bacteria are called "bacteriolysins," or less strictly "lysins." The process of disintegration of the bacteria is called "bacteriolysis" or simply "lysis."

The process of bacteriolysis was first described by R. Pfeiffer, and is known as "Pfeiffer's phenomenon." Several valuable additions were made to Pfeiffer's description by Metschnikoff and Bordet. The most important discovery was made by Bordet, who found that it is just as easy to immunize animals against other cells as against bacteria. Bordet inoculated guinea-pigs with the red blood corpuscles of rabbits, and found that the serum of the guinea-pig acquired the power of agglutinating and also of dissolving the corpuscles of the rabbit. These observations have been extended so that now it can be stated as a general law "that the serum of an individual of species A, which has been treated with . . . inoculations of the erythrocytes of species B acquires new properties which enable it to dissolve the erythrocytes of species B" (Sachs, Lubarsch-Ostertag, vii. Jahrgang).

The substances in the serum which cause the dissolution of the red corpuscles are called "hæmolysins"; the serum is "hæmolytic," the process is "hæmolysis."

It is possible to produce sera which will dissolve other cells also. In the literature of the day one finds accounts of "leucolysins," sera which dissolve leucocytes; "nephrolysins," sera which dissolve kidney cells; "hepatolysins," sera which dissolve liver cells, etc.

In the same way there can be produced "haemoagglutinins," etc.

"Precipitins" can be formed by inoculating one animal with the serum of another. "Coagulins" have been produced by inoculating one animal with the milk of another.

An animal is said to be "immunized" when it is treated with inoculations, whether of toxins, bacteria, red blood corpuscles, serum, or any other material, and the animal thus treated is spoken of as an "immune" animal. Thus a guinea pig can be immunized against cholera vibrios, the guinea-pig's serum dissolving the vibrios. The guinea-pig can be immunized against typhoid bacilli, the serum agglutinating the bacilli. A rabbit can be immunized against human serum, the serum of the immune rabbit producing a precipitate in human serum. The goat can be immunized against the red blood corpuscles of the ox, the serum of the immune goat producing lysis of the red blood corpuscles of the ox, and so on.

In all such cases the serum of the immune animal becomes toxic for the species from which material was taken for inoculation. In the last case mentioned the serum of the immune goat is toxic for oxen. A serum which is toxic for the cells of another animal is called a "cytotoxin," though of course cytotoxin includes all other cell toxins also. The general name for the process of dissolution of cells is "cytolysis." Sera which cause the dissolution are "cytolysins," though of course any other substance which produces solution of cells is a cytolysin also. All of these reaction products in the serum of an immunized animal appear to have their energies especially directed against material like that with which the animal was inoculated; hence these reaction products are termed "antibodies."

Much information concerning the process of cytolysis, especially of hæmolysis, has been furnished in recent years by the investigations of Ehrlich and his pupils (see particularly the works of Ehrlich, Morgenroth, and Sachs). In their first researches Ehrlich and Morgenroth worked with the serum of a goat which had been immunized against the red blood corpuscles of a sheep, the goat's serum, therefore, dissolving the red blood corpuscles of the sheep. Subsequently, a great number of different combinations was employed. Ehrlich and Morgenroth corroborated Pfeiffer and Bordet in their conclusion that there are two substances in the serum concerned in producing cytolysis. One of these substances appeared as the result of inoculating or immunizing the animal. It was, therefore, called the "immune body."

Ehrlich and Morgenroth found that the immune body in the serum of the immunized goat readily unites with the red blood corpuscles of sheep. This immune body by itself, however, even when united to the corpuscles of the sheep, produced no change in them. The lysis of the red blood corpuscles resulted only when a second constituent of the serum was added. This substance was, therefore, called "complement," because it completed the action of the immune body.

The immune body was a new constituent of the goat's serum which first appeared after the goat had been inoculated with red blood corpuscles of the sheep. The immune body was quite a stable body with marked resistance to heat, light, and chemical reagents. It possessed the property of uniting with the red blood corpuscles of sheep. This union occurred quickly and even at low temperatures. The immune body had an affinity for the red blood corpuscles of sheep which was specific. This specificity, it was found, was of a chemical nature, as described above. The distinguishing feature of immune body was that when immune body, complement, and red blood corpuscles of sheep were brought together at a suitable temperature (about 37° C.) lysis of the red blood corpuscles resulted.

The complement was a normal constituent of the goat's serum, being neither increased nor diminished by the inoculations with corpuscles of sheep. The complement occurred in normal goats which had not been inoculated. It was also found in the serum of normal sheep and of other normal animals. Complement was a very unstable body with little resistance to heat, light, and chemical reagents. It could not be made to unite directly with red blood corpuscles. Only after the immune body had united with the sheep's corpuscles was it possible to bring about union of the complement, and even then union would not occur at low temperatures. The distinguishing feature of complement was that when complement, immune body, and the red blood corpuscles of sheep were brought together at a suitable temperature, lysis of the red blood corpuscles was produced.

Ehrlich was able to explain in terms of the side-chain theory the various phenomena manifested by the antibodies mentioned in the outline just given. He concluded that there must be several forms of side chain. The simplest form is a side chain whose only function is to unite with the foodstuff, thus bringing the food within reach of the central group of the cell. This form of side chain has been considered at length in describing the side-chain theory of assimilation and of antitoxin immunity.

A second form of side chain is so constructed that it not only unites with the foodstuff but also exerts a certain digestive or enzyme-like action upon it before the central group comes into play. This type of side chain contains two chemical groups: the haptophorous group and the zymophorous or enzyme-like group.

If any inoculated material happens to have an affinity for an haptophorous group of such side chains union occurs. The side chain is thrown off from the cell, new formation, overproduction and setting free of side chains follow according to the requirements of the side-chain theory. The side chains set free in the circulation being identical with the pre-existing side chain, are characterized by having both an haptophorous and a zymophorous group. When such a free side chain or antibody encounters material for which it has an affinity, in the first place, union occurs between the mutually attractive groups, and then the zymophorous group of the side chain exerts its action upon the material.

Agglutinins and coagulins are to be classed as free side chains or antibodies of this order, for they not only unite with substances for which they have an affinity, but also produce definite changes in those substances.

A third type of side chain remains to be considered. Here the side chain possesses both a haptophorous group with affinity for some foodstuff and also a second binding group with affinity for an enzyme-like substance in the circulation. Suitable food molecules unite with the haptophorous group of these side chains, whereupon the second binding group picks up the enzyme-like substance for which it has an affinity, and changes are brought about in the food by this enzyme-like substance.

If inoculated material happens to have an affinity for the haptophorous group of such side chains, union occurs, the side chains are thrown off, new formation and overproduction follow, and the new side chains are set free in the circulation. The free side chains or antibodies, being like the pre-existing side chains, are capable of uniting with two substances: first, the inoculated material; the other, the enzyme-like substance in the serum of the immune animal.

If such a free side chain or antibody encounters material for which it has an affinity, union occurs between the mutually attractive groups, and then the second binding group of the antibody picks up from the circulation the enzyme-like substance, which in turn exerts its action through the antibody upon the inoculated material.

This is the mechanism of cytolysis. The inoculated cells have led to the new formation, overproduction, and setting free in the circulation of certain side chains. These free side chains or antibodies are the immune bodies in the serum of the immunized animal. The enzyme-like substance normally present in the serum of the animal is the complement. If some cells of the sort inoculated are treated with serum of the immunized animal under proper conditions the immune body unites with the cells, the complement unites with the immune body, and lysis of the cells results.

It is not yet definitely settled whether precipitins are antibodies of the second order like agglutinins, or of the third order like cytolysins. Recent investigations indicate that the precipitins are antibodies of the third order.

These three types of side chain suffice to account for all the reaction products thus far investigated. There are many features of the side-chain theory which cannot be entered into in this review. In general it may be said that the chemist's point of view has been adhered to by Ehrlich in dealing with all the complicated phenomena met with in studies in immunity. From what has been said it is evident that the prerequisites of antibody formation are few—a substance inoculated into an animal must possess a chemical group (the haptophorous group) which will unite with the side chain of some cell of the animal. If the cell is not injured and if the inoculated substance is not removed by digestion by the central group, conditions are favorable for antibody formation.

Several other antibodies are known in addition to those already mentioned. By inoculating an animal with ferments it has been possible to produce "antiferments" which are of the same type as antitoxins. By inoculating with a serum rich in agglutinins or coagulins it has been possible to produce antibodies which prevent the action of the agglutinin or coagulin. These substances are termed "antiagglutinins" or "anticoagulins." They are really "anti-antibodies." It has also been possible to produce substances which prevent the action of the complement, *i.e.*, "anticomplements" and substances which prevent the action of the immune body, *i.e.*, "anti-immune bodies."

Many of the substances mentioned above, such as agglutinins, cytolysins, anticomplements, etc., have been found in the serum of many normal animals. Such normal antibodies can be readily accounted for as free side chains.

It has been found that the physical and chemical properties of the immune body and of the complement are subject to quite wide variations, and also that there are great numbers of different immune bodies and complements in the serum of any one animal.

Evidence goes to show that the complement arises from cells in the circulation, probably leucocytes. It has been found also that a certain quite definite chemical substance, lecithin, can act as complement.

It has been possible to apply nearly all of the deductions made from studies with hæmolytic sera to the various infectious diseases and to various animal and vegetable poisons.

There seems to be no fundamental antagonism between the side-chain theory of Ehrlich and Metschnikoff's phagocytic theory of immunity.

In concluding it will be well to give a list of other terms used in the literature of immunity. It has been stated that the complement is the unstable enzyme-like material normally found in certain animals. This material is also spoken of as "addiment," "cytase," or "alexin."

The immune body is also called "amboceptor" (that is, receptor with two binding groups), "substance sensibilisatrice," "präparator," "fixateur," "copula," "desmon," "intermediary body," or "Hilfskörper." The anti-immune bodies are also spoken of as "anti-amboceptors."

Harry T. Marshall.

SIDEROSCOPE.—The use of a magnetic needle for detecting foreign magnetic bodies in the eye was first advocated in 1880 by Thomas R. Pooley, of New York, but the suggestion did not attract much attention until the subject was taken up by Edward Asmus in 1894, who utilized the principle in an instrument which he called a *sideroscope*. Since then several modifications of the instrument have been brought forward, but for practical purposes Hirschberg's model is probably the best. This consists essentially of a magnetic needle suspended by a vertical thread, to which is attached a small mirror. The deflections of the needle produced by a foreign body in the eye of a patient is indicated by a beam of light from a lamp which is reflected by the mirror upon a graduated scale. The chief disadvantage of the instrument lies in its instability, for which reason it can be used with success only in places free from vibration. While it is quite delicate, many ophthalmologists claim that it is entirely unnecessary where Haab's giant magnet and an *x*-ray apparatus are available. *Frederick Herman Verhoeff.*

SIDEROSIS.—Ordinarily this term is used to designate the pigmentation of the lungs produced by the inhalation of any sort of metallic dust, but strictly it should refer to the deposition of iron pigment alone in any of the tissues of the body. A full account of siderosis used in the former sense will be found under *Pneumokoniosis*. True siderosis is usually due to the breaking down of the red corpuscles of the blood, and is best spoken of as *hæmatogenous siderosis*. This takes place to some extent in many chronic diseases, but especially in pernicious anæmia, and involves particularly the liver, spleen, bone marrow, and kidneys. It also occurs as the result of the disintegration of hemorrhages, as is the case, for instance, in chronic passive congestion of the lungs, and not infrequently in tumors. For this reason tumors should always be subjected to the test for iron before a conclusion is drawn as to their melanotic nature.

A condition of considerable importance in ophthalmology is *siderosis bulbi*, which is due to the presence of iron within the eye that has lodged there as the result of an injury. This is of little importance where the severity of the injury has been so great as to destroy sight at once, or where it has given rise to panophthalmitis, but not infrequently a small bit of iron may penetrate the globe without producing much damage or setting up serious inflammatory disturbances. Under these conditions the iron gradually disintegrates, and minute particles of iron rust are carried to various parts of the eye, especially the iris and retina, which take on a brownish-red color. In the specimens examined by the writer, the iron has been deposited in the form of small pigment granules, which are always found within cells. They are not confined to any special type of cell, though the connective-tissue cells of the iris stroma and the pigment cells of the retina, including those over the ciliary body and iris, seem to take them up most freely. Both the circular and radial muscle fibres of the iris, however, take them up, as do also to some extent the ganglion cells and nuclear bodies of the retina. The connective-tissue cells about the canal of Schlemm, as might be expected, are markedly involved. The cornea does not seem to be involved unless iron particles have lodged in its stroma, in which case the corneal corpuscles may become packed with iron pigment to such an extent that the cornea assumes a rust color. The epithelial cells beneath the lens capsule may also take up the pigment. The writer has never seen the choroid involved, nor the optic nerve, though the disc may be pigmented. The iron pigmentation of the retina leads to atrophy of the latter, as is manifested subjectively by night blindness, contraction of the visual field, and finally total blindness. Siderosis bulbi, however, does not always result when a particle of iron remains in the eye, because in many cases the foreign body is thoroughly encapsulated in connective tissue. In one of the writer's specimens the eye became intensely pigmented within three years after the injury, and in this case the foreign body was not encapsulated but was simply adherent to the retina, where it had sunk down and come in contact with it below. Siderosis bulbi can also be hæmatogenous in origin, sometimes resulting from an intraocular hemorrhage. In order to distinguish this from the siderosis dependent upon the disintegration of a foreign body, von Hippel applies the term *xenogenous siderosis* to the latter. *Siderosis conjunctivæ* may be produced by the long-continued use of sulphate of iron as a collyrium. The best differential method of staining histological sections for iron is to place them for six hours in a two-per-cent. solution of equal parts of potassium ferro- and ferricyanide, and then in acid alcohol for six hours. In this way both the ferrous and ferric salts give a beautiful blue reaction.

Frederick Herman Verhoeff.

SIDONAL, piperazine quinate, is a compound designed to combine the solvent power of piperazine for uric acid with the power of quinic acid to restrain uric acid formation. Blumenthal and Levin found the compound to reduce the excretion of uric acid and to increase that of hippuric acid. Bardet, in three cases of gout, administered 3–5 gm. (gr. xlv.–lxxv.) a day, and tested the urine twice a month; there was a moderate but steady decrease in uric acid. Salfeld speaks highly of the remedy in gout, but obtained no effect in a case of acute articular rheumatism. F. F. Ward, of New York, applied the remedy in various cases with gouty, rheumatic, or neuralgic pains. In those cases with excessive secretion of uric acid there was marked amelioration, and in all other cases no effect. The dose of sidonal is 1 gm. (gr. xv.) several times a day. Its combination with lithium citrate is called "urosin."

"New sidonal" is described by Huber and Lichtenstein as quinic anhydride. It is given for gout in dosage of 2.5 gm. (gr. xl.) a day.

W. A. Bastedo.

SILICOSIS.—The term applied to the pulmonary condition arising from the inhalation of *quartz dust.* The histological changes and the symptomatology are identical with those of *chalicosis*, or "marble-cutter's lung." Silicosis is of much less frequent occurrence than the latter condition, and is seen chiefly in those parts of the country in which mining, crushing, and stamping of quartz ores are carried on ("miner's consumption"). In granite-workers silicic dust is deposited in the lungs in association with the dust of the other constituents of the stone. The condition of silicosis may also be seen in the lungs of individuals exposed to silicic dust, in such occupations as the crushing of flints in glass manufacture, polishing and cutting of rock crystal, agate, etc. It has been said that the symptoms of silicosis develop more rapidly than those of chalicosis, and as a rule are more severe, for the reason that the quartz dust is more irritating and less capable of solution by the body juices than is dust composed of calcium carbonate. The clinical picture of silicosis is that of a fibroid pneumonia, and, as secondary tuberculosis is of very frequent occurrence, the final course of the disease is usually that of a fibroid tuberculosis. (See also *Pneumonokoniosis*).

Aldred Scott Warthin.

SILVER.—I. GENERAL MEDICINAL PROPERTIES OF COMPOUNDS OF SILVER.—In medicinal dosage the most important effect that follows persistent internal medication with silver is the tendency to a bluish-black discoloration of the skin and mucous membranes. This staining shows first on the mucous membranes, so that by inspection of the inner surfaces of the lips and of the fauces, during a course of medication by silver, and by stoppage of the medicine upon the first beginning of a bluish discoloration of those parts, no serious risk of staining of the skin need be incurred. As a rule, efficient dosage with silver can be maintained for from one to three months before coloration begins. In overdosage silver is a constitutional poison, impairing nutrition generally, and deranging the nervous system particularly. Therapeutically, impregnation of the system with silver tends to oppose, albeit feebly, the onward march of certain diseases of the nervous system, such as epilepsy and tabes dorsalis. But in the more intractable of these diseases, such as tabes, the influence is so slight as to be of no value—if, indeed, it exist at all—and in epilepsy other remedies are far more potent. The use of silver for constitutional effect is, therefore, in modern practice, quite abandoned.

Locally, the effects of silver compounds differ with the individual preparations according to their solubility, and will be described in connection with the several compounds themselves.

II. THE COMPOUNDS OF SILVER USED IN MEDICINE.—These comprise the *oxide*, *iodide*, and *nitrate*. The *cyanide* is also official in the United States Pharmacopœia, but for pharmaceutical purpose only.

Silver Oxide: Ag_2O. Silver oxide is official in the United States Pharmacopœia as *Argenti Oxidum*, Silver Oxide. It is a heavy, dark brownish-black powder, odorless, but of a metallic taste. It is liable to undergo reduction upon exposure to light. It is very slightly soluble in water and is insoluble in alcohol. It should be kept in dark amber-colored bottles, protected from the light. This oxide readily yields its oxygen in presence of oxidizable matter, and hence should not be triturated with any such material. It dissolves in water of ammonia. From its comparative insolubility this compound has little local effect, but when swallowed, probably through chemical conversion, it is capable of absorption, and exerts the constitutional effects of silver such as they are. In such operation the oxide is thought to be less prone to discolor the skin than the nitrate, but it is certainly not wholly innocent of this tendency. Upon the stomach and bowels silver oxide has quite a marked potency to allay irritability, tending to quell vomiting, even in such complaints as ulcer and cancer of the stomach, and to control diarrhœa when arising as a reflex of nervous irritation. The principal employment of the medicine is in such disorders of the digestive apparatus. The average dose is about 0.06 gm. (gr. i.), best given in powder or capsule. The pill form is bad, because of the deoxidation of the compound by the organic matter of the excipient, which reaction may even be attended by explosion. Gum arabic is recommended as the least objectionable excipient.

Silver Iodide: AgI. The salt is official in the United States Pharmacopœia as *Argenti Iodidum*, Silver Iodide. It is a heavy, light yellow powder, which, when pure, is not affected by light other than to change color to a greenish-yellow. It is insoluble in water or alcohol. It should be kept in dark, amber-colored bottles, protected from the light. Silver iodide is, medicinally, substantially a duplicate of the oxide, and may be used for the same purposes and in the same dose.

Silver Nitrate: $AgNO_3$. This, by far the most important compound of silver, is official in the United States Pharmacopœia in three conditions, namely, in crystals, in cylindrical sticks moulded by fusion, and in similar sticks in admixture with equal parts of potassium nitrate.

Argenti Nitras, Silver Nitrate. This title signifies the salt in crystals. These crystals are small, transparent rhombs, originally colorless, but gradually becoming grayish-black on exposure to light and air. They are odorless, but have a strong metallic taste. They dissolve freely in water, in twenty-six parts of cold alcohol, and in five parts of boiling alcohol. When heated to about 200° C. (392° F.), the crystals fuse to a faintly yellow liquid, which, on cooling, congeals to a purely white, crystalline mass. Silver nitrate should be kept in dark amber-colored vials protected from the light. These crystals constitute the purest form of the nitrate, and are used for internal giving or for the making of solutions.

Argenti Nitras Fusus, Moulded Silver Nitrate, "Fused Nitrate of Silver," "Lunar Caustic." The crystals are melted by heat, and the fused salt poured into moulds where it sets on cooling. But inasmuch as the pure nitrate is, when fused, inconveniently brittle, the Pharmacopœia provides for a trifling admixture of silver chloride, which is a tough compound. To this end about four per cent. of hydrochloric acid is added to the melted crystals, whereby a small portion of the nitrate is converted into chloride. Reaction having ceased, the mixed mass is ready for moulding. Lunar caustic is cast in narrow cylindrical sticks, which are hard, brittle, and, when freshly made, white in color. As commonly found, however, they are gray, or even blackish, through chemical reaction with matters present in the atmosphere. Fused nitrate of silver should be used only for its legitimate purpose, that of external application. The sticks should be kept protected from the light.

Argenti Nitras Dilutus, Diluted Silver Nitrate. Silver nitrate and potassium nitrate, the latter in double the quantity of the former, are melted together by heat and the fused mass moulded into sticks like those of the simple moulded silver nitrate. The sticks of the diluted nitrate resemble those of the pure nitrate except that they are granular rather than fibrous in texture. They are commonly called "mitigated sticks" of silver nitrate. They should be kept protected from the light. The sticks dissolve freely in water and possess the same properties as the undiluted lunar caustic, only in milder degree. They are used only for local application.

Silver nitrate differs from the oxide and iodide in the essential particular of free solubility, on which property depend the most valuable medicinal virtues of the salt. The most important reactions of the nitrate are that its solutions are precipitated by soluble chlorides to form the very insoluble salt, silver chloride. This reaction is one of the most delicate in chemistry, and since traces of chlorides are present in almost all natural waters, the use of distilled water is necessary for solutions of silver nitrate, if a clear, bright solution be desired. Silver nitrate also reacts on organic matter generally, suffering decomposition, and forming, with the organic substance, compounds insoluble and acquiring a rusty brownish black color under the action of light. Hence sticks of lunar caustic grow gray and black on the surface by keeping, by reaction with the organic dust of the atmosphere, and solutions of silver nitrate deposit a fine black sediment, and stain textile fabrics and skin. The stain on the skin, if recent, can be removed fairly well by rubbing with a moistened lump of potassium cyanide, and washing—always remembering the very irritant and poisonous character of such cyanide. But if the stain be old, and fixed by exposure to sunlight, the cyanide fails, and the following means may be resorted to: Moisten the stains, drop on them a little tincture of iodine, and then wash in a six-per-cent. solution of sodium hyposulphite. Or, very efficient, mix in a saucer a few bits of iodine with a little water of ammonia; rub the stains quickly with the resulting preparation, and immediately wash both skin and saucer while they are still wet. This latter precaution is necessary, since the compound of iodine and nitrogen produced by the mixture of chemicals spontaneously explodes upon slight agitation when dry. Other reactions of silver nitrate are its precipitation by sulphuric, hydrosulphuric, phosphoric, hydrochloric, and tartaric acids and their salts; by the alkalies and their carbonates, lime water and the vegetable astringents, and arsenical and albuminous solutions.

Silver nitrate is an irritant astringent, with also the peculiar specific effects of silver compounds already detailed, viz., the allaying of gastric irritability, and the induction of certain constitutional control over nervous disease. The local effects are the more important, and are as follows: The salt readily combines with albumin to make an insoluble compound, the albuminate of silver; hence, when in strong solution or in solid stick, its application to the surface of a mucous membrane or of granulation tissue produces a white streak of cauterization, which, by the insolubility of the compound formed, limits the action of the caustic to the production of such shallow slough. Concentrated applications to the skin speedily blacken the epidermis, and, more slowly, raise a blister. In solutions less than ten per cent. in strength the salt is hardly caustic, but acts only as an irritant astringent. When swallowed, quite small doses act locally like the oxide, while large produce irritant poisoning. Therapeutically, local applications of silver nitrate judiciously made have a marked tendency to promote absorption in such tissues as are capable of undergoing this process; to induce healing; to limit and abate the catarrhal process; to destroy skin parasites, though not very searchingly; and to neutralize the virulence of specifically noxious pus.

The medicinal uses of silver nitrate are such as may be deduced from the foregoing. Internally the medicine may be given, for constitutional or local effect, in doses of from 0.015 to 0.03 gm. (from about one-fourth to one-half grain) in pill or solution. In neither way of giving does the salt probably reach the stomach as nitrate; for, if in solution, a medicinal dose must almost certainly be decomposed in the swallowing, and, if in pill, be acted on similarly by the necessary organic matter of the excipient. To obviate this effect as far as possible in the case of pills, it is advised that bread-crumb be particularly avoided as an excipient, because of its containing a soluble chloride (common salt) as well as organic matter, and that some vegetable extract, or a dry powder made sticky by a minimum of gum, be selected. In any case the crystallized silver salt should alone be prescribed. Externally, silver nitrate may be used as a caustic, but only where a superficial effect is wanted, as for the destruction of the lining membrane of a cyst. The fused stick is in such cases used, its moistened surface being swept over the surface to be destroyed. More common is the application to promote absorption, as in case of exuberant granulation tissue or trachoma bodies; to determine healing, as in unhealthy ulcers, or to shorten and abate the course of a catarrh. For such purposes various strengths of the nitrate are used, from application of the pure or diluted sticks of lunar caustic to that of solutions of not more than the one-fifth of one per cent. strength. To determine absorption the stronger applications are necessary, to control catarrhs the weaker; but in all cases care should be taken not to overdo the matter, and, by too strong or too frequent application, actually to interfere through excess of irritation with healing or with resolution. In the case of catarrhs, moreover, the remedy should not be used at all until the second stage of the process is reached, as betokened by the establishment of the catarrhal secretion and abatement of the initial pain or sensitiveness. Then, too, the strength of the application should be adjusted to the different degrees of sensibility of the different mucous membranes; for while the comparatively insensitive membranes, such as those of the fauces or vagina, may take a five-per-cent. solution, or even stronger, hardly more than the one-tenth of this strength can be applied without undue irritation to the nasal passages or to the male urethra. When a very brief action is wanted, the application of silver may be followed immediately by one of a solution of common salt, which salt immediately precipitates all excess of nitrate as the insoluble, and therefore inert, compound, silver chloride.

Silver Cyanide: AgCN. This salt is official in the United States Pharmacopœia as *Argenti Cyanidum*, Silver Cyanide. This salt is an insoluble white powder, not used in medicine, and official only for the making, by the pharmacist, of diluted hydrocyanic acid.

Besides the foregoing, a number of unofficial preparations of silver deserve brief notice.

Silver Vitellin, Argyrol.—This remarkable compound has recently been prepared and proposed for medical use by Barnes and Hille, of Philadelphia (*Medical Record*, May 24th, 1902). A salt solution of vitelline, a derived proteid obtained from gliadin, is precipitated by silver nitrate. Such precipitate—silver vitelline—properly dried, appears as a dark-brown powder. The substance contains thirty per cent. of silver, about half the amount contained in silver nitrate, and is remarkable for being extremely soluble in water, while at the same time it does not precipitate albumin or sodium chloride, and is wholly unirritating. Its solution also penetrates albuminoid tissues very readily and thoroughly. Silver vitelline thus possesses all the desiderata for an ideal silver preparation, and has been used with great success as a local application in inflammations of the mucous membrane of the eye, ear, nose, vagina, urethra, and bladder. It is employed in aqueous solution ranging in strength from one-tenth of one per cent. to twenty-five per cent. and upward, according to the character and sensitiveness of the part. Even a ten-per-cent. solution applied as an injection in acute gonorrhœa produced no irritation (Christian).

Colloidal Silver (Soluble Silver, Collargol).—This is a bluish green substance obtained by precipitating with silver nitrate a mixed solution of ferrous sulphate and sodium citrate. Collargol contains 97.2 per cent. of silver, dissolves in 25 parts of water forming a dark reddish-brown solution, and is easily decomposed. Its aqueous solution, on standing, deposits a small sediment of insoluble silver.

Collargol, introduced into the general circulation, has been declared by Credé and others to exercise a remarkable curative power over the conditions of general septic infection, whether by action on the micro-organisms themselves or on their toxins is not clear. At the same time the remedy is non-poisonous and, being rapidly eliminated after absorption, does not produce argyria. The only untoward effect observed has been a slight chill and rise of temperature, but even this is not seen if (using by intravenous injection) care is taken that the solution be free from sediment.

Collargol may be administered by inunction or by intravenous injection. For the latter method a carefully prepared, freshly made solution in distilled water is to be used, of a strength of one-half to one per cent. If a sediment forms, the supernatant liquor must be decanted. Of such a solution from half a fluidrachm to five fluidrachms may be injected directly into some superficial vein once or twice daily, or every two or three days. The more common method of administration, however, is by inunction. For this purpose a fifteen-per-cent. ointment is used, of which the quantity of from thirty to forty-five grains is rubbed thoroughly into the skin of the inner side of the arms or thighs, or of the back, from one to three times daily. Collargol ointment decomposes readily and should not be exposed to the air. An ointment should not be used that shows white crystals on the surface, or that fails to color the skin black on inunction. An ointment having the official sanction of Professor Credé is on the market under the title "Unguentum Credé." This ointment contains fifteen per cent. of collargol in a mixture of lard, wax, and benzoic ether.

Silver Sulphocarbolate, $C_6H_4(OH)SO_3Ag$. This compound occurs as a white crystalline powder soluble in water. It contains twenty-eight per cent. of silver. If exposed to light and air it decomposes spontaneously. It has been proposed as a substitute for silver nitrate because non-corrosive.

Silver Citrate: Itrol, $Ag_3C_6H_5O_7$. This compound is a fine, dry powder, without taste or smell, very slightly soluble in water. Its solution is immediately decomposed by organic matter. Like silver vitelline, it is non-irritant and penetrating, and has been proposed as a surgical disinfectant and for injection in gonorrhœa and cystitis. The strength of solution ranges from 1 to 4,000 to 1 to 8,000.

Silver Lactate: Actol, $AgC_3H_5O_3$. This compound is a white powder, without taste or smell, and soluble in from fifteen to twenty parts of water. It is a powerful germicide, and penetrates tissues, although decomposed by contact with the same. It is used as a surgical antiseptic, and strong, even saturated solutions may be applied to infected parts. Ordinary strengths are 1 to 1,000 or 2,000 parts of water.

Silver Quinaseptolate or *Oxy-chinolin-sulphonate: Argentol,* $C_9H_5N.OHSO_3Ag$. This compound is a yellow powder, slightly soluble only in water. In contact with septic substances it decomposes into oxyquinolin and metallic silver. It is used in surgery as a dusting powder, or applied in ointment (1 or 2 parts to 100 of ointment) or in solution, 1 to 3 parts to 1,000 of water.

Argentamin.—This name is given to a solution of silver phosphate (10 parts) in a ten-per-cent. aqueous solution of the organic base ethylendiamin. It is a clear fluid, strongly alkaline, and is devised to give a non-poisonous and unirritating antiseptic solution which shall not precipitate albumin. It is diluted one thousandfold for use.

Argonin.—This name is given to a body obtained by precipitating with alcohol a mixed solution of silver nitrate and a sodium compound of casein. Argonin is a white powder, neutral in reaction; insoluble in cold water, but readily soluble in warm or albuminous water. Solutions must be kept away from exposure to light. It has been used in gonorrhœa in solutions of from 1 to 7 parts in 1,000 of water.

Largin.—This name is given to an albumin compound of silver occurring as a gray powder soluble in 9 parts of water. Largin is powerfully germicidal while non-irritating, and is not precipitated by albumin or sodium chloride. It has been used in gonorrhœa in solutions ranging in strength from one-fourth to one and a half per cent.

Protargol.—This name is given to a silver albumose containing eight per cent. of silver. It is a yellow powder, freely soluble in water; unaffected by heat, albumin, or sodium chloride in weak solution, and wholly unirritating. It may be used with great freedom as a local application, being employed in solutions varying in strength from five to twenty-five per cent.

Edward Curtis.

SILVER, POISONING BY.—See *Argyria.*

SIROLIN is a ten-per-cent. syrup of thiocol. (See *Thiocol.*) *W. A. B.*

SITKA HOT SPRINGS.—Location on Baronoff Island, Alaska, sixteen miles south of Sitka. They are reached from Sitka by boats only. Four houses have been built at this place, three with bath-rooms attached. In 1860 a hospital for rheumatism and skin and blood diseases was opened by the Russian-American Company. The baths were found to be very beneficial in syphilitic affections. The Indians have resorted to the springs for many years. They are about thirty feet above the sea-level, and distant from salt water about fifty yards. The springs are four in number, but the rate of water flow is unknown. The temperature of the water is 120° F., and it is said to contain sulphur, iron, manganese, and chlorine. The weather in this region is generally clear during the summer months, with a temperature ranging from 60° to 80° F. The spring and fall seasons are rainy, and the winters cold and cloudy, the temperature varying from zero or a little below to 40° F. The spring season is considered preferable for visiting the springs. Other hot springs are located on Chickagoff Island, about eighty miles from Sitka, but as yet no name has been given to them. Little is known concerning them, except that they have some reputation among the Indians in the same diseases as those mentioned above. Within half a mile of Sitka, on a road called Davis Avenue, there is an iron spring flowing from a rock. It has not been analyzed, but it was formerly esteemed by the Russians for its tonic properties.

James K. Crook.

SKAGG'S HOT SPRINGS.—Sonoma County, California.

Post-Office.—Skagg's Springs. Hotel and cottages.

Access.—From Tiburon Ferry, San Francisco, 7:40 A.M. and 3:30 P.M.; arrival at Geyserville, where connection is made with stage for springs at 11 A.M. and 7 P.M. Connections from Sacramento by Carquinez and Santa Rosa Railroad to Santa Rosa, thence viâ San Francisco and Northern Pacific Railroad to Geyserville.

Skagg's Hot Springs are pleasantly located in the Coast Range Mountains, in a picturesque spot, nine miles west of Geyserville and twenty miles east of the coast. The surrounding mountains are clothed with every variety of California verdure, and they abound with trout streams. Many varieties of game are also found, including bear, deer, grouse, and quail. We are informed that a new road from the springs to the coast has recently been constructed, making accessible the Gualalla River, a widely celebrated trout-fishing stream. The springs, four in number, yield fifteen gallons per minute, the water having a temperature of about 120° to 140° F., and a somewhat pungent, agreeably alkaline taste. Excellent bathing facilities have been provided. Analyses have been made by Prof. Eugene W. Hilgard and Dr. Winslow Anderson, which show no material difference in their results. That of Professor Hilgard is as follows:

One United States gallon contains (solids): Sodium chloride, gr. 5.90; sodium bicarbonate, gr. 161.27; sodium biborate, gr. 26.47; magnesium carbonate, gr. 11.11; calcium carbonate, gr. 2.20; silica, gr. 7.02; sodium iodide, potassium chloride, potassium sulphate, potassium iodide, magnesium sulphate, ferrous carbonate, barium carbonate, lithium carbonate, strontium carbonate, alumina, and organic matter, very small quantities. Total solids, 214.80 grains.

Free carbonic-acid gas, 124 cubic inches.

The waters here are very useful in rheumatism, neuralgia, sciatica, etc., as well as in affections involving the bladder and kidneys. They are highly recommended by medical men on the coast, and the proprietor has determined to keep the resort open all the year.

James K. Crook.

SKIN, ANATOMY OF.—See The Appendix.

SKIN, FUNCTIONS OF.—The functions of the skin may be conveniently classified as follows:

I. Protective; II. Excretory; III. Temperature regulating; IV. Absorptive; V. Sensory.

I. Protective Functions of the Skin.—As an outer covering of the body, the skin protects the deeper parts (*a*) from evaporation, (*b*) from excessive wear and tear, and (*c*) from mechanical violence. The outer layer of the skin (epidermis) has a structure like horn, and forms a shell over the entire body. The deeper layers of the skin and the subjacent tissues and organs are constantly bathed with lymph, which must be renewed from the blood, and if it were not for the horny covering of the epidermis the lymph would evaporate from the surface more rapidly than it could be renewed, and the nerve endings and other delicate structures in the deeper layers would be thrown out of function. The secretion of the sebaceous glands (oil glands), by keeping the epidermis slightly permeated with oil, is of material aid in preventing this evaporation. It is very important that some water should be evaporated from the surface of the skin, but this is provided for through the sweat glands, whose function will be considered in Sections II. and III.

The epidermis of the skin is obviously a great protection against wear and tear, which the softer parts, underneath, would not stand. It varies in thickness in different parts of the body, being thickest in those parts which are most used in such a manner as to wear them away; for example, the palms of the hands and the soles of the feet. In some places it is reinforced by nails and by hair, which are in structure simply modified epidermis. As the outer layer of epidermis is worn off it is replaced from the deeper layers.

Lying immediately under the epidermis comes the dermis (cutis vera, true skin), and beneath this is the subcutaneous connective tissue (superficial fascia). In this connective tissue there is a large amount of fat in an ordinarily well-nourished individual. This fat, in proper quantity, not only covers the angularity of muscles and joints, thus giving beauty to the figure, but it forms a protective pad, which breaks the force of blows, prevents the penetration of foreign bodies (as in puncture wounds and cuts) to important deeper lying structures (arteries, nerves, etc.), and otherwise adds to the protective function of the skin. As a protection against mechanical violence the hair often plays an important part, as on the scalp.

II. The Skin as an Excretory Organ.—The chief excretions of the skin are the sebum (oil) and the sweat. In many of the lower animals the skin is an important respiratory organ—a frog will live for days with his respiratory centre destroyed—and this function is not entirely lost in man. It is certain that some carbon dioxide is given off by the skin of man, and it is probable that a very slight amount of oxygen may be taken in, but in either case the amount is so small that for practical purposes it may be disregarded.

The sebum (oil) is secreted by the sebaceous glands, which are found all over the skin with the exception of the palms of the hands and the soles of the feet. Where hairs occur the sebaceous glands commonly empty into the hair follicles. One of the chief functions of the sebum is to keep both the hair and the skin from becoming harsh and brittle.

The sweat glands are the most important excretory organs of the skin, but it is a common error to suppose that *in health* they play a *prominent part* in the elimination of waste products, such as urea and allied substances. Chemical analysis shows that the sweat contains about 98.8 parts of water and 1.2 parts of solids. Of these solids common salt (sodium chloride) is the most abundant—the salty taste of sweat is probably known to every one. By weight there are only 8 parts of urea to 10,000 of sweat, and sometimes it is present merely in traces, while the amount of urea in urine is about two per cent. In disease, however, this relation is greatly altered, and when the kidneys refuse to secrete nitrogenous waste products, the sweat glands take up this function to a large extent, so that they form the great safety valve against what is commonly called uræmic poisoning. By far the most important function of the sweat is to furnish the surface of the skin with water, which, by its evaporation, produces a loss of heat from the surface of the body. This will be more fully taken up under the temperature-regulating functions of the skin. The quantity of sweat varies greatly. It depends upon the temperature of the surrounding air, muscular activity, the amount of liquid drunk, the activity of the kidneys, etc.

The secretion of sweat is intimately under the control of the nervous system. The effect of certain mental states (such as fear) upon sweating is proverbial. There is a definite set of secretory nerves to the sweat glands. The course of these fibres has been fairly well mapped out. The best experimental evidence is also in favor of the view that there are sweat centres in the spinal cord, and that these are all dominated by a chief sweat centre in the medulla oblongata. This arrangement helps us to understand the localized sweating in certain nervous diseases; and the moist skin, in the crisis of fevers, can best be interpreted as a return of the centres to normal action after a temporary suspension of activity.

When the skin of an animal is varnished, the animal in most instances dies. A case is on record in which a boy was covered with gold foil in order to represent an angel at a religious ceremony, and lost his life as the result of such coating. These cases are often quoted as showing the baneful effects of retention of the perspiration with the poisonous waste products which it was supposed to contain. This explanation, however, is erroneous. In numerous animals, experimented upon by varnishing, it was found that the body temperature falls with great rapidity, that they may be kept alive for a long time by artificial warmth, and that there is no such accumulation of poisons in the blood as would be called for by the old theory. The cause of death is the excessive and rapid loss of heat from the skin.

III. Temperature-Regulating Function of the Skin.—This is certainly one of the most important functions which the skin has to perform. The temperature of the body depends upon two factors, viz., the heat produced in the body, and the heat lost from the body; or, as they are generally called, heat production and heat dissipation. Each of these is controlled by the nervous system, and each may vary independently of the other. The constant temperature of warm-blooded animals depends upon a constant balance between these factors. For a fuller discussion of this question, see article *Calorimetry*, this Handbook, Vol. II., especially pp. 567–570.

The skin is the chief seat of heat dissipation. This is regulated by the nervous system in two ways, viz., through the blood supply to the skin, and by perspiration. When heat dissipation is to be increased, the vaso-motor centre, acting through the vaso-dilator nerves to the blood-vessels of the skin, causes these vessels to dilate, and thus to receive an extra supply of blood. The skin becomes flushed and warm, and a large amount of heat is radiated off. On the other hand, when heat dissipation is to be reduced the vaso-motor centre acts through the vaso-constrictor nerves to the vessels of the skin, causing their calibre to diminish. The blood is driven from the skin to the deeper parts of the body; the skin becomes pale, or blue, and cold and the radiation of heat from the surface is consequently diminished.

The vaso-motor centre responds readily to impulses reaching it through afferent nerves and is also probably capable of being stimulated by changes in the temperature of the blood itself, so that it forms a self-regulating machine for controlling heat dissipation, and is probably the most delicate mechanism involved in maintaining the temperature of the body constant. For a more detailed discussion of vaso-motor nerves, containing much that has a direct bearing on vaso-motors to the skin, the reader is referred to the article *Circulation of the Blood*, this Handbook, Vol. III., especially pp. 115–118.

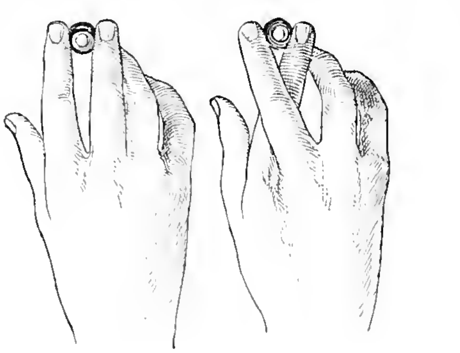
As an important adjuvant to vaso-motor changes in the skin, and their influence on body temperature, we have the sweat glands. These are directly under the control of the nervous system, and are commonly called into activity at the same time that the vessels of the skin are dilated. This relation is so pronounced that for a time it was contended that the blood supply was the cause of their secretion. The question was settled, however, by the simple experiment of stimulating the sciatic nerve in an amputated leg (cat), and observing that drops of sweat appeared on the balls of the feet; though, of course, the blood pressure was *nil*, thus proving that true secretory nerve fibres to the sweat glands exist. The sweat centres are therefore important regulators of the body temperature.

The sweat glands are always in a state of greater or less activity. Most of the time the sweat evaporates as soon as it reaches the surface, and is not perceived by us. This is commonly called insensible perspiration. The amount thus evaporated from the entire surface of the body in twenty-four hours may be considerable. Some have estimated it as high as two litres, though this is probably excessive. Half that amount would be a fairer average. When much heat is produced in the body, as during muscular work, or when the air about us is hot, the quantity secreted may be several times as great. In this case the amount of heat lost through the warm sweat which rolls off the body is considerable, but the main loss of heat is always by evaporation. In the dry hot skin of certain fevers, the trouble is probably in the nervous system (involving the sweat centres), and the lack of sweat and evaporation helps materially to keep up the fever temperature (see article *Calorimetry*, § 6).

IV. Absorptive Function of the Skin.—Under ordinary circumstances the skin absorbs practically nothing, so that from a physiological standpoint it might be disregarded; from a practical standpoint in clinical medicine its absorptive powers are of great importance, especially as a channel for the administration of drugs. It is commonly stated that medicines injected hypodermically will produce their effects four or five times more rapidly than when given by the mouth, when the skin and the stomach each exhibit their normal powers of absorption; but far more important than this is the *certainty* of absorption by the hypodermic method. The stomach is very treacherous as an absorptive organ. In many cases its absorptive function seems to be suspended for hours, and is then suddenly resumed with full vigor; repeated doses of strong medicines fail to produce any effect, and then without warning the patient exhibits symptoms of an overdose, amounting even to poisoning. When given by the hypodermic method the medicine is thrown into the subcutaneous tissue where the absorption takes place by the blood capillaries. When the skin is used for the absorption of drugs by inunction, the material to be absorbed is finely divided and rubbed up with some fat. The fat penetrates the skin and carries the drug with it. The old method of blistering the skin to raise the epidermis, and applying the drug to the raw surface for more ready absorption, has now been replaced by the hypodermic method.

V. Sensory Functions of the Skin.—A superficial view of the sensory functions of the skin would make them appear to be manifold and complex, though a more careful study will reduce them to compounds of several simpler senses. In order to understand this a certain knowledge of the central nervous system is absolutely necessary. In attempting to get at them from a skin standpoint merely, we should be very much in the position of one who would try to study the electrical call apparatuses of a great city, and who would consider only the fire-alarm boxes, the police-patrol boxes, the telephones, etc., without going into the engine houses, the police stations, and the telephone central offices to see how the calls were received and how they were treated there. It is, therefore, necessary to remember that the nerves from the skin communicate with centres in the nervous system, just as the wires referred to above run to definite offices. These centres are in communication with each other, and the effect of a nervous message from the skin may be simple or complex according to the centres which are called into activity. Again, it must be remembered that what we call a "sensation" is a function of the brain centres and not of the skin which contains the call-box or sending organ. Properly speaking, there is no sensation in the skin; it is entirely in the brain. The brain centres *interpret* the receipt of a message from the skin in accordance with their *experience*, and they act accordingly. This often gives rise to sensory illusions, as is illustrated by Aristotle's experiment. If a small round pebble be held, as shown in Fig. 4299, position A, we feel only one pebble; but in position B, while we know from sight that we have only one pebble, we "feel" two. This is especially marked if we rotate the pebble. The explanation is that we have never, as the result of experience, had a small round surface touch the thumb side of the index finger and the outer side of the middle finger at the same time, unless there were two small round bodies to furnish the touching surfaces, so we *interpret the message* received by the brain in accordance with the *past experience* of the *receptive centres*. After the amputation of a limb the patient often has sensations of pain, of heat or cold, of tingling, of numbness, etc., "in the amputated member." This is due to irritation of the nerve in the stump. A certain message reaching a certain centre has always meant a certain condition in the part where that nerve formerly ended, and he continues to interpret the receipt of such a message as he had always done before.

The compound character of the sensations referred to the skin may be illustrated by the following example: If we touch a knife-blade to our finger, we may feel simply a gentle touch or pressure, or we may perceive that it is cold or hot, or that it is rough or smooth. If we draw it along, we perceive the sense of motion and



A *B*

FIG. 4299. Aristotle's Experiment.

notice whether it is sharp or dull. If it cuts we have the added feeling of pain. Touch (including pressure), heat, and cold, are generally regarded as simple special senses, because they obey laws which hold good for other special senses, have definite areas on the skin which, when stimulated, produce a definite sensation, and probably have definite nerve fibres and end organs which belong to them exclusively, and more or less definite cerebral centres which receive the impulses over these fibres.

A *B* *C*

FIG. 4300.—Chart of Portions of Palm of Left Hand, showing the Distribution of Sense Spots for Touch, for Heat, and for Cold. In *A* the black spots mark the areas on which touch can *not* be perceived. In *B* are shown the areas which may be stimulated by heat. The degree of sensitivity is marked by the shading; the black areas are most sensitive, the line-shaded next, the dotted next, and the blank areas cannot be stimulated by heat at all. In *C*, the same thing is shown for cold as is shown in *B* for heat. (After Goldscheider; from Sherrington, in "Schäfer's Physiology.")

All of this, however, cannot be regarded as definitely proved at present.

Pain is usually classified with what are called common sensations, because it does not obey all the laws of the special senses, its skin areas are not as sharply localized as those of touch and temperature, and its possession of exclusive nerves and end organs is more doubtful, though continued researches are tending to lessen this distinction rather than to accentuate it. In accordance with the above we will, therefore, classify the cutaneous sensations as follows:

Special sensations	Touch (including pressure). Heat. Cold.
General sensations	Pain. Muscle sense, etc.

SPECIAL CUTANEOUS SENSATIONS.—*Touch (Including Pressure), Heat, and Cold.*—If the skin be tested by appropriate experiments, it may be mapped out into areas which are connected with one kind of sensation but not with another. For example, if we touch one point of the skin with a small warm body, like a blunt needle, we shall feel the sensation of touch, but not of heat, while on an adjacent area we shall feel the heat, but not the touch. In the immediate vicinity another area might be found where the warm needle would give rise to no sensation, but where a cold needle would "feel cold," and still produce no sensation of touch. Touching either of these latter areas with a needle having the same temperature as the skin would elicit no sensation whatever. Again, areas might be found which did not call forth any sensation of touch or temperature, but whose stimulation would produce pain. These various areas are called "sense spots," and are designated as "touch spots," "hot spots," "cold spots," and "pain spots," respectively. They nearly always overlap, so that we commonly find the same area of the skin capable of awakening at least two or three of the four sensations mentioned. This is well shown in Fig. 4300, which is Goldscheider's chart for the distribution of the spots for touch, for heat, and for cold, in part of the palm of the left hand. By superimposing *A*, *B*, and *C*, it is readily noticed that most of the area is connected with all three sensations, but the parts marked by black spots in *A* would be devoid of the sensation of touch.

The touch spots are not evenly distributed over the surface of the body. In some parts they lie very close together, and practically cover nearly all of the area in question, as is shown in Fig. 4300, *A*, the whole white area being covered by them; on the finger tips they would be even closer. In other parts, such as the skin of the back and certain areas on the arm and on the thigh, the touch spots may be separated from each other by oval areas measuring about 10 cm. (4 in.) along the major axis, and about 6.5 cm. (2½ in.) along the minor axis. As a rule the touch spots bear a close relation to the hairs on the skin. Where these exist, the touch spots radiate from the point at which the hair comes to the surface, and are grouped most thickly on the side away from that to which the hair slopes. On hairless parts of the body they are also grouped around central points. The hairs are important factors in exciting the end-organs which are connected with the sensory nerves. They act as levers, and thus magnify the stimulus. Their sensory functions in some of the lower animals is very marked, as in the case of the whiskers of a cat.

The nerve endings for touch are stimulated by unequal stress on the ridges of the skin. If we plunge our finger into mercury which has the same temperature as the finger, we do not feel the mercury on the submerged part, though it is under considerable pressure. We only feel it at the surface, and if we move the finger up and down, the sensation is like slipping a ring on and off. This is because the liquid fills the crevices between the ridges of the skin, and makes equal stress in all directions.

The smallest observable pressure varies with the different parts of the skin, due largely to the structure, and hence the greater or less pressure it takes to deform the ridges. Touch is the most delicate of the skin senses—a pressure of less than 1 mgm. (about gr. $\frac{1}{70}$) may be perceived. With delicate stimuli a push (pressure) or a pull (traction) produces the same sense of touch, and to the same degree (von Frey). Tactile and pressure sensations obey the Weber-Fechner law, that is, the intensity of the sensation varies (approximately) as the logarithm of the strength of the stimulus. Nerve endings are necessary for the true perception of touch. If the exposed nerve be touched, pain is the only sensation perceived. A stimulus too weak to excite the exposed nerve is sufficient to excite the tactile end-organ in the skin.

Our ability to *locate* the point touched varies greatly on different parts of the body. This sense of locality is often called the "local sign" (Lotze, Wundt). Two compass points 65 mm. (2½ in.) apart, if touched simultaneously to the skin of the back, would be felt as one point. On the tip of the finger they would be recognized as two points when 2.2 mm. ($\frac{1}{12}$ in.) apart, and on the tip of the tongue at half this distance. In using the æsthesiometer to test impaired cutaneous sensibility in nervous diseases, we commonly employ this method.

The question as to whether specific nerve endings exist for the various cutaneous sensations is an old one. It existed before our present knowledge of mapping the skin was thought of, but with that knowledge it assumed a greater importance than before. After mapping out the areas on portions of their own skin, some observers (Blix, Donaldson) had these pieces of skin cut out to see what nerve endings correspond to the respective areas, and many investigations have been made on human skin from the cadaver, to determine the kind of end-organs which are distributed more or less in the same way as the various sense spots. The result of all this work has been to throw considerable light on the subject, but it would be premature at present to say that any definite end organ had been identified beyond doubt as the specific and exclusive nerve ending for a given cutaneous sense. According to von Frey (quoted by Bowditch): "The free nerve endings are sense organs for pain, the end bulbs for cold, the terminal coils or networks for heat, and the tactile corpuscles for pressure sensations."

The evidence from clinical study and from pathological lesions is clearly in favor of the assumption that there are specific nerves for the different cutaneous sensations, and that these have pathways in the spinal cord and centres in the brain, which are not identical. Cases are recorded (especially of lesions of the cord) in which one or two of the cutaneous senses was lost while the others remained. There seems to be a tendency for touch and cold, and for heat and pain to be retained or lost together, though this is disputed. In the brain the fibres, which are concerned with cutaneous sensations, are found to run to the optic thalamus, the corpora quadrigemina, and parts of the cortex. The cortical centres are not sharply localized, but are probably much scattered. They are supposed to be located principally in the limbic lobe (especially the gyrus fornicatus) and among the motor areas in the Rolandic region.

General Cutaneous Sensations.—*Pain, Muscle Sense, etc.*—By muscle sense we mean the sense of weight or tension which we feel on lifting a weight. Muscular fatigue is also, probably, a modification of this sense. Muscle sense is generally considered with the general senses like pain, sexual sensations, etc.; the paths of its nerves and its cerebral centres are closely allied to those for the cutaneous senses of neighboring regions. These general senses are distinguished from the special ones by the lack of sense of locality (local sign). This is especially marked for pain. The pain may be referred to a spot widely remote from the point of irritation. Again we may interpret as pain something which apparently has to do with a totally different sense, as headache from eye strain. Pain was formerly thought to be due to excessive stimulation of any special sense, but stimulation of the optic nerve gives no pain, and touch spots are found where a pin may be thrust in without producing any sensation but that of pressure. On the other hand, there are pain spots where a pin causes pain, but no sense of touch. In spinal diseases pain may be lost, and yet touch and temperature sense (especially cold) remain. In some cases pain may be inhibited at will, probably by suggestion (hypnotism). This, of course, involves the receptive centres rather than the nerve endings in the skin.

In discussing the relation of stimuli on the surface of the skin to the various nerve endings, Sherrington gives the following apt figurative illustration:

"The surface of the skin is found to be a mosaic of tiny sensorial areas. . . . The individual fields may be reduced to mere 'spots.' Each of these 'spots' is found to subserve a specific sense—touch, cold, warmth, or cutaneous pain. Each doubtless coincides with the site of some sensorial 'end-organ' or with a tiny cluster of such. Rather, indeed, than to a mosaic may the skin be likened to a sheet of water wherein grow water plants, some sunken and some floating. An object thrown upon the surface moves the foliage commensurately with the violence of its impact, its dimensions, and with their propinquity to its place of incidence. Where the foliage grows densely, not a pebble striking the surface but will meet some leaf; and beyond that or those directly struck, a number will be indirectly disturbed before the equilibrium of the surface is re-established."

George T. Kemp.

SKIN-GRAFTING.—Since the appearance of the last edition of this work no noteworthy advance has been made in the subject of skin-grafting. The method devised by Thiersch has in this interval come into much more general use, not because it has been improved upon, but simply because with the lapse of years its transcendent merits have received a wider recognition. There is still room for improving the technique in the direction of taking grafts of larger size and more expeditiously. Some mechanical devices with these ends in view have appeared, but they are as yet so inadequate as not to deserve special mention. The chief value of the Thiersch method of skin-grafting lies in the fact that it prevents the deformities that would result from the natural healing of the wound by granulation and the subsequent contraction of the scar. A second advantage, in some cases one of extreme importance, lies in the fact that even very large surfaces may be healed promptly.

The grafts consist of shavings of the superficial portions of the skin removed by a razor, and are applied so as completely to cover a wound surface which is free from granulations and presents only normal tissues. A special dressing is applied. The grafts adhere, and by the end of two days they are receiving blood from their new site. The formation of granulation tissue ceases, the wound is healed, and no contraction takes place. A soft, pliable integument is provided, of good vitality and well able to withstand the wear and tear to which a cutaneous surface is exposed. In removing the grafts, the razor does not cut deep enough to include the hair bulbs. No hair will grow from the grafts. Grafts from a hairy thigh may be planted upon the face or hands without fear of transplanting hairs.

This form of skin-grafting has a very wide sphere of usefulness. Where there is extensive loss of skin in the vicinity of a joint, as may follow a burn or other injury, it will entirely prevent cicatricial limitation of motion. Similarly, where the healing of a wound by granulation would result in a distortion of soft parts, it will prevent the deformity. Large areas of malignant disease may be freely removed and rapid healing secured. Thus, extensive areas of tuberculous skin may be dissected off, leaving a healthy wound surface, and the defect covered at once by grafts. Cancerous breasts may be radically removed, regardless of flaps, and the large raw surface, consisting of fat, muscle, and periosteum or bare bone, all covered by a good integument. A thick graft contains a sufficient supply of anastomotic vessels to allow the graft to bridge over a slight interval, independently of nutrition from beneath. For example, after a burn involving the outer half of the little finger, causing superficial necrosis of the bones and opening the first joint, the author applied rather a thick graft so as to bridge over the interval from bone to bone and close the joint. The graft retained its vitality perfectly, and the joint is neatly closed and capable of a little motion. Congenital deformities which could be relieved by making an incision, drawing the edges of the skin apart and covering the wound surface with integument, can be remedied by this method. In cases in which scar contraction has already caused deformity, the scar tissue should be freely and completely excised, the parts brought into their natural position, retained by splints if necessary, and then the wound covered by grafts. If the faulty position has not caused grave damage to the deeper structures, deformity can be relieved and lost function restored. In short, Thiersch's method of skin-grafting finds application wherever it is desired to interpolate an area of soft and healthy integument and normal tissues can be provided for its reception.

Certain details of the operation are of the first importance. The excellence of the results obtained and the extent of surface that can be covered in a given space of time depend much on the skill and experience of the operator, but the operation is not a difficult one, and no surgeon should hesitate to undertake it.

The following is a condensed description of the technique which the author has chiefly used:

As was said above, the surface to be grafted should be one of normal tissues. An operative wound usually needs no preparation for the reception of the grafts. A granulating surface may be washed every other day with soapsuds and with sublimate solution and dressed with iodoform gauze saturated with balsam of Peru, until it presents a smooth, firm, and red surface. Preparatory to operation it may be dressed with sublimate gauze. If the patient has syphilis, it is well to give iodide of potassium or mercury for a week or two before operating; otherwise the grafts are liable to perish.

If there is freedom of choice as to the place from which the grafts shall be taken, the thigh should be chosen. The day before operation it should be shaved, scrubbed with soapsuds and with 1-to-1,000 sublimate solution, and wrapped in sublimate gauze. Shortly before operation it should be washed again with sublimate solution. Time will be saved at the operation if two sublimate towels are applied as follows: Let the lower edge of one come below the knee, wrap it round the limb, and secure its lower border by a sublimate gauze bandage round the knee; let the upper edge of the other towel encircle the thigh as high as possible and secure it similarly by a bandage. When the second towel is turned up and the first down, the thigh is at once exposed and is neatly bordered by sublimate towels. Wrap the thigh in wet sublimate gauze, and secure the towels over it.

Select a razor ground flat on one side. It is well to be provided with two. The edge must be very keen. For scraping away granulations, any instrument with a blunt edge will serve. Cicatrized borders can be removed by the Volkmann scoop or the knife. A probe aids the fingers in nice adjustments of the grafts. A pair of rough bathing mittens are a help to the assistant in getting a proper grip upon the skin. The mittens should be boiled or baked before using. The razors may be soaked in five-per-cent. carbolic solution for fifteen minutes and dipped in salt solution before being used.

During the operation the only solution to be used is one of sodium chloride of the strength of 6 parts to 1,000 of water. This is the so-called "physiological salt solution" and does a minimum of damage to the grafts. A large tin-pail of this solution should be boiled for an hour, and then kept at blood heat by being set in a vessel of larger size and surrounded by water which is kept lukewarm. At the operation four sterilized bowls should be filled with this solution, one for the hands, one for sponges, one for gutta-percha strips, and one to receive the grafts as they are cut.

Prepare strips of gutta-percha tissue three-quarters of an inch wide, and long enough to reach across the wound and lap over on each side. These should be washed with soap and water and with sublimate solution and placed in salt solution before being used. Sublimate gauze and sublimate gauze bandages should be wrung from salt solution to serve as the inner dressing. Sponges should be taken from carbolic solution and wrung out in salt solution for use.

Much depends on the position of the patient on the operating table. Build up the table by pillows placed beneath the body and head, and a smaller prop under the foot, so as to elevate the patient half a foot above the table, and allow the thigh to form a bridge, and thus be readily got at from all sides. If the surface to be grafted is on an extremity, it should be suspended vertically, in order to check hemorrhage and to permit of free handling without altering the position of the limb.

Unless the operation is a very trifling one, and in a patient of especially good endurance, ether or chloroform should be given.

This operation is performed not with antiseptic, but with aseptic, precautions. The field of operation must be sacredly guarded from the ingress of germs. The hands must be scrupulously disinfected with soap and water and with sublimate solution, and the operative field surrounded by bichloride towels. The first step of the operation is to remove any abnormal tissues. Granulations may be scraped away and cicatrized borders cut away or removed by the Volkmann scoop. Then wash with salt solution and apply at once a compress of gauze. Bind it on, or have an assistant maintain the pressure. Next throw back the towels from the thigh, take off the gauze, let an assistant grasp the skin with both hands and draw it tense transversely. Place the thumb of the left hand on the tense skin at one end of the thigh, to make a little longitudinal tension, and apply the razor to the skin at a moderate angle. Make a short sawing motion, and at the same time increase the angle at which the razor meets the skin until the edge bites into the skin and begins to raise its upper portion. This angle is then maintained, and with the continuance of the short sawing motion a graft is cut whose length is limited only by the length of the thigh. The tough corium is of great assistance in preventing the razor from cutting too deep. In width the grafts will vary from half an inch to two inches, according to the locality from which they are taken and the skill of the operator and his assistant. Very wide grafts may be got from the comparatively flat surface over Scarpa's triangle. As fast as cut, the grafts should be dropped into a bowl of salt solution.

The manner of cutting the grafts is illustrated in Fig. 4301.

In about ten minutes oozing will have ceased, the compress may be removed, and the grafts applied. It will be found that they have curled, with the cut surface inside. To uncurl them, place one end on the surface to be grafted, uncurl it, and keep it uncurled by pressure with a finger of the left hand. The whole graft may now be uncurled by making a rapid to-and-fro motion with a finger of the right hand, and carrying it along the entire length of the graft. The graft is now flat upon the surface and can be moved about with the fingers or probe. The grafts should be made to meet or overlap each other, and also the surrounding skin. Overlapping does no harm, for the superficial edge of a graft will die from lack of nutrition and come away, leaving a mere line of union visible. If not enough grafts have been cut, more should now be cut and applied directly. When the whole surface has been covered, douche it gently with salt solution, and apply the gutta-percha strips in the following manner: Lay one end upon the sound skin at one side of the wound and secure it by a thumb, then, with a winding motion, lay the strip across the wound and out upon the sound skin beyond. In this way the strip is laid on without in any way disturbing the grafts. Let the next strip slightly overlap the first. Continue imbricating each upon the last till the whole surface is covered by the tissue. If the surface is on an extremity, take a wet gauze bandage and apply a snug spiral to hold the tissue and grafts firmly in place. Next apply damp salt gauze, a sheet of gutta-percha tissue to maintain the moisture, sublimate gauze, cotton, a bandage, and a splint suitable to the region. The surface from which the grafts have been taken may be covered with gutta-percha tissue and moist gauze. This is a particularly comfortable dressing, but any simple dressing will answer.

Fig. 4301. Taking the Grafts.

It is advisable to change the dressings every two days for the first eight days. At the end of six days the gauze had best be allowed to dry, by omitting from the dressings the sheet of gutta-percha tissue. This will obviate too great maceration of the horny layer of the grafts, and fit them sooner to withstand the wear and tear of exposure. At the end of ten days the gutta-percha strips are no longer needed. If there are any spots of granulation from faulty adjustments of the grafts, they had best be covered with yellow adhesive plaster. If the surface is uniformly covered with grafts, it needs only to be protected for a few days by a piece of cloth spread with lanolin or vaseline.

To illustrate the value of Thiersch skin-grafting, the citation of a single case in which it was particularly called for and achieved its fullest function will suffice.

In August, 1889, C. A——, a girl, aged twelve, met with an injury by which a very large skin flap was torn from about the right knee. It involved the inner side of the thigh, knee, and leg, and extended outward beyond the ligamentum patellæ and crest of the tibia. In the following November I grafted the surface. Her general condition was poor, and I did not think it wise to continue anæsthesia long enough to cover the large area completely; a portion was only partially covered with grafts, and intervening spaces about half an inch wide were left to cicatrize. In four weeks healing was firm. The limb had been in splints for more than a third of a year, and, when they were left off, there was scarcely any motion at the knee. A cylinder of cloth, stiffened by a covering of oiled muslin, was spread with vaseline and suspended about the limb for a few weeks to guard it from harm. Exercise of the limb was encouraged, and occasionally moderate force was used to aid flexion. In March, 1890, the knee came to a right angle, and she was able to go upstairs one foot after the other. Freedom of motion became progressively greater until it was as perfect in the right knee as in the left, and the limb as useful as before the injury. The accompanying figure (4302) is from a photograph of the case taken in May, 1892, and shows how the grafted area offers no hindrance whatever to complete flexion.

Theodore Dunham.

Fig. 4302.—Shows the Condition of the Knee (in Case C. A.) in May, 1892.

SKIN, TUBERCULOSIS OF THE.—The discovery of the tubercle bacillus by Koch has had two effects on modern dermatology. One is the formation of a new group of dermatoses in which actual proof of the existence of the organism has been furnished according to the laws of general pathology, and the other is the attempt at reconstruction in the disturbed pre-existing dermatological classifications. This second effect has in turn caused another group of diseases to appear which in contradistinction to the true tuberculoses of the skin have been called toxituberculids. The group is a large one and includes lichen scrofulosorum, erythema induratum, lupus erythematosus, lupus pernio, and certain rare dermatoses. Although it is not unlikely that future investigations may yet place some of the toxituberculids in the list of cutaneous tuberculosis, they should not at the present time be so regarded.

As in tuberculosis situated in other parts of the body, three methods are known by which a lesion may be recognized as tuberculous. (1) The recognition of the tuberculous granuloma which consists of new-formed connective tissue and giant cells, and which is sufficiently characteristic for diagnostic purposes. (2) The actual presence of the bacilli. (3) The test by inoculations of guinea-pigs with the suspected tissue. Briefly speaking, all the cutaneous diseases which have up to the present time been identified by either of the last two methods as tuberculous have all contained the tuberculous granuloma, and those diseases which have from time to time been regarded as of possible tuberculous nature on clinical grounds, and which have not contained the specific granuloma, have failed to give positive bacteriological results in the end.

While there are a few other rare affections which might be added, roughly speaking, true cutaneous tuberculosis may be classified under five heads:

(1) Tuberculosis verrucosus cutis.
(2) Tuberculosis cutis orificialis.
(3) Tuberculosis disseminata.
(4) Lupus vulgaris.
(5) Scrofuloderma.

I. Tuberculosis Verrucosus Cutis. — (Synonyms: Verruca necrogenica; Lupus verrucosus; Lupus scléreux [Vidal]).

This type of cutaneous tuberculosis was first well described in 1886 by Riehl and Paltauf. These authors gave a description of the histology of the lesions and identified the bacillus in cases inoculated from diseased animals. They also showed the similarity of their cases with anatomical wart, and since the publication of their paper the two affections have been classified together.

Verruca necrogenica, or anatomical wart, consists in a lesion due to the handling of dead bodies, and is due to direct inoculation from this source. Its favorite site is on the back of the knuckles, and consists of the occurrence of pea-sized warts, which are extremely chronic in their course. They are apt to be fissured and pigmented, and at times become crusted from superficial infection and pustulation. The typical lesion of tuberculosis verrucosus cutis has slight clinical differences. Its favorite site is the back of the hand and forearm. The lesions start as small ovoid warty patches which extend peripherally at an extremely slow rate until they involve considerable areas of the skin. Associated with the warty development are often papules of a dark purple color and more or less hyperæmia of the skin. The surface is apt to be moist and crusted, and pus can usually be expressed from between the warty excrescences. The central portion may undergo involution into the scar-like atrophic skin seen in an old lupus case. True ulceration does not occur, but involvement of the lymph glands draining the area is not infrequent. As rare sequelæ may be mentioned infection of the lymph channels with the formation of tuberculous nodules which break down and form ulcers, and the extension of the disease to the lungs.

Etiology.—The known sources of infection are the sputum of phthisical subjects and infected meats. As regards the first, mention may be made of children who in creeping around the floors of hospital wards have become infected on the front of the knees, direct infection during ritual circumcision, and cases of auto-infection in phthisical subjects. Infection from meats occurs in cooks, butchers, handlers of hides, and in those who have charge of tuberculous cattle.

Pathology.—In these lesions the tubercle bacilli exist in larger number than in lupus vulgaris, but they are less numerous than in tuberculosis cutis miliaris. They cause less reactive connective-tissue growth than in lupus vulgaris, and the corium is not completely filled with the granulomatous development. The papillæ above the infiltration are enormously hypertrophied in height, and if seen without the underlying tuberculous corium they cannot be distinguished from many other warty growths. In this type the tuberculosis appears as a linear infiltration quite unlike the nodular appearance of lupus vulgaris, but both giant cells and cheesy degeneration are always present. In cases that have been infected from without, small abscesses and cocci can be noted in the superficial portion of the section, but they have no pathological value.

Diagnosis.—Small anatomical warts may at times be distinguished with difficulty from simple warts, especially if the history of the patients does not show the mode of origin. In such cases excision of a piece for diagnostic purpose is justifiable, and will clear up the diagnosis. The larger types of verrucous tuberculosis somewhat resemble patches of chronic eczema, but they can usually be differentiated by the fact that eczema is harder and less friable, instruments do not easily penetrate the lesion, and there is never any tendency to the formation of scar tissue in eczema.

Treatment.—The indications for treatment do not differ from that of other forms of tuberculosis of the skin. The overlying hypertrophic tissue should be removed by instruments and the tuberculous tissue thoroughly scraped away with the curette or destroyed by caustic applications. Strong salicylic-acid plasters repeatedly applied have been recommended for the removal of the excessive epithelial growth. These in turn have to be followed by some caustic, as acid nitrate of mercury. This method is especially valuable in lesions of large area in which it is desirable to treat small portions at a time, but it has the disadvantage of being painful.

II. Tuberculosis Cutis Orificialis. — (Synonyms: Tuberculosis cutis vera; Miliary tuberculosis of the skin; Tuberculosis ulcerosa.)

This form of cutaneous tuberculosis is due to the secondary involvement of the skin either by contiguous extension from tuberculosis of the mucous membranes or by an infection from a contaminated discharge of a remote tuberculosis of the viscera.

In the beginning the lesions consist in a number of miliary tubercles. These rapidly coalesce and break down, the resulting ulcer forming the typical lesion of the disease. The main characteristics of the ulcer are the same as those of tuberculous ulcers situated on the mucous membrane. The floor is made up of indolent reddish-yellow tuberculous tissue in which the single miliary tubercles are apparent, if they are not covered up by a superimposed development of granulation tissue, and the edges are, as a rule, rather irregular in contour. The compactness of the tuberculous tissue and the superficial nature of the ulceration allow of only a thin purulent discharge, which may or may not result in the formation of a crust. Generally there is little pain. The course is slow, although more rapid than that of lupus vulgaris. Although cases have been reported to have healed by cicatrization, nearly all the ulcers show no tendency to improve, but gradually spread by peripheral extension.

The regions commonly affected are those of the mouth, anus, and genitalia. Kaposi has reported twenty-two cases, and has added much to the accepted knowledge of the disease. He states that the condition is not of extreme rarity, nor is it confined to advanced stages of tuberculosis of the lungs or other viscera.

Treatment.—Treatment consists usually in palliative methods, as dusting with iodoform or applying antiseptic solutions, but little hope can be entertained of a cure of the lesions without destructive interference with the base of the ulcers.

III. Tuberculosis Disseminata.—In this class are included the rare examples of tuberculosis which show a general cutaneous distribution. Very few cases have been reported, but they are in sufficient numbers to demonstrate the possibility of tuberculosis becoming disseminated by the circulation. The diagnosis in the cases reported by Pelagatti and others was confirmed by pathological findings. Most of the patients were young children, but the lesions do not seem to be identical. At times the eruption is unusually acute for a tuberculosis, and consists in the formation of papules, pustules, and vesicles in which the bacilli can be demonstrated, and at other times the lesions have appeared more like the papules of lichen scrofulosorum, in which case their evolution shows the distinctive chronicity of the process.

Little needs to be said on the diagnosis, for it depends on the demonstration of the germs either by sections or by inoculation. The prognosis is subservient to that of the other lesions of tuberculosis which are commonly present. The treatment does not differ from that of lupus vulgaris or other tuberculous deposits.

IV. LUPUS VULGARIS. See *L. Vulgaris*.

V. SCROFULODERMA. See *Scrofuloderma*.

Oscar H. Holder.

SKULL, THE.—The characters that may be noted in the skull are very numerous. They can be divided into *descriptive*, which gives an account of the conformation of the bony structure of the skull and its parts; *topographical*, which is of special importance in practical medicine; *craniometrical*, which gives the dimensions of the various parts of the skull by exact measurements taken by means of special instruments; and *comparative*, in which the human skull is contrasted more particularly with those of the anthropoids.

The skull may also be investigated from the points of view of embryology and general morphology.

This article will deal especially with the applied anatomical and the craniometrical characters of the skull, though presenting very briefly such descriptive and comparative matter as is necessary for an adequate treatment of the subject.

THE EXTERIOR OF THE SKULL (Figs. 4303 to 4305).—The skull in a general way is spheroidal in shape. It is flattened and uneven below, compressed from side to side, and smooth above. It presents, externally, six regions for investigation, viz.: an inferior region or base (*norma basilaris*), two lateral regions (*norma lateralis*), a posterior or occipital region (*norma occipitalis*), an anterior or frontal region (*norma frontalis*), and a superior region or vertex (*norma verticalis*).

Many *sutures* can be noted. The sutures are the lines of union of the facial (excluding the mandible) and cranial bones.

The uneven edges of the bones form closely fitted articulations (*synarthroses*) and are separated only by a fibrous membrane continuous with the dura mater and periosteum. The only places where cartilage intervenes, forming *synchondroses*, are the basilar and jugular portions of the occipital bone at the base of the skull. These cartilages are ossified in the adult. The sutures bind the bones so firmly together, by being bevelled alternately on each side, that dislocations are practically impossible. They diminish shocks, and during early life permit a rapid growth of the skull. The sutures, with the exception of the coronal (fronto-parietal), sagittal (interparietal), and lambdoid (occipito-parietal), are best named from the bones which form them.

The skull, whether viewed from the norma frontalis, the norma lateralis, the norma basilaris, or the norma occipitalis, displays well the teeth.

In its highest development the typical mammalian dentition is indicated by the following formula:

$$\mathrm{i}\,\tfrac{3}{3}\ \mathrm{c}\,\tfrac{1}{1}\ \mathrm{pm}\,\tfrac{4}{4}\ \mathrm{m}\,\tfrac{3}{3} = \tfrac{22}{22} = 44.$$

Man presents the following formula:

$$\mathrm{i}\,\tfrac{2}{2}\ \mathrm{c}\,\tfrac{1}{1}\ \mathrm{pm}\,\tfrac{2}{2}\ \mathrm{m}\,\tfrac{3}{3} = \tfrac{16}{16} = 32.$$

Accordingly in man two incisors and four premolars are wanting in each dental arch. Anatomists entertain divergent views as to which teeth have been suppressed; most probably the second incisors on either side of the median line, and the first and second premolars on either side are the ones that have disappeared.

All the teeth are alike in form in most vertebrates below mammals and in them the dentition is *homodont*. The dentition is described as *heterodont* in most of the mammals, since in them the teeth are arranged in groups of different form and size.

The jaws of the oldest known fossil mammals have tritubercular teeth with the tubercles arranged in an antero-posterior line. Since practically all the lower vertebrates possess simple conical teeth, it is quite prob-

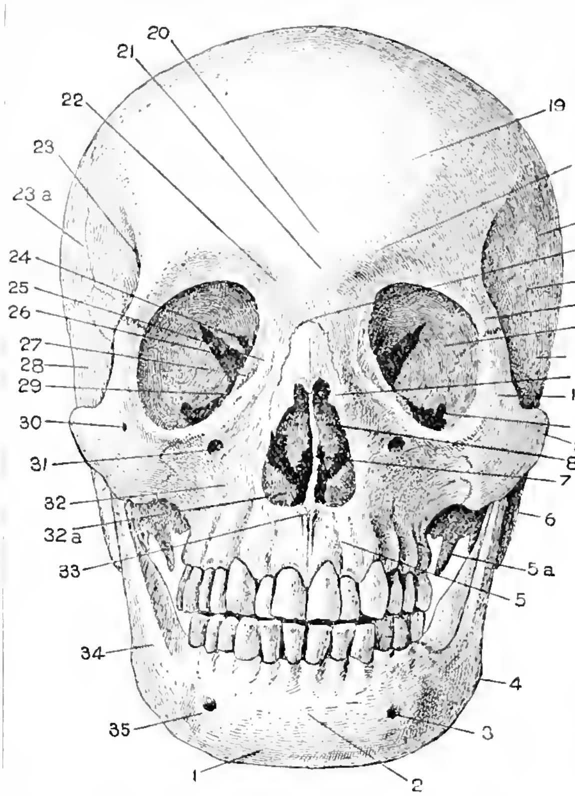


FIG. 4305.—Norma Frontalis. 1, Mental tubercle; 2, symphysis menti; 3, mental foramen; 4, angle of jaw (gonion); 5, incisor fossa; 5*a*, styloid process; 6, mastoid process; 7, nasal septum in middle of anterior nasal aperture; 8*a*, middle turbinated bone of ethmoid; 8, zygomatic arch; 9, sphenomaxillary fissure; 10, malar bone; 11, nasal bone; 12, 15, 17, temporal fossa, the sutures of which are obliterated; 13, orbital surface of great wing of sphenoid; orbital sutures are obliterated; 14, external angular process of the frontal bone; 16, nasion; 18, superciliary ridge; 19, site of frontal eminence; 20, ophryon; 21, glabella; 22, supra-orbital margin; 23 temporal crest of frontal bone; 23*a*, antero-inferior angle of parietal bone, articulating with frontal, great wing of sphenoid, and squamous portion of temporal; 24, optic foramen; 25, nasal process of superior maxilla; 26, sphenoid fissure; 27, lachrymal groove bounded posteriorly by lachrymal crest; 28, squamous portion of temporal bone; 29, lachrymal tubercle; 30, malar foramen; 31, infra-orbital foramen; 32, canine fossa; 32*a*, inferior turbinated bone; 33, subnasal point at root of anterior nasal spine; 34, ramus of mandible; 35, mental foramen.

able that the earliest toothed vertebrates in the phylogenetic series likewise possessed simple conical teeth. The method of development of the tritubercular mammalian tooth from the simple conical one has given rise to much speculation. One theory teaches that the single conical tooth developed lateral buds which, growing larger, induced in the tooth the antero-posterior tritubercular form. A second theory is that in consequence of the shortening of the jaw and crowding together of the several simple conical teeth, fusion into tritubercular teeth occurred. By rotation of two of the tubercles from the antero-posterior direction *laterally* either in or out, a form of tritubercular molar was produced in certain other fossil skulls which makes easy the transition to an ordinary mammalian molar.

The roots of the upper bicuspids and of the lower canines and incisors are flattened, and hence must be loosened by lateral movement in extracting them; the lower bicuspids and the upper incisors and canines have cylindrical roots, therefore these teeth should be first loosened by a slight rotatory movement during extraction; the roots of the first and second upper molars are three and they are frequently divergent; the roots of the wisdom teeth are convergent, generally curved backward and welded together, particularly in the lower jaw.

THE INTERIOR OF THE SKULL.—A study of the interior of the skull is of the greatest importance from a topographical point of view. In order that the interior of the skull may be investigated to the greatest advantage it is necessary to make sections in three different planes—horizontal, sagittal, and coronal. These sections not only facilitate the study of the numerous points on the interior of the skull, but also reveal the great preponderance in size of the cranial cavity over those situated in other parts of the skull.

A skull bisected in any of the planes recommended shows that its walls consist of an outer and inner table of compact bone and an intervening or connecting cancellous diploë. The spaces of the diploë contain veins communicating in the interior of the cranium with the meningeal veins and the sinuses of the dura mater, and on the exterior of the skull with the veins of the pericranium. There are other apertures in the cranial wall through which *emissary veins* pass that also establish communication between the sinuses of the dura mater inside the skull and the veins external to it.

These veins pass through the mastoid, parietal, the posterior and anterior condyloid foramina; others pass through the foramen ovale, the foramen lacerum medium, and through the foramen of Vesalius. Through these diploic and emissary veins pyogenic infection may extend from the outside of the skull, leading to osteophlebitis of the diploë and inflammation of the membranes of the brain. By means of the emissary veins blood may be abstracted almost directly from the sinuses of the dura mater, as, for instance, where leeches are applied over the mastoid process to abstract blood from the lateral sinus.

The thickness of the cranial wall varies very much in different places; it is very thick at the external occipital protuberance, and along the ridges bounding the grooves for the lateral, longitudinal, and occipital sinuses, the mastoid process, and the lower part of the frontal bone. It is comparatively thin and translucent in the cerebellar fossæ, the squamous portion of the temporal bone, and the antero-inferior angle of the parietal. The average thickness of the bones of the cranial vault is 5 mm. In *trephining*, the pin of the trephine should not penetrate over 3 mm.

A Horizontal Section of the Skull.—This section of the skull should be made to traverse the ophryon and the maximum occipital point, passing 1 or 2 mm above the pterion.

The removal of the calvarium or vaulted skull cap by a horizontal section (Fig. 4307) shows the floor of the cranial cavity, consisting of three irregular depressions, viz., the anterior, middle, and posterior fossæ.

The weak areas of the floor of the cranial cavity through which fractures are liable to extend are: The horizontal plates of the ethmoid and frontal bones in the anterior cranial fossa; the region of the foramen ovale of the sphenoid bone, and of the glenoid fossa of the temporal, in the middle cranial fossa; the cerebellar fossæ of the occipital bone in the posterior cranial fossæ. The internal auditory canal and the tympanum weaken the otherwise strong petrous portion of the temporal bone.

A Sagittal Section of the Skull.—A sagittal section should be made a little to one or the other side of the mesial plane so that one-half will reveal the nasal septum in position while the other half will display the lateral wall of the nasal fossa (Fig. 4308, *A*).

It will be very instructive to remove the middle turbinated bone in order to observe structures of great importance. There will then be observed two prominent objects on the lateral wall of the middle meatus, viz., a bulging of one of the ethmoidal cells (*bulla ethmoidalis*), and immediately below it the well-defined curvilinear border of the uncinate process (*processus uncinatus*) of the ethmoid bone. A narrow semilunar opening (*hiatus semilunaris*) occurs between the two projections. The air cell in the bulla communicates directly with the meatus by an opening upon or close to its superior surface. The hiatus serves as a direct and only communication between the meatus and the important *infundibulum*, and is a deficiency in the mesial wall of the latter. The infundibulum is a small gutter-like channel immediately external to the hiatus. It corresponds in direction and length to the border of the uncinate process. In the majority of cases the infundibulum continues up, as the *naso-frontal duct*, to the *ostium frontale*. Sometimes

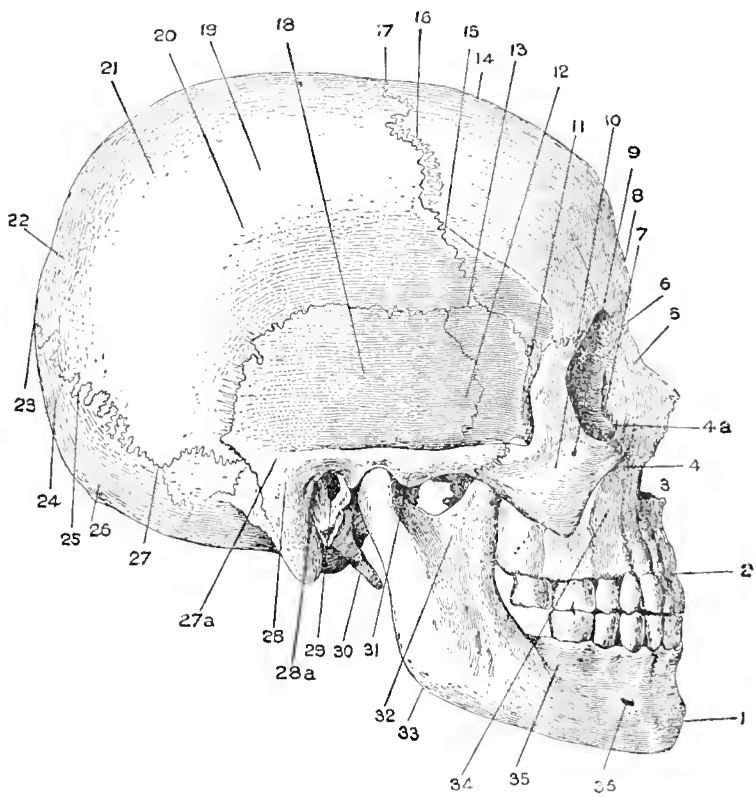


FIG. 4304.—Norma Lateralis. 1, Mental tubercle; 2, alveolar point; 3, anterior nasal spine; 4, infra-orbital foramen; 4*a*, lachrymal tubercle; 5, nasal bone; 6, nasion; 7, lachrymal groove for nasal sac; 8, glabella; 9, malar foramen; 10, malar bone; 11, great wing of sphenoid; 12, temporal fossa; 13, pterion; 14, frontal bone; 15, stephanion; 16, coronal suture; 17, bregma; 18, squamous portion of temporal bone; 19, site of upper temporal ridge; 20, site of lower temporal ridge; 21, parietal bone; 22, obelion; 23, lambda; 24, occipital bone; 25, lambdoid suture; 26, inion (or external occipital protuberance); 27, asterion; 27*a*, supramastoid crest; 28, mastoid process; 28*a*, suprameatal spine with the suprameatal fossa immediately back of it; 29, aperture of external auditory canal; 30, styloid process; 31, zygomatic arch; 32, ramus of mandible; 33, gonion; 34, superior maxilla; 35, body of mandible; 36, mental foramen.

the supero-anterior end of the infundibulum terminates in a bony lamina; in these cases the naso-frontal duct opens into the middle meatus in front and independently of the infundibulum.

The opening of the maxillary sinus (*ostium maxillare*) is situated in the most depressed part of the infundibulum beneath the bulla. It is concealed from view by the uncinate process. The size of the opening varies from 2 to 18 mm. There may be one or more accessory maxillary openings in the membranous portion of the outer wall of the middle meatus, varying in size from 1 to 8 mm. They do not open into the infundibulum but directly into the meatus at the posterior part of the infundibulum. The middle ethmoidal cell, when present, opens into the meatus above the bulla. The anterior ethmoidal cells open into the superior part of the infundibulum.

A Coronal Section of the Skull.—The most instructive coronal section of the cranium is through the basio-bregmatic axis (Fig. 4309). Such a section of the skull facilitates the examination of the parts about the posterior nares; it divides the parietal bones slightly in front of the parietal eminences, and thus makes it possible to indicate the greatest transverse measurement of the cranial cavity by a line drawn transversely across the cavity. The section will traverse the petrous portion of the temporal bone in such a way as to pass through the external auditory canal and expose the tympanum proper (atrium) and its attic, as also the vestibule. It will also pass through a part of the internal auditory canal.

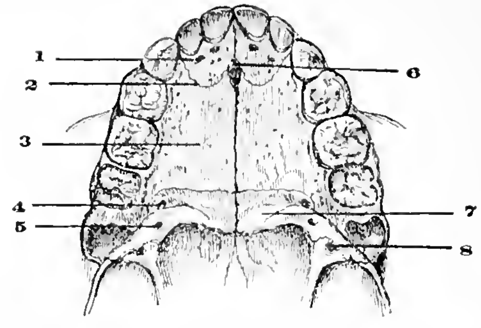


FIG. 4306.—Hard Palate of a Child (about the sixth year). 1, Premaxilla; 2, maxillo-premaxillary suture; 3, palate process of maxilla; 4, posterior palatine canal; 5, and 8, accessory palatine foramina; 6, anterior palatine fossa; 7, horizontal plate of palate bone.

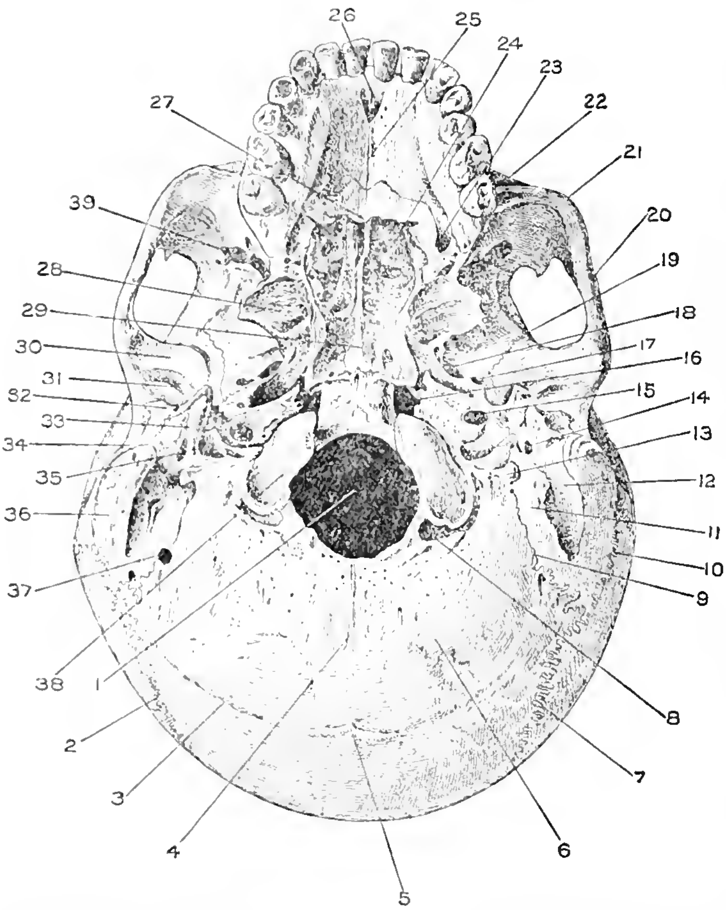


FIG. 4305. Norma Basilaris. 1, Foramen magnum; 2, lambdoid suture; 3, superior curved line of the occipital bone; 4, external occipital crest; 5, inion; 6, site of inferior curved line; 7, lambdoid suture; 8, posterior condyloid foramen; 9, occipito-mastoid suture; 10, parieto-mastoid suture; 11, groove for occipital artery; 12, digastric fossa; 13, jugular process of occipital bone; 14, stylo-mastoid foramen; 15, carotid canal; 16, foramen lacerum medium; 17, foramen spinosum; 18, foramen ovale; 19, sphenosquamous suture; 20, zygoma; 21, malar; 22, superior maxilla; 23, posterior palatine canal; 24, lateral mass of ethmoid in nasal fossa; 25, intermaxillary suture between the palate processes of the superior maxillæ; 26, anterior palatine canal or fossa; 27, posterior nasal spine on palate bones; 28, pterygoid fossa; 29, part of nasal septum (vomer); 30, eminentia articularis (anterior root of zygoma); 31, glenoid fossa; 32, auditory process floofing the external auditory canal; 33, styloid process; 34, supramastoid crest (posterior root of zygoma); 35, jugular foramen; 36, mastoid process; 37, mastoid foramen; 38, condyle of occipital bone; 39, sphenomaxillary fissure.

The inner surface of the cranial wall shows certain grooves and depressions, viz., for (1) the meningeal arteries (especially the middle meningeal), (2) the dural sinuses, (3) the Pacchionian bodies, and (4) the cerebral convolutions. In trephining, these facts should be borne in mind.

It may be stated here that in studying the macerated skull, through which no sections have been made, *transillumination* with a small electric bulb, such as that used in laryngological work, will be found very instructive. Especially is this the case in studying the nasal fossa, the grooves for the lateral sinuses, the maxillary sinus, the tympanum, the relations of the carotid canal and jugular fossa to the tympanum, etc.

The skull presents certain *buttresses* where the bones are thicker and stronger than the intervening thinner and weaker regions. The latter regions are the more readily fractured. These buttresses pass from the vertex to the foramen magnum. The *anterior buttress* is represented by the median portion of the frontal, the ethmoid, the body of the sphenoid, and the basilar portion of the occipital. The *posterior buttress* passes through the external occipital protuberance and crest to the foramen magnum. On either side there are two *lateral buttresses*—an antero-lateral one which extends from the vertex to the external angular process of the frontal and thence through the great wing to the body of the sphenoid; and a postero-lateral one which runs through the parietal eminence, the mastoid process, the posterior part of the petrous portion of the temporal bone, the jugular process and condyle of the occipital bone.

There are several factors that lessen the liability of the cranial wall to fracture: (1) The elasticity of the wall due to its shape and its formation of a number of elastic bones separated by sutures and suture membranes which act slightly as buffers; (2) a rounded form favoring glancing blows; (3) the mobility of the head on the spinal column; (4) the mobility and density of the scalp.

From the fact that there is much membrane and cartilage between the bones the skull of the infant is much more elastic than that of the adult. The yielding character of the infant's skull is shown during delivery, when frequently the parietal bone may be flattened by pressure against the sacral promontory or by the forceps without producing fracture.

A Comparison of the Human and Anthropoid Skulls.—The principal difference between the skull of man and that of the anthropoid apes is in the excessive development of the brain cavity (Fig. 4308, *A* and *B*). The average weight of a man's brain in European races is 1,360 gm. These figures may fall to 1,025 gm. or rise to 1,675 gm. Brains weighing less than 1,000 gm. are pathological. On the other hand, the brains of the anthropoid apes have an average weight of 360 gm. In a few isolated cases this weight may rise to, but never exceed, 420 gm. The excessive development of the cranial cavity induced by the enlarged brain has been the main factor, according to Prof. J. Ranke, in determining the change in attitude of our anthropoid progenitors from the semi-erect to the erect posture. Several peculiarities in the anatomical structure of man compared with those of the anthropoid apes give this theory an air of plausibility. In the majority of mammals very powerful *cervical ligaments* maintain the equilibrium of the head. In the anthropoids *very strong muscles* extend from the occiput to the spinous processes (twice as long as those of man) of the cervical vertebræ, thus preventing the massive muzzle from falling upon the chest and pressing on the organs of respiration. In man those structures are very feebly developed. In him the very voluminous brain case suffices to counterbalance the weight of the much reduced face, thus permitting the head to be balanced on the spinal column. But in connection with this point it should be remembered that Broca and other anthropologists teach that the assumption of the erect attitude was one of the conditions of the development of the brain and its large cranial cavity, since this attitude alone permits the free use of the hands and an extended range of vision.

In order to convince ourselves that the excessive development of the human brain and its enclosing cranial cavity are correlative with the reduction of the facial part of the skull, we have only to compare the human skull with that of an anthropoid, placing both in the same horizontal plane and approximately parallel to the line of vision.

As a rule the bony structure of the human skull, when viewed from the norma verticalis, leaves nothing of its facial part to be seen; at the very most, in rare instances, may be observed the alveolar segment of the upper jaw, or the lower portion of the nasal bones. In the anthropoids almost all of the facial part of the skull is observed

On comparing the profiles (norma lateralis) of the human and anthropoid skulls it is noted in the latter that the facial portion forms a bestial and massive muzzle in advance of the cranium, while in the former the much-reduced face is placed below the anterior portion of the cranium. The mastoid processes in the anthropoid are relatively much smaller than in man. In the anthropoid the facial part of the malar bone is greatly developed in comparison with its temporal portion. The contrary obtains in man.

The skulls, when viewed from the norma occipitalis, reveal plainly the foramen magnum in the monkeys, while the foramen is not seen at all in man.

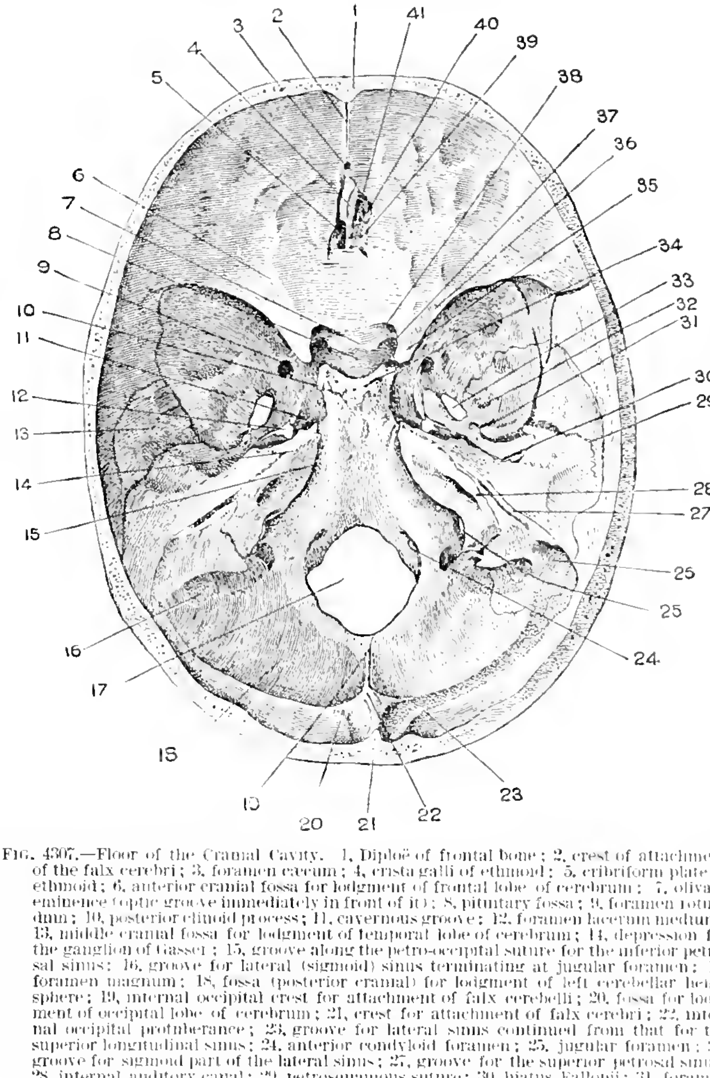
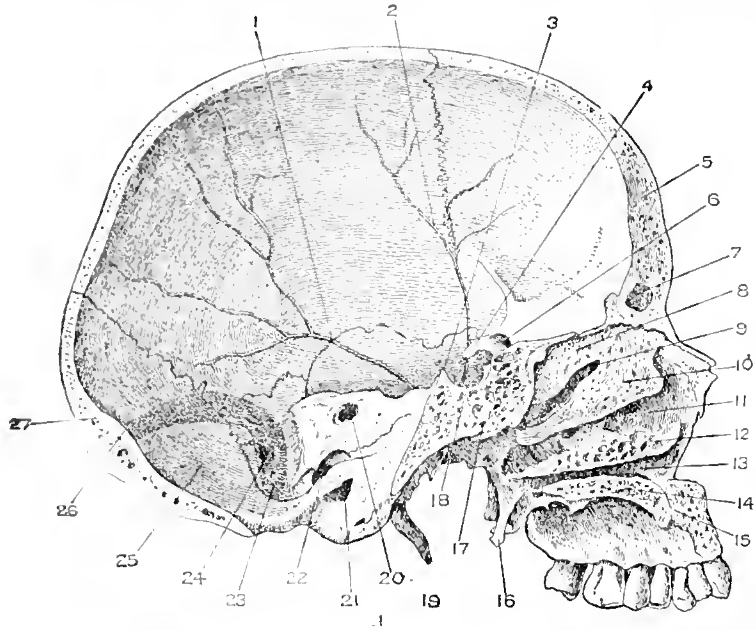


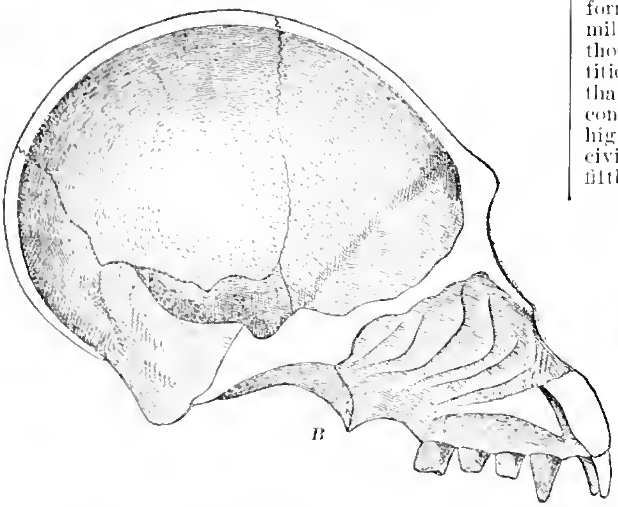
Fig. 4307.—Floor of the Cranial Cavity. 1, Diploë of frontal bone; 2, crest of attachment of the falx cerebri; 3, foramen cæcum; 4, crista galli of ethmoid; 5, cribriform plate of ethmoid; 6, anterior cranial fossa for lodgment of frontal lobe of cerebrum; 7, olivary eminence (optic groove immediately in front of it); 8, pituitary fossa; 9, foramen rotundum; 10, posterior clinoid process; 11, cavernous groove; 12, foramen lacerum medium; 13, middle cranial fossa for lodgment of temporal lobe of cerebrum; 14, depression for the ganglion of Gasser; 15, groove along the petro-occipital suture for the inferior petrosal sinus; 16, groove for lateral (sigmoid) sinus terminating at jugular foramen; 17, foramen magnum; 18, fossa (posterior cranial) for lodgment of left cerebellar hemisphere; 19, internal occipital crest for attachment of falx cerebelli; 20, fossa for lodgment of occipital lobe of cerebrum; 21, crest for attachment of falx cerebri; 22, internal occipital protuberance; 23, groove for lateral sinus continued from that for the superior longitudinal sinus; 24, anterior condyloid foramen; 25, jugular foramen; 26, groove for sigmoid part of the lateral sinus; 27, groove for the superior petrosal sinus; 28, internal auditory canal; 29, petrosquamous suture; 30, hiatus Fallopii; 31, foramen spinosum; 33, foramen ovale; 34, dorsum sellæ; 35, anterior clinoid process; 36, lesser wing of sphenoid; 37, cavernous groove; 38, optic foramen; 39, 40, cribriform plate of ethmoid; 41, slit for nasal nerve.

Viewed from the front, or norma frontalis, the human skull shows that the top of the nasal opening is always situated higher than the lowest point of the infra-orbital margin; in the anthropoid apes it is always observed below this point.

All the other characteristics which distinguish the human from the anthropoid skull are the direct results of the excessive development of the human brain case at the expense of the face, and the assumption of the erect attitude and biped progression.

The adult chimpanzee and gorilla possess those enormous crests which give so horrible an aspect to their skulls. These bony ridges are adaptations and are due to the extreme development of the muscles of mastication and of those cervical muscles which insure the equilibrium of the head on the spinal column. The cranium, being too small to afford sufficient room for the insertion of these muscles, has been forced, in the course of development, to deposit these crests for the purpose of affording an enlarged bony area for muscular attachments. In this connection it is interesting to note that the young of these anthropoids have no crests, and that the distance on their skulls between the temporal lines marking the insertion of the temporal muscles is almost as great as in man.





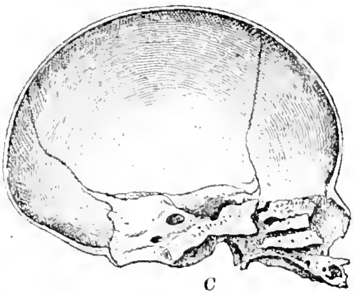


FIG. 4308.—Sagittal Sections of Human (A), Chimpanzee (B), and Infantile (C) Skulls, showing Relative Proportions of Cranium and Face and Relative Sizes of the Three Skulls. A: 1, Posterior division of middle meningeal artery; 2, anterior division of the artery; 3, dorsum sellæ; 4, anterior clinoid process; 5, diploë of frontal bone; 6, optic foramen; 7, frontal sinus; 8, superior turbinated bone of the ethmoid; 9, superior meatus; 10, middle turbinated bone of the ethmoid; 11, middle meatus, showing antral openings; 12, inferior turbinated bone; 13, inferior meatus; 14, hard palate; 15, anterior palatine canal; 16 hamular process of the internal pterygoid plate; 17, body of sphenoid (diploetic instead of pneumatic); 18, pituitary fossa; 19, styloid process; 20, internal auditory canal; 21, anterior condyloid foramen; 22, jugular foramen; 23, groove for lateral sinus; 24, mastoid foramen; 25, cerebellar fossa; 26, internal occipital protuberance (site of torcular Herophili); 27, diploë of occipital bone.

The size of the teeth in proportion to that of the body is much greater in the anthropoids than in man.

Ignoring the canines and incisors, we may state that the size of the premolars and molars, in apes, is larger in relation to the length of the face. In man the arrangement of the teeth on the alveolar border is in a compact line forming a continuous series; there is no conspicuous projection of any one tooth above the common level. On the contrary, in all apes there is observed an interval (*diastema*) between the lateral incisors and the canines of the upper jaw, and between the canines and the first premolars of the lower jaw. These diastemæ receive, in each jaw, the projecting part of the opposite canine.

Man and the anthropoid apes have alike five tubercles in the lower molars. Very often the fifth posterior tubercle is missing in the last two molars of man. In the anthropoids the wisdom tooth is of the same size as, or a little smaller than, the other molars, and this is usually the case in man, though in the latter it is often entirely wanting. The dental arch in the anthropoids usually has the form of **U**, while in man it tends to the elliptical or parabolic form.

It is in consequence of the inequality of the development of the face that the size and form of the teeth are different in man and the apes. The milk teeth of man present a much greater similarity to those of the anthropoids than the teeth of the second dentition. It is an instructive fact that all the characters that distinguish man from the anthropoids tend to become more marked with the change from a natural to a highly artificial environment, as in the development of civilization. Thus in European races the absence of the fifth tubercle in the molars of the lower jaw is more frequent than in Melanesians and Negroes. The wisdom tooth is apparently in a state of retrogressive evolution among several populations. In the white races especially it is almost always smaller than the other molars and the number of its tubercles is reduced to three instead of four or five; very often it does not erupt, remaining permanently in its alveolus. It is interesting to know that the differences between man and the anthropoids that have been noted above are very pronounced only when adult individuals are compared. The fœtus of the gorilla at five months bears a very close resemblance to a human fœtus of the same age. Young chimpanzees or gorillas, by their not very prominent muzzle, by their globular skull and relatively large cranium, and other traits, remind one of young Negroes. In comparing the skulls of chimpanzees, from the fœtal state through all the subsequent changes to the adult, we can follow step by step the transformation of a face that is almost human into a muzzle of the most repellent and bestial aspect. As has been indicated above, all of these changes have been brought about by the development of the cranium upward and behind in man, and the growth of the face below and in front in the anthropoids, "as if these parts moved in different directions in relation to a central point in the interior of the skull near to the *sella turcica*."

Craniology.—The races of mankind display great variations in their physical attributes, and these differences are more or less characteristic of the stock to which they belong. For instance, the various races manifest great differences in the size and form of the cranial cavity and of the face. Variations are observed in the prominence of the chin, and in the form of the dental arch, the palate, the nasal aperture, the orbit, etc. Craniology deals with these variations to the extent that they affect the skull. In order that the differences between skulls may be recorded, it is necessary that accurate measurements, in many details, should be made. Some craniologists have multiplied the measurements to more than a hundred, but those worth mentioning are comparatively few. These measurements constitute Craniometry. In order to make the various measurements required, many complicated instruments have been invented, but for all practical purposes the calipers designed by Fowler are sufficient.

While there is a great difference of opinion as to the value of the various measurements, all anatomists endeavor to select such fixed *anatomical points* on the skull as may be easily located. Some of these "anatomical points" are as follows (Figs. 4304, 4305, 4306, 4307, 4308, A):

Nasion.—The middle of the naso-frontal suture.

Glabella.—The mid-point between the two superciliary ridges.

Ophryon.—The mid-point of the narrowest transverse diameter of the forehead.

Bregma.—The point of junction of the sagittal and coronal sutures.

Vertex.—Highest point of the cranial vault.

Obelion.—A point in the sagittal suture on a line extending between the parietal foramina.

Lambda.—The point of junction of the sagittal and lambdoid sutures.

Maximum Occipital Point.—That point on the squamous portion of the occipital bone and in the sagittal plane that is most removed from the glabella.

Inion.—The external occipital protuberance.

Opisthion.—The mid-point of the posterior margin of the foramen magnum.

Basion.—The mid-point of the anterior margin of the foramen magnum.

Mental Tubercle.—The tubercle of the chin.

Alveolar Point.—The mid-point of the anterior margin of the alveolar border of the upper jaw.

Subnasal Point.—The mid-point of the inferior margin of the anterior nasal aperture at the base of the nasal spine.

Stephanion.—The point where the temporal crest crosses the coronal suture.

Pterion.—The region of the antero-inferior angle of the parietal bone. As a rule there is a *sphenoparietal suture* so that the squamous portion of the temporal bone is separated from the frontal.

Asterion.—The region of the postero inferior angle of the parietal bone.

Jugal Point.—Located at the angle between the upper border of the zygomatic process and the posterior border of the frontal process of the malar bone.

Gonion.—The outer surface of the angle of the mandible.

Auricular Point.—The centre of the aperture of the external auditory canal.

Preauricular Point.—That point which lies immediately in front of the upper end of the tragus on the posterior root of the zygoma.

Postauricular Point.—That point on the supramastoid crest which lies immediately behind and 18 mm. (a finger's breadth) below the upper attachment of the auricle.

Dacryon.—That point at the supero-internal angle of the orbit where the fronto-nasal suture meets the lachrymomaxillary suture.

Another anatomical point used in craniometry is the *mid-point* of the *spheno-ethmoidal suture* (called by some anatomists the gonion).

The Temporal Crest (linea temporalis).—Curving in a longitudinal direction over the lateral region of the calvarium is the temporal crest. It is often double. The upper ridge marks the limit of attachment of the temporal fascia, whilst the lower line defines the attachment of the temporal muscle. It commences in front on the external angular process of the frontal bone at the fronto-malar suture and sweeps backward and upward across the lower part of the frontal bone, and then crossing the coronal suture at the stephanion, passes to the parietal bone. Curving over this toward the postero-inferior angle of the parietal, it is continued on to the temporal bone to form the supramastoid crest.

The Supramastoid Crest.—The upper edge of the zygomatic process of the temporal bone passes back over the external auditory canal and becomes confluent with a ridge (posterior part of the temporal ridge or crest) that separates the mastoid from the squamous portion of the temporal bone; this ridge is the supramastoid crest or posterior root of the zygoma.

The *basicranial axis* is represented by a line drawn from the basion to the mid-point of the spheno-ethmoidal suture, and is formed by the basi-occipital, the basisphenoid, and the presphenoid bones.

The *basifacial axis* is indicated by a line drawn from the mid-point of the spheno-ethmoidal suture to the subnasal point.

The *craniofacial axis* comprises the basi-occipital, basisphenoid, presphenoid, and mesethmoid bones.

The *basibregmatic axis* extends from the basion to the bregma.

The *craniofacial angle* is the one formed by the basicranial and basifacial axes. It is useful in making comparative measurements of crania.

The *longitudinal arc* of the cranium is measured from the nasion along the vertex to the opisthion, and may be subdivided by measuring the lengths of its frontal, parietal, and occipital portions so that the relative proportions of these bones may be noted.

The *basinasal length* is the distance from the basion to the nasion.

The *basi-alveolar length* is the distance from the basion to the alveolar point.

The *dental length* is the distance, in the upper jaw, from the anterior surface of the first premolar to the posterior surface of the third molar.

The *total circumference of the cranium*, in the sagittal plane, may be obtained by adding together the longitudinal arc, the distance between the opisthion and the basion, and the basinasal length.

Reid's Base Line.—This is a line drawn from the auricular point to the lower margin of the orbit.

The *horizontal circumference* of the cranium is measured around a plane cutting the glabella anteriorly, and the maximum occipital point posteriorly.

In ascertaining the *maximum breadth of the cranium*, which is very variable in its position, it should be noted whether it is above or below the squamo-parietal suture.

The *length of the cranium* may be measured between a number of different points, as between the nasion, glabella, or ophryon anteriorly, and the maximum occipital point, or the inion posteriorly.

The *bistephanic width* of the cranium is the distance from one stephanion to the other in the horizontal plane.

The *biasterionic diameter* of the cranium is the distance, in the horizontal plane, from one asterion to the other.

The opisthion and the floor of the posterior cranial fossa occupy the same horizontal plane as the hard palate. The basion is a little higher than the opisthion. By consequence the plane of the foramen magnum in the higher races is oblique, being directed downward and slightly forward.

In order to describe the cranial peculiarities correctly and to have fixed coördinates to which the measurements can be referred, the skull should be placed, when studied, in the horizontal plane. Anthropologists are not agreed as to this initial plane. In Germany the plane in favor is one passing through the centre or top of the contour of the osseous external auditory canal and the inferior border of the orbit. In France and England Broca's alveolo condylean plane is adopted; this plane passes through the alveolar border of the superior maxilla and the condyles of the occipital bone.

Cranial Capacity.—The size of the brain cavity or the cranial capacity is estimated in various ways. Were it not for the fact that the brain cavity of the skull contains so many foramina which it is difficult to close, fluids would be the most accurate agents to use in ascertaining cranial capacity. But practically leaden shot, or seeds, or glass beads are the most serviceable. Cranial capacity is intimately correlated with the development of the brain, and, apart from individual variations and the proportion of head size to stature, it may be stated that the size of the cranium in highly civilized races is greatly in excess of that observed in the lower races.

For the purposes of comparison skulls are grouped according to their cranial capacity as follows: *megacephalic*, with a brain capacity over 1,450 c.c. (mixed Europeans, Japanese, Eskimaux); *mesocephalic*, with a capacity varying from 1,350 c.c. to 1,450 c.c. (some African Negroes, American Indians, Chinese); *microcephalic*, with a capacity below 1,350 c.c. (Veddahs, Australians, Andamanese, Bushmen).

The Cephalic Index.—Comparisons between crania may be made by *indices*. An index is the ratio between two dimensions that have a natural relation; the normally greater dimension is employed as a base and is assumed to be 100. The ratio is expressed as follows:

Greater dimension : lesser dimension :: 100 : index. Or,

$$\frac{\text{Lesser dimension} \times 100}{\text{Greater dimension}} = \text{Index.}$$

The cephalic index expresses the relation of the breadth to the length of the cranium and records the proportion of its maximum breadth to its maximum length (the latter being assumed to be equal to 100) in the following formula:

$$\frac{\text{Maximum breadth} \times 100}{\text{Maximum length}} = \text{Cephalic index.}$$

According to the amount of the cephalic index skulls are classified as follows: *Brachycephalic* index over 80 (American Indians, Malays, Andamanese), *mesaticephalic*, index varying from 75 to 80 (mixed Europeans, mixed Polynesians, Chinese); *dolichocephalic*, with an index below 75 (Australians, Zulus, Fijians, Kaffirs, Eskimaux).

The dolichocephalic skull is more primitive than the brachycephalic one. Generally tall men have long heads, while short men have short or rounded ones. The Norwegians are the tallest men as well as the largest-skulled nation in Europe, the Auvergnats are the shortest of European whites and possess the roundest heads.

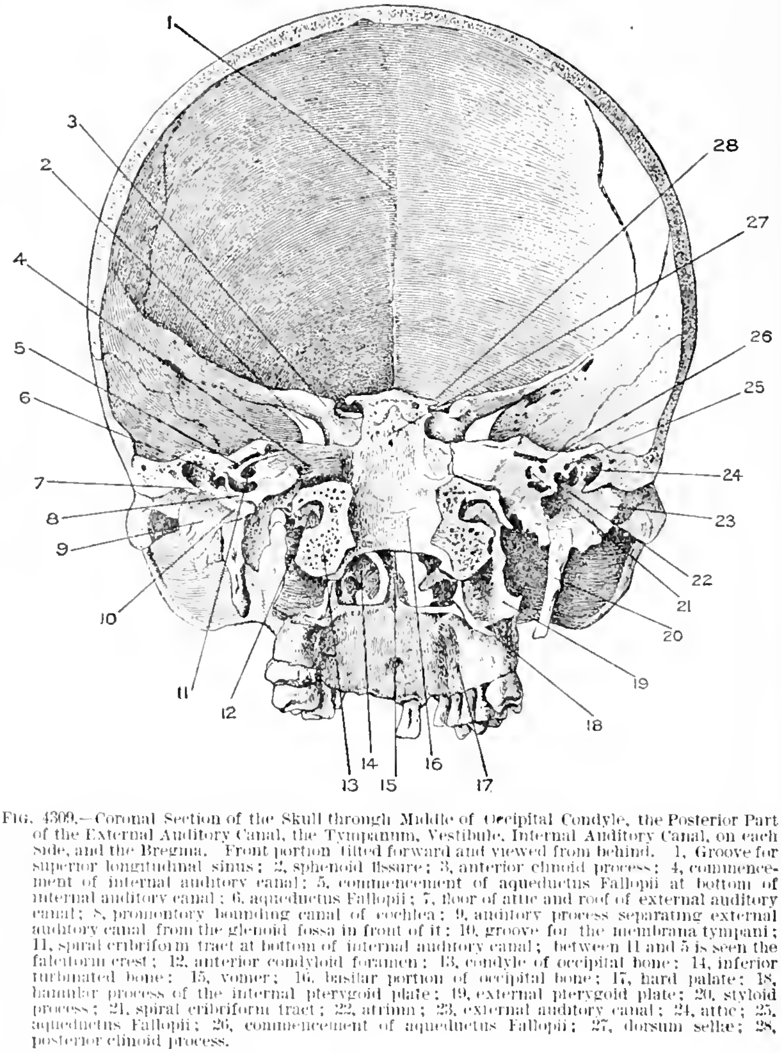


FIG. 4309.—Coronal Section of the Skull through Middle of Occipital Condyle, the Posterior Part of the External Auditory Canal, the Tympanum, Vestibule, Internal Auditory Canal, on each side, and the Bregma. Front portion tilted forward and viewed from behind. 1, Groove for superior longitudinal sinus; 2, sphenoid fissure; 3, anterior clinoid process; 4, commencement of internal auditory canal; 5, commencement of aqueductus Fallopii at bottom of internal auditory canal; 6, aqueductus Fallopii; 7, floor of attic and roof of external auditory canal; 8, promontory bounding canal of cochlea; 9, auditory process separating external auditory canal from the glenoid fossa in front of it; 10, groove for the membrana tympani; 11, spiral cribriform tract at bottom of internal auditory canal; between 11 and 5 is seen the falciform crest; 12, anterior condyloid foramen; 13, condyle of occipital bone; 14, inferior turbinated bone; 15, vomer; 16, basilar portion of occipital bone; 17, hard palate; 18, hamular process of the internal pterygoid plate; 19, external pterygoid plate; 20, styloid process; 21, spiral cribriform tract; 22, atrium; 23, external auditory canal; 24, attic; 25, aqueductus Fallopii; 26, commencement of aqueductus Fallopii; 27, dorsum sellæ; 28, posterior clinoid process.

The Height Index.—This index expresses the proportion of the height to the length of the cranium and is obtained by the following formula:

$$\frac{\text{Basiobregmatic height} \times 100}{\text{Maximum length}} = \text{Height or vertical index.}$$

According to the index skulls are divided into *hypsicephalic*, index 75.1 and upward; *orthocephalic*, index from 70.1 to 75; and *chamaecephalic*, index below 70.1.

The Nasal Index.—This index expresses the proportion of the maximum nasal width to the nasal height (measured from the subnasal point to the nasion) and is obtained by the following formula:

$$\frac{\text{Maximum nasal width} \times 100}{\text{Nasal height}} = \text{Nasal index.}$$

The form of the nasal aperture is of great value from an ethnic point of view, since it is so intimately associated with the shape of the nose in the living. According to the nasal index skulls are classified as follows: *Platyrhine*, with index above 53 (Australians, Negroes, etc.); *mesorhine*, index varying from 48 to 53 (Japanese, Chinese); and *leptorhine*, index below 48 (mixed Europeans, American Indians, ancient Egyptians).

The Orbital Index.—This index, though varying considerably in different races, is of much less value for purposes of classification than the nasal index. It expresses the proportion of the height to the width of the orbit. The orbital height is the distance, at its middle, between the lower and upper margins, while the width is measured from the dacryon to the most distant point on the anterior edge of the outer border of the orbit. The orbital index is obtained by the following formula:

$$\frac{\text{Orbital height} \times 100}{\text{Orbital width}} = \text{Orbital index.}$$

Skulls are divided, according to the index, into *megaseme*, index above 89; *mesoseme*, index between 89 and 84; and *microseme*, index below 84.

The Palatomaxillary Index.—This index is used to record the variations occurring in the form of the palate and dental arch. The width is measured between the outer surfaces of the alveolar borders immediately above the second molar tooth of each side, while the length is taken from the alveolar point to the mid-point of a line drawn from the posterior border of one superior maxilla to that of the other. The index is obtained by the following formula:

$$\frac{\text{Palatomaxillary width} \times 100}{\text{Palatomaxillary length}} = \text{Palatomaxillary index.}$$

According to the index skulls are classified as follows: *Brachyuranic*, index above 115; *mesuranic*, index between 110 and 115; and *dolichuranic*, index below 110.

The Dental Index.—From an ethnic point of view the proportion of the space occupied by the premolar and molar teeth (dental length), on one side, to the length of the basinasal line has been found to be a character of much value. The dental index is obtained by the following formula:

$$\frac{\text{Dental length} \times 100}{\text{Basinasal length}} = \text{Dental index.}$$

According to the index skulls are divided into *megadont*, index above 44 (Australians, Negroes); *mesodont*, index between 42 and 44 (Mongolians); *microdont*, index below 42 (Caucasians).

The Facial Index.—The characteristic features of the race are most readily noted in the face, and measurements of the skeleton of the face are of more value than those of the cranium, though more complex. As a general rule, to which there are many exceptions, it may be stated that a long or dolichocephalic cranium is associated with a long face, and a brachycephalic one with a shorter and rounder face.

There are two varieties of facial index, according to whether the mandible is included in the measurements or not. With the mandible present the measurement is taken from the nasion above to the mental tubercle below, and compared with the greatest bizygomatic diameter. This constitutes the *total facial index*, and is obtained by the following formula:

$$\frac{\text{Naso-mental length} \times 100}{\text{Bizygomatic diameter}} = \text{Total facial index.}$$

Since the mandible is frequently missing in skulls it is important to express the relation of length to the breadth of the face by the *superior facial index*, which can be obtained by the following formula:

$$\frac{\text{Naso-alveolar length} \times 100}{\text{Bizygomatic diameter}} = \text{Superior facial index.}$$

According to the facial index the following types of face are noted: *chamæprosopic* (broad or low face), *mesoprosopic* (medium size face), and *leptoprosopic* (high or narrow face). The terms *brachyfacial* and *dolichofacial* have also been employed to record the different faces observed. The proportion of the width of the face to that of the cranium is expressed by terms which indicate that the zygomatic arches are either concealed or observed when the skull is inspected from its norma verticalis. In the former case skulls are roughly described as *cryptozygous*; in the latter as *phænozygous*.

The Alveolar Index.—The degree of projection of the superior maxillæ, so characteristic of certain races, is most readily ascertained by the *alveolar index*. This expresses the proportion of the basi-alveolar to the basinasal length, the latter being equal to 100. The index is secured by the following formula:

$$\frac{\text{Basi-alveolar length} \times 100}{\text{Basinasal length}} = \text{Alveolar index}$$

According to the index races are classified into three groups: *prognathous*, index above 103 (Australians, various African Negroes, Melanesians, Tasmanians); *mesognathous*, index from 98 to 103 (Chinese, Eskimaux, Japanese, mixed Polynesians;) *orthognathous*, index below 98 (ancient Egyptians, mixed Europeans).

In calculating indices the *index calculator*, invented by Dr. Waterston, will be found of great service in saving time.

The amount of projection of the face may be measured by certain angles, the two most important of which are the following, viz., the facial and the maxillary.

The *facial angle* is that subtended by a line drawn from the most prominent part of the forehead above to the most projecting portion of the upper jaw below, and a second line drawn horizontally from the first through the centre of the aperture of the external auditory canal. The more acute this angle is, the smaller is the cranial capacity. The angle is 40° in the orang-outang, 70° to 75° in the African Negro, and 80° in the European whites.

The *maxillary angle* is subtended by lines drawn from the most projecting portion of the upper jaw to the most prominent points of the chin below and the forehead above. The more acute this angle, the more prognathic is the face and the less the chin. The angle is 110° in the orang-outang, 140° in the African Negro, and 160° in the European whites.

Sutures.—The lines of union or sutures between the several bones of the skull also give indications of great value in differentiating races. They are much simpler in the lower races than in the higher, and become obliterated earlier in life. Through this means the bones of the cranium unite into a compact mass and prevent the continued expansion of the brain cavity. Occasionally, in some races more frequently than in others, small distinct bones (Wormian bones) are observed in these sutures. One of these occurs so frequently in certain tribes of American Indians that it has been named the *Inca* bone. It is situated toward the back of the head.

The presence of inferior physical traits in certain races of men is either the perpetuation of the ape-like (pithecoid) characters of the lower animal, which was man's immediate ancestor, or they are atavistic.

As a very brief summary we may say that some of these inferior traits are a wide nasal aperture with synostosis of the nasal bones; simplicity and early union of the cranial sutures, with retarded union of the facial sutures; recession of the chin; prominence of the jaws; articulation of the temporal with the frontal bone; early appearance, large size, and permanence of the wisdom teeth.

In nearly all the black people (Soudanese, Australians, Melanesians, etc.) the wisdom teeth are ordinarily furnished with three separate fangs, while among the whites they decay early and have only two fangs.

It has been justly objected that ethnologists who are mere anatomists have claimed too much for craniology, and that they have given it a prominence which it does not deserve, too often applying it to the exclusion of other elements. The shape of the skull is no indication of race in the individual; only in the average of large numbers has it importance. Within the limits of the same race, as the Slavonians, the greatest variations in skulls are observed. Again the cranial indices were found to vary from 70 to 83 among the pure blooded natives of one of the small islands of the Pacific Ocean.

Nevertheless, employed with a due regard for all the ethnic elements, and in large averages, craniometry is extremely useful as furnishing additional data for comparison.

The cranial characters not only vary according to *race*, but also in each race there are other variations due to *age* and *sex*.

Age Differences in the Skull.—The skull of a new-born infant presents two striking peculiarities, viz., the great predominance of the cranial over the facial portion (8 to 1) (Fig. 4308, *C*) and its relatively large size in comparison with the body. The diminutive facial portion is due to the small size of the maxillary antrum, the undeveloped condition of the mandible and maxillæ, and the small size of the nasal fossæ which are as broad as they are high and almost filled with the turbinals. The parietal and frontal eminences are large and conspicuous, but the frontal sinuses and superciliary ridges are wanting. The bones of the vault are without any diploë, and therefore consist of a single layer. The sutures are absent in the cranium. Each angle of the parietal bone is undeveloped and in relation with a fontanel. The anterior fontanel is large and lozenge-shaped, the posterior small and triangular, and the lateral ones irregular in shape (Figs. 4310 and 4311).

The most striking facts about the base of the skull are the absence of the mastoid processes, the large angle formed by the pterygoid processes with the base, and the existence of the occipital condyles on the same level with the lower border of the symphysis menti. The frontal bones consist of two elements separated by a *metopic* suture.

The temporal bone consists of three parts, viz., the *squamosal*, *tympanic*, and *petrosal* (Fig. 4312). The squamosal has its postero-inferior angle prolonged downward into a *postauditory process*, which forms the outer wall

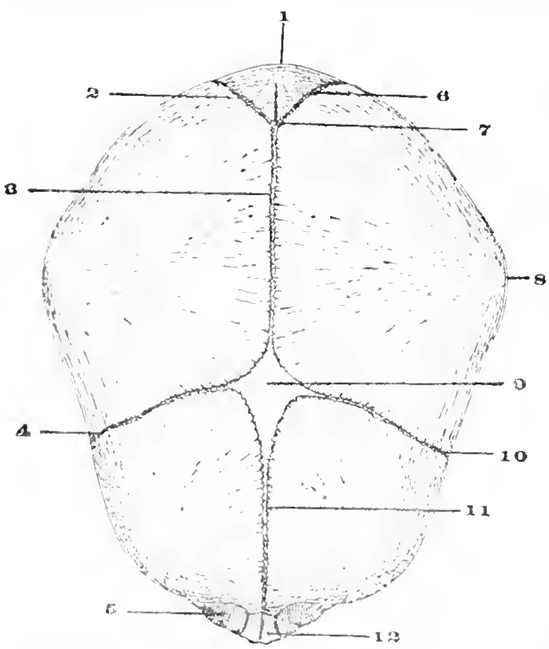


FIG. 4310.—Norma Verticalis of Infant. 1, Interparietal; 2 and 6, lambdoid suture; 7, posterior fontanel; 3, sagittal suture; 8, parietal eminence; 9, anterior fontanel; 4 and 10, coronal suture; 11, interfrontal metopic suture; 5, upper jaw; 12, nasal bone.

of the mastoid antrum. Its glenoid fossa is very shallow and has a relatively large post-glenoid tubercle.

The horseshoe shaped tympanic bone is attached to the inferior border of the squamosal by its anterior and posterior extremities. A striking feature of the norma lateralis is the absence of the bony external auditory canal. The petrosal presents a cartilaginous styloid process except for a minute nodule of bone (*tympano-hyal*) in its base. There are no mastoid sinuses, but a relatively large mastoid antrum; there is a large and conspicuous

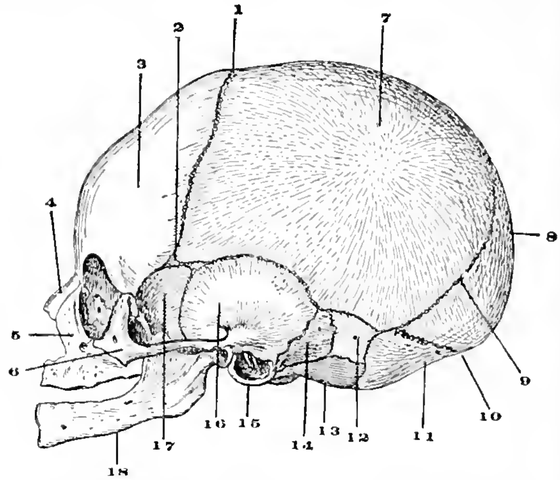


FIG. 4311.—Norma Lateralis of Infant. 1, Coronal suture; 2, antero-lateral fontanel; 3, frontal bone; 4, nasal bone; 5, superior maxilla; 6, malar; 7, parietal eminence; 8, interparietal portion of occipital bone; 9, lambdoid suture; 10, fissure between inter- and supra-occipital portions of occipital bone; 11, supra-occipital portion of occipital bone; 12, postero-lateral fontanel; 13, exoccipital; 14, petrosal; 15, tympanic plate; 16, squamosal; 17, alisphenoid; 18, mandible.

floccular fossa. The ossicles of the middle ear are about as large as in the adult. The processus gracilis may reach 2 cm. in length.

The occipital bone consists of four elements at birth, viz., *basi-occipital*, *exoccipitals*, and *squamo-occipital* (Fig. 4313). There are two deep fissures in the latter, separating it partially into a *supra-occipital* portion and an *interparietal* portion (the latter being a membrane bone). There is no jugular process or pharyngeal tubercle. The grooves for the lateral sinuses are lacking.

The maxilla presents on the oral surface of its palatine process the maxillo-premaxillary suture (Fig. 4306). The mandible at birth consists of two parts united by fibrous tissue in the line of the future symphysis menti.

The ethmoid presents three elements, viz., two lateral portions (*ectethmoids*) and a median portion (*ethmovomerine* plate). The uncinate process is undeveloped and the ethmoidal sinuses are represented by shallow depressions.

The sphenoid at birth consists of two lateral segments (*alisphenoids* with their pterygoid processes) and a composite median portion. This median portion is composed of the body of the sphenoid (ankylosed *presphenoid* and *postsphenoid*), the lesser wings of the sphenoid (*orbitosphenoids*), and the *lingulæ*. There is no foramen spinosum, and the future foramen ovale is merely a deep notch in the posterior border of the alisphenoid. The presphenoid is solid and gives no evidence of the sphenoidal sinuses which occupy this region in the adult. The Vidian canal of the adult occurs in the skull at birth as a *groove* between the lingula, the alisphenoid, and the internal plate of its pterygoid process. The sphenoidal turbinals lie in the perichondrium on either side of the ethmo-vomerine cartilage near its union with the presphenoid. They are two small triangular pieces of bone. The palate bones have their horizontal and vertical portions of the same length.

The vomer presents quite a different appearance from that in the adult.

The lachrymals are thin, delicate lamellæ. The inferior turbinal and the malar are relatively large. The nasals are broad and short.

From the above hasty survey of the skull of the new-born child it will be observed that there are many more bones than are present in the adult. At various periods in intra-uterine life the bones are still more numerous. With increasing age the bones are reduced in number through the ankylosis of two or more adjacent bony segments into composite bones. The child has fewer separate bones in his skull than the infant, the adult fewer than the child, and so on, more or less, until old age. These facts are the explanation of the occurrence of blood-vascular and nerve foramina in various parts of the adult skull.

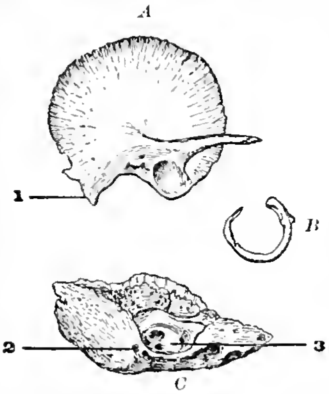


FIG. 4312.—Temporal Bone at Birth—the separate pieces. A, squamosal; B, tympanic or annulus; C, petrosal. 1, Outer wall of antrum (postauditory process); 2, stylo-mastoid foramen; 3, promontory on inner wall of tympanum proper or atrium.

The foramina and canals which transmit nerves have been subdivided into primary and secondary groups. *Primary foramina* occur at the points where the nerves leave the general cavity of the dura mater. In a morphological sense a nerve becomes extracranial where it perforates the dura mater, since this membrane largely represents the primitive connective-tissue cranium. Two illustrations of primary foramina are the *foramen magnum* and the *optic foramen*. The former is formed by four bones (the exoccipitals, the basi-occipital, and the supra-occipital) ankylosing around the medulla oblongata. The optic foramen is formed by the presphenoid and the orbitosphenoid ankylosing around the optic nerve.

Owing to the fact that human and other high vertebrate adult skulls have undergone, during the evolutionary process, complicated modifications, resulting in highly composite bones, it is observed that elaborate bony canals occur in these adult skulls that are not represented in the adult skulls of more primitive vertebrates, as the Elasmobranchs. In similar manner the adult skulls of high vertebrates contain foramina and elaborate tunnels that are not found in their embryonic condition. Such channels come under the category of *secondary foramina*. A few illustrations are as follows, viz.: the Vidian canal, to which reference has already been made; the anterior ethmoidal canal formed by bony ankylosis of the ecto-ethmoidal and the frontal bones around the nasal branch of the ophthalmic nerve; the *iter chordæ posterius* is a passageway for the chorda tympani nerve to enter the tympanum, and is formed by the ankylosis of the squamosal and tympanic bones around the nerve. The inferior dental canal of the mandible is formed by the ankylosis of several bony embryonic elements around a portion of the inferior dental nerve.

In the adult the face is at least one-half the size of the cranium. About the age of puberty the air sinuses, especially the frontal sinus, expand and develop, leading to characteristic alterations in face and head form. The age of the skull may be approximately estimated by several factors; for instance the eruption of the teeth in infancy and adolescence. When permanent dentition is completed the wear of the teeth may assist in hazarding an approximation. Complete bony union between the sphenoid and occipital bones is an indication of maturity. In old age the cranial bones become thinner and the whole skull lighter; also the condition of the sutures may guide us, since the sagittal and coronal sutures do not undergo synostosis until late in life; also at this period the obtuseness of the mandibular angle increases on account of the flattening of the vault of the hard palate, which is induced by changes in the alveolar borders of the mandible and maxillæ; for owing to the loss of the teeth in the aged, these borders become absorbed. Through this means is induced also a change in the relative position of the mental foramina.

SEXUAL DIFFERENCES IN THE SKULL.—It is always a matter of difficulty to determine with certainty the sex of a skull. The cranial capacity of the female skull is about a tenth less than the male of the same race; her skull is smaller and lighter; it has less prominent mastoid processes; it is smoother in consequence of the inferior development of the muscular ridges. The supra-orbital margin of the frontal bone is sharper and thinner in consequence of the less pronounced character of the superciliary ridges. For the same reason the frontal eminences are more conspicuous and the forehead more vertical. The parietal eminences are more prominent and the glabella less so in the female than in the male.

The edge of the tympanic plate of bone is more rounded and tubercular, whereas in the male it is sharp and divides to ensheath the styloid process. In the female the height of the skull is reduced in consequence of a more flattened vertex. No one of these sexual differences is characteristic, but taken together they enable us to arrive at a fairly accurate conclusion. It may be interesting to recall in this connection that Broca taught that if a skull rests on its mastoid processes it is almost certainly a man's.

PNEUMATIC SPACES IN CONNECTION WITH THE NASAL FOSSÆ AND THE NASOPHARYNX.—Connected either with the nasal fossæ or with the nasopharynx are the following air sinuses or pneumatic spaces, viz., the maxillary, frontal, ethmoidal, orbital, sphenoidal, and tubotympanic (Figs. 4314, 4315, 4316, and 4317).

The *maxillary sinus* or *antrum of Highmore* (Fig. 4314) occupies the body of the superior maxilla, and therefore is situated to the outer side of the nasal fossa on either side. It is a pyramidal cavity with its apex directed toward the malar bone and its base formed by the outer wall of the nose. Its walls are relatively thin and are directed forward to the face, inward to the nose, upward to the orbit, backward to the sphenomaxillary and zygomatic fossæ, and downward to the alveolar border. Portions of several bones assist in the formation of the thin osseous partition, which nearly, save for the small antral

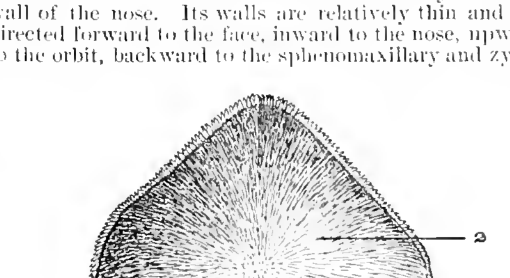


FIG. 4313.—Occipital Bone at Birth—Cerebral Surface. 2, Interparietal portion (develops in membrane); 4, supra-occipital portion (develops in cartilage); 1 and 3, infantile fissures, occasionally persists in adult; 2 and 4, form the squamo-occipital of the adult; 5, exoccipital; 6, basi-occipital.

orifices, separates it from the nasal fossa. These bones are the uncinate process of the ethmoid bone, the ethmoidal process of the inferior turbinated bone, a portion of the lachrymal, and the vertical plate of the palate bone. The floor of the antrum is separated from the roots of the molar and bicuspid teeth by bone of varying thickness. Ordinarily the floor of the antrum is on a level with the floor of the nasal fossa. But sometimes the floor of the antrum, when it is thin and devoid of spongiosa, sinks below the level of the fossa; under these circumstances suppuration at the roots of one or more of the teeth in this locality is very prone to extend to the antrum. Wide variations are noted in the size of the maxillary sinus. The cavity may be represented by a narrow cleft; more rarely it is entirely absent.

A large adult antrum will hold 32 c.c. The average capacity is 14.5 c.c. In a sinus of average dimensions the line of junction of its facial and nasal walls is indicated externally by the outer edge of the canine ridge.

Small recesses and pockets are frequently found on the inner surface of the walls of the sinus, thus favoring the collection of abnormal secretions. The sinus may rarely be completely subdivided into two compartments by a horizontal or vertical partition. In these circumstances both cavities may communicate with the middle meatus; or the superior or posterior compartment may communicate with the superior meatus, while the inferior or anterior one opens into the infundibulum. In the event of this anomaly, the surgeon might fail to find the source of suppuration in the superior or posterior compartment.

The antral orifice is unfavorably situated for natural drainage, since it is at the highest part of the antrum. It opens into the middle meatus of the nose through the posterior extremity of the hiatus semilunaris.

Ordinarily the antrum of Highmore is separated from the neighboring pneumatic spaces by thin bony partitions, and it communicates only with the nasal fossa.

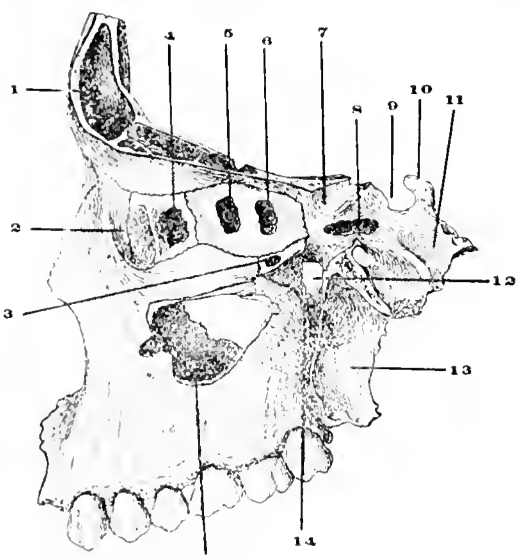


FIG. 4314. A Section of the Skull showing the Inner Wall of the Orbit and the Air Sinuses. 1, Frontal sinus; 2, lachrymal groove for the nasal sac; 3, orbital sinus; 4, infundibulum shown through opening in lachrymal bone; 5 and 6, anterior and posterior ethmoidal sinuses seen through openings in os planum of ethmoid; 7, optic foramen; 8, opening through body of sphenoid to show sphenoidal sinus; 9, pituitary fossa; 10, dorsum sellæ; 11, cavernous groove; 12, sphenopalatine foramen; 13, external pterygoid plate; 14, sphenomaxillary fossa; 15, maxillary sinus or antrum of Highmore revealed by removal of malar process.

Occasionally I have seen a direct, non-pathological channel of communication between the antrum and the anterior ethmoidal cells. In other specimens I have seen, as I explain below, a direct channel of communication between the antrum, the orbital, the posterior ethmoidal, and the sphenoidal sinuses.

At birth the maxillary sinus exists in a very rudimentary form, but reaches its full development about twelve years of age.

The opening through which the cavity may be evacuated and drained, in empyema of the maxillary sinus, may be made (1) through the canine fossa external to the canine eminence; (2) through the alveolus of the first or second molar or the second bicuspid tooth; or (3) through the lateral wall of the inferior meatus of the nose.

There are two principles that place the *canine fossa operation* at a great advantage in comparison with any other method of treatment. They are as follows, viz.: (1) by a free opening into the antrum of Highmore through the canine fossa the sinus can be carefully examined and its contents thoroughly controlled; (2) free drainage is established from the sinus into the nasal fossa and on a level with the floor of the sinus. When the bone is exposed by an incision made a few millimetres below the gingivo-labial furrow and extending from the level of the canine eminence to the first molar, the canine fossa (Fig. 4303, *32*) is broken down with mallet and chisel. The opening should be made well forward in order that it shall approach closely to the nasal wall of the sinus, and downward so as to be on a level with the alveolar floor of the cavity. An opening of this character is preferable because (1) it is most suitable for the further procedure of making the opening into the nasal fossa from the sinus; (2) it gives the best view of the sinus; (3) it is the most favorable situation for drainage. Care should be taken to avoid injury to the infra-orbital nerve. The margins of the opening should be made as smooth as possible. The mucoperiosteum should be injured as little as possible.

In creating a nasal opening from the antrum, blood should be prevented from escaping into the nasopharynx by inserting therein a small sponge attached to a tape. Prior to making the opening the anterior third of the inferior turbinal should be amputated. This gives free access to the naso-antral partition, which is to be broken through. This is done by mallet and chisel through the opening in the canine fossa. The operator should work as far forward as possible, keeping close to the antral floor. As soon as the chisel has penetrated the partition, a Krause cannula with probe-pointed trocar should be used to define and enlarge the opening. This opening should then be enlarged with mallet and chisel until the front third of the lateral wall of the inferior meatus has been removed. The opening should be large on account of the great tendency to after-contraction. During the operation care should be taken not to injure the nasal septum.

The *frontal sinus*, one on either side, lies between the outer and inner tables of the frontal bone over the root of the nose and extends outward under the superciliary ridges (Fig. 4314, *1*). The septum of bone which separates them is very seldom in the mesial plane. It may be so far removed from this plane that an opening made on one side of it may expose the sinus on the opposite side of the body. The sinus, on either side, communicates, through the infundibulum and front part of the hiatus semilunaris, with the fore part of the middle meatus of the nasal fossa. The sinus is smaller in young people and in women than in men. While there is no necessary correlation between a capacious frontal sinus and a prominent superciliary ridge, it may be stated as a general rule that there is a greater probability of the presence of a well-developed sinus where there is a prominent supra-orbital area (including a prominent superciliary ridge and nasal eminence). The outer table of the sinus is the thickest, but varies considerably in different skulls. Its average thickness is about 5 mm. It has a large amount of diploic tissue, which accounts for the possibility of septic infection when it is opened, and also for the hemorrhage that occurs from it. The inner table is thin and brittle. The floor of the cavity overlies the orbit, as well as the upper border of the lachrymal and the anterior part of the superior border of the lateral mass of the ethmoid. The floor is the thinnest wall, especially at the supero-internal angle of the orbit. Accordingly when there is empyema of the sinus the pus tends to point at the upper and inner angle of the orbit. This pneumatic chamber may extend upward on the forehead for 40 mm.; laterally as far as the external angle of the orbit; backward as far as the lesser wing of the sphenoid, on either side, thus separating the horizontal portion of the frontal bone (the roof of either orbit) into two tables, viz., orbital table and cerebral table. It may communicate by a large opening with a well-marked sinus in the crista galli.

The cavities are very unsymmetrical and irregular. They may be very small or altogether absent. The sinus may be present on one side and absent on the other. The sinus becomes funnel-shaped as it passes downward to the ethmoidal infundibulum. The ostium of the frontal sinus is found at a short distance from the septum and at the most dependent part of the cavity. It may be situated 28 mm. behind the outer table of the frontal bone. Incomplete trabeculæ of bone often divide the sinus into recesses of various sizes and shapes.

The frontal sinus is absent at birth. It appears about the seventh year and develops only slightly up to puberty, when it increases rapidly in size, reaching its maximum growth about the twentieth year.

When through empyema or other diseases of the frontal sinus it becomes necesary to open the cavity, there are several methods of procedure. 1 The infero-external wall (orbital surface) of the sinus may be opened at the upper and inner angle of the orbital fossa. The orbital surface of the sinus must be so freely removed that the little finger can be passed into the cavity after its contents have been thoroughly evacuated by syringing with an antiseptic solution. The little finger of the other hand should be placed in the corresponding nostril and pushed up to a point where the finger in the sinus can be felt. With a sharp gouge an aperture of considerable size should be made along the space between the two fingers. A serious objection to this operation is the almost certain injury of the pulley attachment of the superior oblique muscle and the production thereby of distressing diplopia. 2. A more satisfactory procedure, after exposing the bone by making an incision through the shaven eyebrow, is to open the cavity through the external table of the vertical portion of the frontal bone—that is, through the forehead. After the tissues have been raised and turned back sufficiently to expose the bone, the cavity is best entered just above the mesial or inner extremity of the supra-orbital margin, and slightly lateral from the median line of the forehead. On account of the very great variations of the shape and size of the sinus the safest procedure is to open its outer wall by a small drill run by an electric motor and controlled by a foot-switch, though the mallet and chisel are much used. The sinus can be explored with a probe through this opening and the relations of its walls and its size determined. Then a button of bone may be removed by a trephine, or a larger drill may be used, or the mallet and chisel. Care should then be exercised in securing a large opening into the nasal fossa in the same manner as indicated in the operation through the orbital surface. This operation not only avoids the possibility of injuring the superior oblique muscle, but facilitates direct inspection and treatment of the sinus.

Lothrop's observations on the cadaver have demonstrated—and the demonstration can be verified by any experienced anatomist in the dissecting-room—that it is impossible to pass a probe from the nose through the infundibulum into the frontal sinus in the majority of subjects. Much more difficult is the procedure in the living subject. In many cases the frontal sinus can be catheterized when free access to the infundibulum is secured by amputating the anterior end of the middle turbinal. The care with which catheterization of the frontal sinus should be carried out is best emphasized by citing the case recorded by Mermod, an experienced rhinologist. He observed a case in which a watery fluid was escaping from one nostril, and judged that it came from the corresponding frontal sinus. The attempt at catheterization induced so much pain that he was compelled to desist. The patient died some days later, and an autopsy showed the entire absence of any frontal sinus. The watery fluid which escaped through a small opening in the floor of the anterior cranial fossa was probably

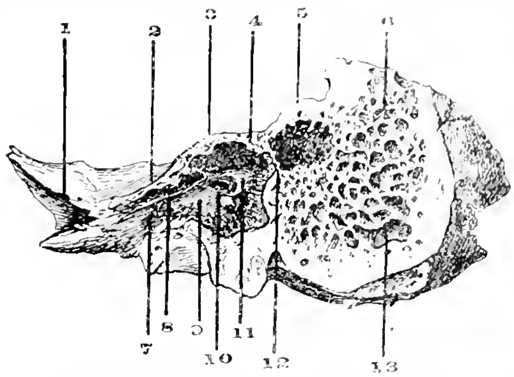


FIG. 4315.—Tubotympanic Pneumatic Cavity and Mastoid Sinuses, shown by removal of outer boundaries of the petromastoid portion of the temporal bone. 1, Carotid canal; 2, tegmen tympani over tube for tensor tympani muscle; 3, tegmen tympani over attic; 4, part of external wall of antrum; 5, tegmen tympani over antrum; 6, mastoid cells; 7, Eustachian tube; 8, processus cochleariformis; 9, promontory in atrium; 10, foramen ovale; 11, external horizontal semicircular canal; 12, part of external wall of antrum; 13, mastoid cells.

cerebrospinal fluid. Pyogenic infection was doubtless carried within the cranial cavity, although every antiseptic precaution had been observed in attempting to catheterize the supposed frontal sinus.

The *ethmoidal sinuses* (Fig. 4314, *5* and *6*) are placed between the cavities of the orbit and the supero-lateral part of the nasal fossæ, being separated from them by thin and papery walls. These pneumatic spaces are completed by the ethmoids articulating with the sphenoidal turbinate, palate, frontal, lachrymal, and superior maxillary bones.

The thin partitions are frequently absent at various points. For instance, some of the ethmo-maxillary septa may be absent, thus permitting the ethmoid cells to communicate directly with the maxillary sinus, as already mentioned; again the ethmo-frontal (orbital plate) partitions may be deficient so that a direct communication may exist between ethmoid cells; and, finally, a large sinus is sometimes present between the two walls of the orbital plate and extends well back toward the optic foramen.

The sinuses are separated into two groups by thin bony septa—an anterior and a posterior group. The anterior and sometimes a middle group of cells open either independently or through the ethmoidal infundibulum into the upper part of the hiatus semilunaris, and therefore into the middle meatus of the nasal fossa; the posterior ones open into the superior meatus. Ordinarily the ethmoidal cells are separated from the orbital cavity by the thin plate of bone called the *os planum*. Occasionally, as a result of arrest of development and in old people, the os planum may be defective in parts and the sinuses are then separated from the orbit only by membrane. A study of horizontal and coronal sections will disclose the fact that the pneumatic spaces increase in size from above downward, and from before backward.

The anterior ethmoidal cells ordinarily communicate, through the infundibulum, with the frontal sinus; occasionally they communicate directly with the maxillary sinus. The posterior ethmoidal cells occasionally communicate with the orbital sinus, and may through the latter communicate with the sphenoidal sinus or the antrum of Highmore, or with both the latter

The ethmoidal cells, on account of their irregular and complicated anatomical features and the importance of their topographical relations, deserve very careful study, with the help of both macerated and recent specimens. Empyema of the ethmoidal cells is frequently associated with pus formation in one or several of the other pneumatic spaces, and may lead to very grave complications involving vision or even life.

The ethmoidal cells are usually absent in infant skulls. They appear about the fourth year, and reach their full development about the twentieth year.

The only effective treatment of disease of the ethmoidal sinuses is to open them freely through the nasal fossa and then to curette them. As a preliminary step, however, the middle turbinal should be more or less extensively removed.

The *orbital sinus* is situated in the orbital process of the vertical plate of the palate bone (Fig. 4314, *3*). The orbital process, therefore, from an ophthalmological and rhinological point of view, is a very important structure, whose relative anatomy should be carefully studied. It presents five surfaces, three of which are *articular*, and two free or *non-articular*. The maxillary surface looks forward, outward, and downward, and articulates with the superior maxilla; the ethmoidal surface looks inward, forward, and upward, and articulates with the lateral mass of the ethmoid, helping to close in the posterior ethmoidal cells; the sphenoidal surface looks backward, inward, and upward, and articulates with the vertical portion of the sphenoidal turbinated bone. The zygomatic surface lies in the spheno-maxillary fossa, looking toward the zygomatic fossa. The orbital surface helps to form the floor of the orbital fossa at its apex. Ordinarily the orbital pneumatic space or sinus communicates with the sphenoidal sinus. Sometimes it communicates with the posterior ethmoidal cells. On several occasions I have seen it communicate not only with both of the above-mentioned pneumatic spaces, but also with the antrum of Highmore, so that there has been a direct continuity between the maxillary, orbital, posterior ethmoidal, and sphenoidal sinuses. Under these circumstances a severe empyema of these sinuses, leading to caries of bone, could produce grave complications, jeopardizing life through extension to the brain, or vision through extension to the orbit and its contents.

The *sphenoidal sinuses* (Fig. 4314, *8*), very variable in shape and size, are usually separated from one another by a sagittally placed bony septum. This septum is frequently displaced to one or other side, and may be more or less oblique. The sinuses are situated in the body of the sphenoid and often extend well down into the pterygoid processes and out into the bases of the great wings of the sphenoid.

In front and below they are bounded, in part, by the sphenoidal turbinated bone. Above the latter an irregular opening is left by which the sphenoidal sinuses communicate with the upper and back part of the nose in the region of the spheno-ethmoidal recess. Occasionally they communicate with the posterior ethmoidal cells.

One or both of the sinuses may be absent or replaced by diploë. The sphenoidal sinus is not present at birth. The time of its appearance is stated to be the third year (Steiner), seventh year (Laurent), or the twentieth year (Tillaux).

The location of the nasal opening into the sphenoidal sinus varies very much. In empyema of the sinus a probe, or the long, slender nozzle of a syringe, can sometimes be made to enter the cavity by passing it directly backward along the inferior margin of the middle turbinal. In other cases the sphenoidal opening is more laterally placed and on a higher level. Under these circumstances the probe must cross the posterior third of the turbinal and curve outward. Certain diseases of the sinus require that it should be freely opened. The distance of the anterior wall of the body of the sphenoid from the end of the nose should be ascertained and indicated on the drill. The anterior wall should then be drilled carefully and, sufficient allowance for the penetration of the wall being made, the surgeon knows precisely the distance beyond which the drill should not be passed. A sufficient opening having been made by the drill, the cavity is cleansed by curetting.

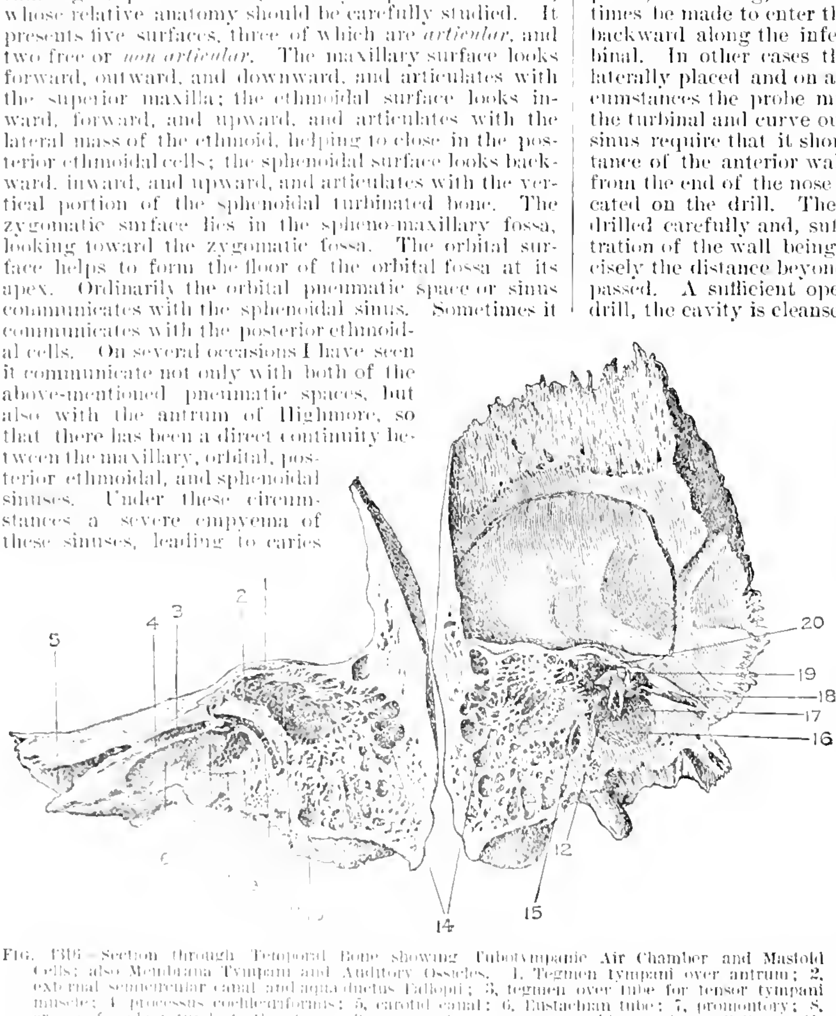


FIG. 4316.—Section through Petrous Bone showing Tubotympanic Air Chamber and Mastoid Cells; also Membrana Tympani and Auditory Ossicles. 1, Tegmen tympani over antrum; 2, external semicircular canal and aquæductus Fallopii; 3, tegmen over tube for tensor tympani muscle; 4, processus cochleariformis; 5, carotid canal; 6, Eustachian tube; 7, promontory; 8, crosses fossula rotunda to the stapes; 9, recessus hypotympanicus; 10, aquæductus Fallopii; 11, diploetic tissue at posterior part of atrium with the aquæductus Fallopii descending through it; 13, antrum; 14, mastoid cells; 15, aquæductus Fallopii; 12, body and short ramus of incus in the attic; 16, membrana tympani; 17, manubrium of malleus; 18, tensor tympani muscle; 19, head of malleus in the attic; 20, tegmen tympani roofing attic.

The Tubotympanic Cavity or Pneumatic Chamber (Figs. 4309, 4315, 4316, and 4317).—This cavity, though varying much in its dimensions in individual cases, is practically of full size at birth. From an anatomical and pathological point of view it is well to remember that the tympanum consists of three very important divisions, viz., the *mastoid antrum*, the recessus epitympanicus or *attic*, and the tympanum proper or *atrium* (Fig. 4315). The recessus hypotympanicus is an arbitrary subdivision of the atrium, interesting because of its relation to the jugular fossa. At birth the mastoid cells do not exist.

The *mastoid antrum*, like the other subdivisions of the tympanum, is practically of the same size at birth as in the adult. Its roof is formed by the thin *tegmen tympani*, and extends forward as the roof of the attic and tensor tympani canal. It communicates in front with the attic. In the rest of its course it is bounded by the diploëtic and pneumatic tissue of the bone. Its vertical measurement is about 7 mm.; the transverse measurement is about 9 mm. At birth the outer wall is bounded by a thin plate of bone belonging to the squamous portion of the temporal bone (squamosal) (Fig. 4312, *A*, *D*), and is only about 1 or 2 mm. thick, but it increases to about 10 mm. at the ninth year. Coincidently with the development of the mastoid process (which begins at the second year and reaches its maximum growth after puberty) the mastoid cells (Fig. 4315, *6* and *13*) develop backward and downward as radiate or racemose diverticula from the tabotympanic pneumatic space, especially from the antrum, and show in different skulls the greatest possible variations. Up to the second year the tiny mastoid contains only diploëtic structure, and in the developed bone this may never be wholly displaced. Randall states that in his study of a thousand bones he found scarcely two per cent. which could be classed as diploëtic, and only about ten per cent. revealed a notable amount of diploë combined with the pneumatic spaces. No mastoid is entirely pneumatic, though we may meet with a large, thin-walled, single pneumatic space occupying the greater part of the process in senile bones.

Through osteosclerosis a solid mastoid process may occasionally be seen. The pneumatic cells, when present, are not limited to the mastoid process, but extend upward toward the squama, forward over the roof of the external auditory canal, and may extend into the zygomatic process; some generally extend into the floor of the Eustachian tube lying in close relation with the carotid artery; others may extend inward toward the temporo-occipital suture, sometimes invading the pars jugularis of the occipital bone. While a dolichocephalic skull is more likely to present a pneumatic mastoid than a brachycephalic one, and while a prominent, large mastoid is more liable to be pneumatic than a small, ill-developed one, there is no method of determining beforehand the condition of the interior of the bone.

The antrum merges, anteriorly, almost imperceptibly into the attic through a triangular-shaped, hour-glass contraction called the *aditus*, made by the outward bulging, from the inner wall of the tympanum, of the horizontal semicircular and facial-nerve canals. The boundaries of the *aditus* (Fig. 4317, *1*, *2*, *12*) are very important surgically and are as follows, viz.: *above*, the base of the triangle is formed by the tegmen tympani; the *inner boundary* is formed by a prominence of compact bone containing the external semicircular canal, and below and in front of this is the portion of the aqueductus Fallopii winding above and behind the fenestra ovalis. The bony wall of the aqueduct at this point is very thin, and at times entirely lacking, so that an inflammation of the tympanum can readily extend to the facial nerve. The *outer wall* of the aditus is formed by the deepest part of the postero-superior wall (squamosal) of the bony external auditory canal. The *apex* of the triangular aditus is formed by the junction of the outer and inner walls in this region. Ordinarily the aditus will admit an instrument about 5 mm. in diameter.

The *attic* (Figs. 4315, *3*; 4309, *24*) is broadest above where it has as its roof the *tegmen tympani*, the latter extending backward as the roof of the antrum and forward as the roof of the canal for the tensor tympani muscle. It is about 7 mm. in its antero-posterior direction, about 5 mm. vertically, and 4 mm. in breadth. The roof, sometimes deficient to a varying degree, separates the tympanic cavity from the cranial cavity; it is limited externally by the *petrosquamous suture* (Fig. 4318, *A 1*, *B 1*). This suture may remain unossified for several years after birth or even permanently and thus afford a channel by which pyogenic infection may spread from the tympanum to the meninges and brain.

The attic overhangs markedly the inner end of the external auditory canal (Fig. 4309, *7*, *24*). It opens backward into the antrum and downward and inward into the *atrium* or tympanum proper. In the rest of its course it is surrounded by the diploëtic tissue of the bone. It contains, enveloped by mucous membrane, the head of the malleus, the body and the short process of the incus, the latter projecting into the aditus.

The *atrium* or tympanum proper (Fig. 4315, *9*) is that portion of the general tympanic cavity which is below the attic and internal to the membrana tympani. It is bounded externally by the tympanic bone or annulus and the membrana tympani, which is fixed in the tympanic groove of the bony ring.

On a level with the upper edge of the membrana tympani in front of the annulus is the tympanic end of the *Glaserian fissure* (remnant of the fissura petrotympanica). Close to the inner end of this fissure, and forming a division of it, is the commencement of the *iter chordæ anterius*, which transmits the chorda tympani from the tympanum.

It is bounded internally by the outer surface of the labyrinth or internal ear. It presents, in the macerated bone, (1) a reniform opening (*fenestra ovalis*) which leads into the vestibule of the labyrinth, but in the recent state of the bone this opening is closed by the foot of the stapes, surrounded by its *ligamentum annulare*. Below this is (2) a rounded eminence (*promontory*) due to the first turn of the cochlea. (3) Above and behind the fenestra ovalis is a portion of the *aqueduct of Fallopius* or canalis facialis. (4) In front of the fenestra ovalis is the *processus cochleariformis*, which here makes a sharp turn outward, and forms a pulley over which the tendon of the tensor tympani muscle plays. (5) A funnel-shaped recess (*fossula fenestræ cochleæ*) is situated at the postero-inferior part of the promontory, and is directed toward the *fenestra rotunda*, which in the macerated bone leads into the cochlea, but in the recent state is closed by a membrane (*secondary membrana tympani*).

The anterior wall of the atrium is narrowed vertically by the ascent of the floor and descent of the roof, and transversely by the approximation of the inner and outer boundaries of the cavity. At this point are two bony parallel canals separated by the bony *processus cochleariformis* and placed one above the other. The upper is the canal for the tensor tympani muscle, while the lower is the osseous Eustachian tube. The latter communicates with the nasopharynx through the membrano-cartilaginous Eustachian tube.

The posterior wall of the atrium presents from above downward the following: 1. A minute conical bony eminence (*pyramid*). The pyramid is hollow and contains the stapedius muscle. The tendon of the stapedius perforates the apex of the pyramid, and is inserted into the posterior surface of the neck of the stapes. The base of the pyramid communicates with the aqueduct of Fallopius by one or two small foramina for the passage of the nerve and vessels to the stapedius. 2. Immediately below the pyramid is the minute aperture of the *iter chordæ posterius*, which communicates with the aquæductus Fallopii and transmits the *chorda tympani nerve* from the facial nerve to the tympanic cavity. The chorda tympani, covered by mucous membrane, passes along the upper border of the drumhead between the handle of the malleus and the vertical ramus of the incus to enter the iter chordæ anterius. 3. There is sometimes seen below the aperture of the iter chordæ posterius a rounded eminence (*prominentia styloidea*) which is caused by the forward and upward prolongation of the styloid process. The aqueduct of Fallopius continues down from the posterior part of the fenestra ovalis through the diploëtic tissue of the posterior wall of the atrium to the stylomastoid foramen.

The front part of the *floor* of the atrium is in relation with the first bend or convexity of the carotid canal. At this point the bony septum may be absent and the artery separated from the tympanum only by membrane.

It may be well to state at this point that the outer wall of the carotid canal is in very close proximity to the bony Eustachian tube, and since dehiscence of the bony septum is here more frequent, the aural surgeon should always exercise great care in bougieing this passage.

The back part of the floor of the tympanum is in relation with the jugular fossa and presents small depressions separated by slight bony trabeculæ, thus producing an irregular region that has been called the *recessus hypotympanicus*. It is important because it is often quite encroached upon by the bulb of the internal jugular vein in the jugular fossa.

At times the lateral sinus is unusually large and arches far forward. Under these circumstances the bulb of the internal jugular is unduly large, and the jugular fossa which contains it may arch well up into the floor of the tympanum and be separated from the cavity by a thin and translucent septum of bone, or even the bone may be dehiscent. In such cases as this the bulb of the internal jugular has been wounded in performing a paracentesis of the tympanic membrane or drumhead.

In the antero-posterior direction the atrium measures about 12 mm., of which 9 mm. is bounded by the membrana tympani; from the floor of the atrium to the commencement of the attic is about 10 mm.; the narrowest part of the atrium, 2.5 mm., is caused by the outward projection of the promontory and the inward traction of the centre of the membrana tympani (*umbo*). Owing to the great obliquity of the drumhead the handle of the malleus is very obliquely placed in the drum; also the long ramus of the incus is quite oblique. The stapes, since it is placed at a right angle to the tip of the long ramus of the incus, passes upward and inward very obliquely toward the fenestra ovalis. The atrium is placed in the midst of the temporal bone, about 20-35 mm. from the entrance of the external auditory canal.

BONY LANDMARKS OF THE SKULL (Figs. 4303, 4304, 4305, 4319).—Among the many landmarks of the skull the following can readily be palpated, viz.: the inion, lambda, glabella, nasion, mastoid process, the supramastoid crest, suprameatal spine, nasal spine, osseous anterior nares, the bridge of the nose, the superciliary ridges, the external and internal angular processes of the frontal bone, the infra- and supra-orbital margins, the supra-orbital notch, the malar bone, the anterior part of the temporal crest, the region of the canine fossa of the superior maxilla, the lower portions of the borders of the ramus, the angle and mental tubercle of the mandible, and the zygomatic arch.

The *inion* is about 50 mm. above the spine of the axis or second cervical vertebra and 25 mm. below the posterior pole of the cranium. The inion not being developed in the child, its position is defined by taking a point at the junction of the middle and upper thirds of a line drawn from the spine of the axis to the posterior pole of the cranium.

The *lambda* can generally be felt through the scalp and is situated about 63 mm. above the inion. The parieto occipital fissure, in the adult, lies opposite, or a few millimetres in front of, the lambda; in the child the fissure may be as much as 25 mm. in front of it.

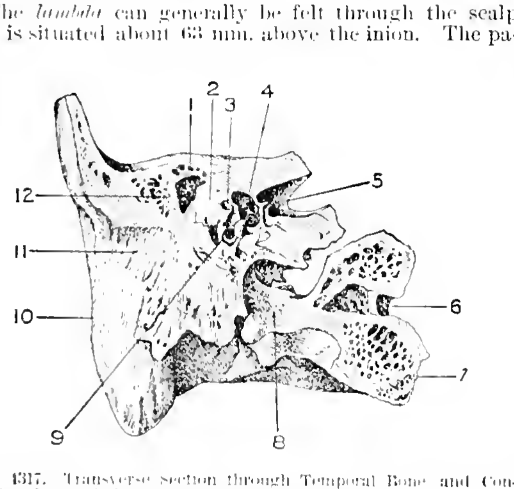


FIG. 4317. Transverse Section through Temporal Bone and Condyle of Occipital Bone, showing especially the *Aditus*. 1, Tegmen tympani roofing in the aditus; 2, inner wall (external semicircular canal) of the aditus; 12, outer (squamosal) wall of aditus; 3, aqueductus Fallopii; 4, vestibule; 5, internal auditory canal; 6, part of anterior condyloid foramen; 7, condyle of occipital bone; 8, jugular foramen; 9, pyramid with foramen at apex for exit of tendon of the stapedius muscle; 10, mastoid portion of temporal bone; 11, external auditory canal.

The *bregma*, in the child, is occupied by the anterior fontanel; in the adult it is about a third of the distance from the nasion to the inion.

The *zygomatic arch* is a very important landmark. In the natural position of the head it is horizontal, and is on the same level as the inion and the infra-orbital margin. Its upper border about indicates the level of the lower lateral margin of the cerebral hemisphere. By tracing the upper border of the zygoma backward we shall find that it passes immediately above the tragus and the external auditory canal to become continuous with the *supramastoid crest* or posterior root of the zygoma (posterior portion of the temporal crest).

If a line is carried in a vertical coronal plane from the *pre-auricular point* on one side to that on the other, it will pass through the bregma. The *lower end* of the fissure of Rolando is situated 50 mm. vertically above the pre-auricular point.

The *pterion* cannot be felt, but may be located two fingers' breadth (37 mm.) vertically above the middle of the zygomatic arch. It locates the *Sylvian point*—the point where the fissure of Sylvius divides into its three branches; it overlies also the anterior branch of the middle meningeal artery.

The posterior extremity of the *left* inferior frontal convolution (*Broca's convolution*) is situated about three fingers' breadth (56 mm.) above the middle of the left zygomatic arch.

The junction of the motor areas for the face and arm is situated at the junction of the lower and middle thirds of the Rolandic area, which is indicated by the highest part of the *temporal crest*.

The *parietal eminence* overlies the supramarginal convolution of the brain, and therefore also the terminal part of the posterior horizontal limb of the fissure of Sylvius.

The *frontal eminence* overlies the middle frontal convolution of the cerebrum.

Slightly above the outer canthus of the eyelids is located the *fronto-malar suture*, directly above which is the *external angular process* of the frontal bone. The lower lateral margin of the frontal lobe of the cerebrum is situated 12 mm. above the tip of the external angular process. About 12 mm. below the process is a small *tubercle* on the posterior border of the malar bone; a line drawn from this tubercle to the lambda overlies the superior temporo-sphenoidal fissure (*parallel fissure*) and corresponds to the descending horn of the lateral ventricle. That part of the temporal crest which extends between the external angular process and the coronal suture is located a little above the level of the inferior frontal fissure.

Situated at the junction of the inner and middle thirds of the supra-orbital margin is the *supra-orbital notch*. A line carried downward from this notch to the lower border of the mandible and crossing the interval between the lower bicuspid teeth will pass over the *infra-orbital* and *mental* foramina, the latter being situated about midway between the upper and lower borders of the mandible, while the former is about 12 mm. below the infra-orbital margin. These foramina furnish the guides for the operation of neurectomy to relieve neuralgia of the trifacial nerve.

On a level with the crown of the last molar tooth and midway between the posterior and anterior borders of the ramus of the mandible the inferior dental nerve enters the inferior dental canal on the inner surface of the ramus of the mandible. Consequently neurectomy of this nerve can be performed by trephining the corresponding outer surface of the ramus. Since the lingual nerve lies a little anterior to the inferior dental nerve, it can be exposed through the same opening.

A landmark of interest to ophthalmic surgeons is the *lachrymal tubercle*, which is situated at the junction of the infra orbital margin belonging to the body of the superior maxilla, and the anterior border of the lachrymal groove on the nasal process of the superior maxilla. In the operation for lachrymal fistula it serves as a guide to the position of the lachrymal sac.

The lachrymal groove is a bony groove situated between the crest of the lachrymal bone and the nasal process of the superior maxillary bone. It contains the lachrymal sac, which is the most important part of the lachrymal apparatus, since it is the seat of very disfiguring diseases. The lachrymal groove is directly continuous with the nasal duct. The latter passes downward and slightly backward and outward to open, under cover of the anterior extremity of the inferior turbinated bone, into the inferior meatus of the nose, at the junction of its anterior fourth with its posterior three-fourths, at a distance of from 30 to 35 mm. from the posterior boundary of the nostril.

The general direction of the duct is best expressed by a line extending from the inner canthus of the eye to the interval between the premolar and the first molar tooth of the upper jaw.

The sac measures from 12 to 15 mm. in length, from 4 to 5 mm. in breadth, and about 7 mm. antero-posteriorly. It is narrowest at its termination in the nasal duct.

The nasal duct has a diameter of 3 or 4 mm., and averages about 18 mm. in length. The duct is somewhat narrower near its middle than at its lower or its upper extremity.

On the living subject by drawing the lids outward, the *internal palpebral ligament* (tendo oculi) is made tense, and can be felt as a narrow tense band passing inward transversely, and in front of the lachrymal sac, to be attached to the nasal process of the superior maxillary bone. The ligament passes a little above the centre of the lachrymal sac, and is a guide to its position. Spontaneous rupture of an abscess of the lachrymal sac almost invariably takes place just below the internal palpebral ligament. In opening a lachrymal abscess in this the best location, the incision should be made a little external to the angular artery.

The position of the mastoid antrum is represented by Macewen's *suprameatal triangle*, situated a little behind and above the bony external auditory canal. This triangle is bounded by the postero-superior segment of the bony external auditory canal below, by the supramastoid crest above, and by an imaginary line joining the above boundaries. According to Macewen, if the aperture of the bony external auditory canal be bisected horizontally, the upper half would approximately be on a level with the mastoid antrum. On bisecting this upper segment vertically its posterior half would correspond roughly to the junction of the antrum and the attic, and immediately behind this is the suprameatal triangle.

Macewen states that the level of the base of the brain will be 1 or 2 mm. above the supramastoid crest and about 5 or 6 mm. above the roof of the osseous external auditory canal.

The supramastoid crest, which indicates the roof of the antrum as well as the floor of the middle cranial fossa, may vary as much as 20 mm. down or up. Measurements on large numbers of skulls show that the middle cranial fossa is never 10 mm. below the supramastoid crest. But the crest is sometimes imperfectly developed and cannot be relied upon as a landmark.

The *suprameatal spine* is situated at the postero-superior portion of the aperture of the bony external auditory canal, and has the suprameatal triangle or fossa back of it (Fig. 4304, *28 a*). This spine can almost invariably be recognized as indicating the postero-superior portion of the opening of the bony meatus. Randall states that he has found the floor of the middle cranial fossa as low as this spine only five times in one thousand bones. It averages about 6 mm. above the spine. The suprameatal spine is a safer guide for avoiding the middle fossa of the cranium than is the supramastoid crest.

In opening the mastoid sinuses it should be borne in mind that the *mastoid foramen*, extending from that portion of the groove for the lateral sinus called the *sigmoid fossa*, and terminating on the exterior at or near the occipito-temporal suture, is very variable in size. It usually transmits a small emissary vein from the lateral sinus to the occipital vein. Sometimes the foramen may be so large as to transmit all the blood from the lateral sinus to the external jugular vein.

The sigmoid fossa, and consequently the lateral sinus, varies very much in its outward curving; it may even project to the external cortex or table of the mastoid process.

In operating upon the mastoid antrum the surgeon chisels away the bone immediately behind and above the postero-superior quadrant of the osseous external auditory canal and endeavors to avoid the *middle fossa* of the cranial cavity by keeping below the suprameatal spine. In opening the mastoid cells he hopes to avoid the *lateral sinus* by chiselling obliquely to the surface and keeping parallel with and close to the external auditory canal. He avoids the *descending portion* of the *facial nerve* by not encroaching upon the lower half of the deepest portion of the posterior wall of the osseous canal.

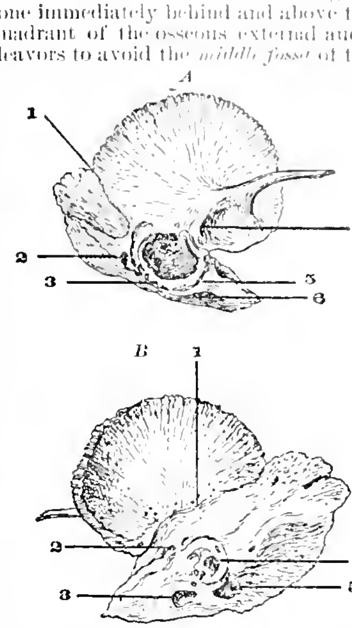


FIG. 4318.—Temporal Bone at Birth. *A*, Outer view. 1, Petrosquamous suture; 2, stylomastoid foramen; 3, tympanic plate; 4, postglenoid tubercle; 5, petrotympanic suture; 6, carotid canal. *B*, Inner view. 1, Petrosquamous suture; 2, hiatus Fallopii; 3, internal auditory canal; 4, floccular fossa; 5, aquaeductus vestibuli.

On account of the non-development of the mastoid process and the tympanic plate in the infant the stylomastoid foramen is situated upon the *lateral surface of the skull* instead of at its base (Fig. 4318, *A*, *2*). Hence the facial nerve emerges from the foramen immediately behind the annulus, and is unprotected. Therefore in infants the incision through the integument and subjacent soft parts, for the purpose of reaching the cranial wall, should not extend too far forward and downward, otherwise the facial nerve will be severed.

CRANIO-ENCEPHALIC TOPOGRAPHY (Fig. 4319).—In the study of what is commonly called *cranio-cerebral* topography, it should be clearly understood that we are to deal not only with the cerebrum, but also with the cerebellum, the ganglia of Gasser, and the brain's meninges or coverings; and the dura mater contains the middle meningeal arteries, and those venous channels called lateral sinuses and superior longitudinal sinus, not to mention other structures of less conspicuous importance from the point of view of applied anatomy. Also in relation with the arachnoid mater is the *cisterna magna*, the largest of the subarachnoidan spaces.

It would seem that the use of the term *cranio-encephalic* topography would be more conducive to accuracy than the more commonly employed expression craniocerebral topography. It may not be amiss to recall the fact that cranio encephalic topography must not be confounded with the cranioscopy of the phrenologists, a pseudo science founded by Gall. Gall quite arbitrarily localized the different intellectual faculties in various parts of the brain, and attempted to establish a relation between certain irregularities or bumps on the surface of the skull and the parts of the brain in which were resident the intellectual faculties. It is now known that the irregularities and bumps of the external table of the cranial walls have no relation whatever with the inequalities of the internal table, and still less have they anything in common with the configuration of the brain's various components.

The human skull varies greatly, in the details of its conformation, according to race, age, sex, and even stature, not to mention pathological variations. In no two individuals of the same race, age, sex, and stature are the skulls ever precisely alike; nor, under such circumstances, are the fissures and convolutions of the brain ever identical in pattern. The relations of the brain's convolutions and fissures to definitely chosen anatomical points on the surface of the skull or scalp vary in individuals of the same race, etc. Lastly, as the convexity or surface area of the brain is always less than the outer surface area or convexity of the skull, and still less than the surface of the scalp, lines drawn on the scalp cannot always correspond exactly to the fissures and convolutions of the brain.

In view of the preceding facts the well informed anatomist knows that the anatomical lines used in cranio-encephalic topography to locate fissures, convolutions, and areas of the brain are simply approximations—approximations that have been correlated from examinations of many brains and skulls. Fortunately, these approximations are found to be exceedingly useful as reliable guides in surgical anatomy. Practically, the surgeon uses the lines and points correlated by the anatomist, and overcomes the difficulties due to variations in individuals, by removing a greater area of the cranial wall than that indicated to him by the anatomist's lines and points as corresponding to the portion of the encephalon which he desires to expose. The brilliant results of modern cerebral surgery clearly proclaim the practical utility of the anatomist's approximations in cranio-encephalic topography.

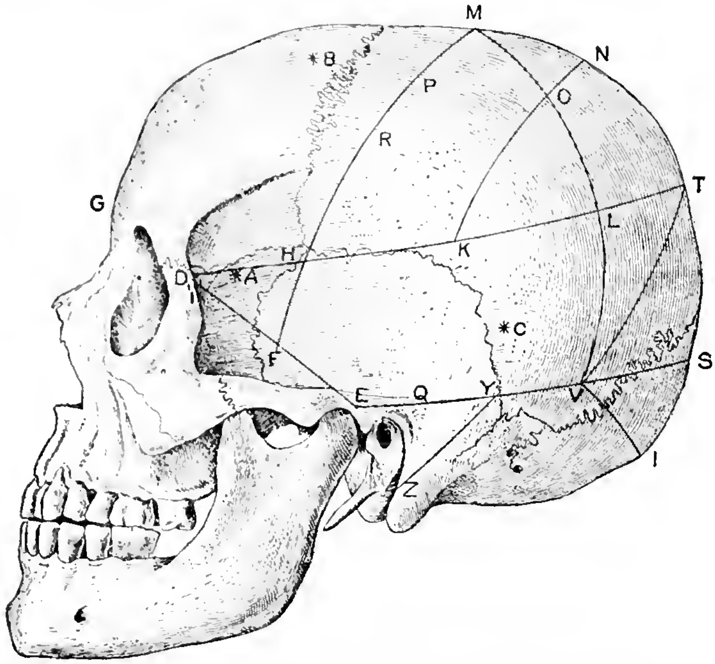


FIG. 4319.—Chiene's Guiding Lines in Cranio-Encephalic Topography. *G*, glabella; *I*, inion and indicates site of torcular Herophili; *M*, mid-point between *G* and *I*; *T*, three-quarter point between *G* and *I* and overlies parieto-occipital fissure; *S*, seven-eighth point between *G* and *I*; *E*, pre-auricular point on root of zygoma; *Q*, post-auricular point on supramastoid crest; *Y*, a finger's breadth behind *Q*; *V*, mid-point of line *E S* and marks highest convexity of lateral sinus; *Z*, near tip of anterior border of mastoid process; *D*, external angular process of frontal bone; *F*, mid-point on line *D E* and overlies point of bifurcation of middle meningeal artery; *H*, Sylvian point located by intersection of the Sylvian line *D T* and the line *F M*; this Sylvian point overlies the Sylvian point of the fissure of Sylvius and also the anterior division of the middle meningeal artery; *L* indicates angular gyrus and extremity of parallel fissure and is located by the intersection of line *D T* and line *V M*; *K*, mid-point of line *H L*; *H M*, precentral line and overlies precentral fissures; *K N*, line drawn from *K* to median sagittal plane parallel with *H M* and is the postcentral line; *H A*, anterior horizontal limb of the Sylvian fissure; *H K*, posterior horizontal limb of the Sylvian fissure; *O K L*, triangular area indicating parietal eminence, supramarginal convolution, and terminal part of Sylvian fissure; *R*, at the level of the temporal crest and on line of inferior frontal fissure; *P*, on line of superior frontal fissure; *T V* courses a little in front of the lambdoid suture; *T V I*, triangular area indicating occipital lobe of cerebrum; *I V Y Z*, guiding lines for lateral sinus; below *I V Y Z* is the region of the cerebellar hemisphere; *F E V L H*, pentagon indicating temporal lobe of the cerebrum except the apex which projects a finger's breadth downward, forward, and inward from *F*; *H K N M*, parallelogram indicating cortical motor area (Rolandic area); *A, site for opening subarachnoid space; *B, Kocher's point for tapping the lateral ventricle; *C, Keen's point for tapping the lateral ventricle; *Y Z*, indicating anterior limit of lateral sinus.

Many methods have been devised for mapping out the relations of the scalp to the cranial contents. From a clinical point of view, that introduced by Professor John Chiene, of Edinburgh, is a very simple and useful one (Fig. 4319). His method is as follows, viz.: The head being shaved, the *mid-point* (*M*) is located in the sagittal plane of the vertex from the glabella (*G*) to the inion (*I*); then the *three-quarter point* (*T*); and then the *seven-eighth point* (*S*). Next locate the *pre-auricular point* (*E*) on the root of the zygoma, and the *external angular process* (*D*) of the frontal bone. Having located these points join *D T*, *E S*, and *D E*. Bisect *E S* at *V* and *D E* at *F*. Draw the line *F M* and also the line *V M*. Bisect *H L* at *K* and draw a line from *K* to *N* parallel to *H M*. Trisect *H M* at the points *R* and *P*. Draw a line from *T* to *V* and another from *V* to *I*. A finger's breadth (18 mm.) posterior to the *post-auricular point* (*Q*) is the point *Y*; at the tip of the anterior border of the mastoid process is the point *Z*. A line drawn from *Y* to *Z* indicates the anterior border of the mastoid portion of the *lateral sinus*. The line *H M* corresponds to the *precentral fissures*, and may be called the *precentral line*. The points of its trisection correspond to the posterior extremities of the *superior* (*P*) and *inferior* (*R*) *frontal fissures*. The line *D T* is called the *Sylvian line*; it intersects the precentral line at the point *H*, which corresponds to the *Sylvian point* of the fissure of Sylvius, and also to the *anterior division* of the middle meningeal artery. *H A* corresponds to the anterior horizontal limb of the Sylvian fissure, and *H K* indicates the posterior horizontal limb of the fissure of Sylvius. This posterior limb of the Sylvian fissure terminates at the parietal eminence in the triangle *K O L* at the level of the temporal crest, indicating the position of the supramarginal convolution. The point *T* is the termination of the Sylvian line, and is somewhat in advance of the *parieto-occipital fissure*. The triangle *T V I* corresponds to the outer surface of the occipital lobe of the cerebrum. The line *I V* about corresponds to the tentorium cerebelli and the upper margin of the *lateral sinus*, while the line *V T* is a little above the *lambdoid suture*. The upper portion of the line *K N* corresponds to the *superior postcentral fissure*, but the lower part of the line is somewhat behind the *inferior postcentral fissure*; the line *K N* may be called the *postcentral line*.

The parallelogram *H K N M* overlies the ascending parietal and ascending frontal convolutions separated by the *central fissure* (fissure of Rolando), and hence corresponds to the cortical motor area (*area of Rolando*). The pentagon *F E V L H* outlines the *temporal lobe* of the cerebrum, except the apex; the latter is directed forward, downward, and inward about 18 mm. (a finger's breadth). About 18 mm. below the line *H L* is the superior temporal fissure (*parallel fissure*), which turns upward and terminates at L, thus indicating the position of the *angular gyrus.*

By drawing a line on the scalp from a point 12 mm. behind the mid-sagittal point (M) downward and forward for 8.5 cm. and at an angle of 67° to the sagittal line, the *fissure of Rolando* will be mapped out.

The inion I corresponds to the *torcular Herophili* and thus overlies the point of junction of the superior longitudinal, straight, lateral, and occipital sinuses. The groove for the lateral sinus may be mapped out by drawing a line from a point 1 or 2 mm. above the inion, in a slightly curvilinear direction with the convexity upward, to the point V at the postero-inferior angle of the parietal bone. The point V forms the highest part of the convexity of the sinus. From this point the upper margin of the sinus follows the line $E V$ for 25 mm.; it then curves forward and downward to a point 18 mm. below and behind the centre of the external auditory canal. The anterior border of the mastoid portion is indicated by the line $Y Z$.

The groove for the superior longitudinal sinus extends from the glabella to the inion. It increases in size from before backward and usually becomes continuous with the right lateral sinus. The edge of the trephine should be maintained at least 18 mm. from the mesial plane when the skull is opened over the posterior part of the vertex.

After the *middle meningeal artery* enters the middle cranial fossa through the foramen spinosum it runs outward and forward for about 37 mm. to the point F, which is located about a finger's breadth (18 mm.) above the mid-point of the zygomatic arch. It here divides into anterior and posterior divisions. The anterior division passes, with a slight convexity forward, across the pterion upward and slightly backward behind the coronal suture. It gives off branches which ascend over the Rolandic area corresponding to the parallelogram $H K N M$. This anterior branch corresponds to the lower two-thirds of the precentral line $H M$. In trephining over the lower part of the Rolandic area, especially over the cortical motor centres for the face and tongue, this anterior division will be encountered.

The *posterior division* of the middle meningeal artery passes backward almost horizontally toward the postero-inferior angle of the parietal bone. It may be indicated on the exterior of the cranial wall by drawing a line backward from the point F (which is 18 mm. above the mid-point of the zygomatic arch) parallel to the line $E V$.

When the calvarium is removed in the recent state the meningeal arteries will be found intimately adherent to the dura mater. The middle meningeal artery is the only one of them that is of surgical importance. In fractures of the skull the artery is frequently ruptured; the extravasated blood will generally be found between the cranial wall and the dura mater, and beneath the clot will be found the bleeding point of the artery.

To expose the anterior division of the artery the point of the trephine should be applied over the Sylvian point H.

To expose the posterior division of the artery the point of the trephine may be applied a finger's breadth (18 mm.) above the zygomatic arch and the supramastoid crest between the points E and V.

To expose the main trunk of the meningeal artery between the foramen spinosum and the point of bifurcation at F, the trephine is applied immediately above the mid-point of the zygomatic arch. When the anterior division of the meningeal vessel is ruptured the extravasated clot presses upon the temporo-parietal portion of the cerebrum and induces motor symptoms through pressure upon the centres for the face and arm; when the *frontal* branch of the meningeal's anterior division is wounded, the clot of blood is in the temporo-frontal region of the cerebrum and produces pressure symptoms in the motor area for the face, and in addition, on the left side, involves Broca's convolution. Wounds of the meningeal's posterior division involves the occipito-parietal region and the pressure symptoms are sensory.

To reach the lateral hemisphere of the cerebellum the point of the trephine is placed over the mid point of a line drawn from the inion to the tip of the mastoid process. In turning down the flap for this operation the mastoid emissary vein and the occipital vessels will be divided.

To tap the lateral ventricle at the commencement of its descending horn the point of the trephine should be placed a finger's breadth (18 mm.) below the mid point of the line $K L$; in this operation only 1 cm. of brain tissue is penetrated through the posterior half of the first temporal convolution.

The asterisk at C overlies the site chosen by Keen for tapping the lateral ventricle; he makes an opening through the cranial wall 31 mm. above Reid's base line and the same distance behind the external auditory canal; he then passes the instrument into the brain tissue toward the summit of the auricle on the opposite side. The undistended ventricle will be reached at a depth of 5 cm. from the surface.

The asterisk at B indicates the site selected by Kocher for draining the lateral ventricle. He makes an opening two fingers' breadth (31 mm.) in front of the point P, the instrument being directed backward and downward through the superior frontal fissure for a depth of 4 or 5 cm.

The asterisk at A overlies the site at which the point of the trephine is entered for draining the subarachnoid space; a small trephine should be used and the operator should be careful to keep in front of the middle meningeal artery.

The cisterna magna is reached by trephining a little above the foramen magnum and a little to one side of the external occipital crest so as to avoid the occipital sinuses.

Daniel Kerfoot Shute.

SKULLCAP.—(*Scutellaria*, U. S. P.). The dried herb, *Scutellaria lateriflora* L. (fam. *Labiatæ*). This genus consists of bitter perennials, nearly destitute of the aromatic properties found in most species of this large family, and further distinguished by a peculiar helmet-like development of the upper sepal, to which it owes its name. Calyx two-lipped, persistent; closed-in fruit until maturity, when it splits and opens widely. Corolla bilabiate, ascending; stamens four, also ascending, and under the upper lip of the corolla; lower anthers one-celled. Leaves opposite, petiolate; flowers axillary, usually solitary, sometimes in apparent spikes or racemes. There are nearly two hundred species, forming a very distinct and natural genus, distributed over nearly the whole north temperate zone. There are about a dozen in the United States, and several of them are used like the official, from which they are distinguished in trade by the appellation "Western skullcap."

The official drug is thus described:

Dark green, smooth, or slightly puberulent on the younger portions, the branches elongated, slender, sharply quadrangular; leaves opposite, exstipulate, shortly petioled, the blades rarely exceeding 8 cm. (3 in.) long and about a third as broad, ovate, rounded or truncate at the base, acuminate, obtusish or acutish, shortly and obtusely serrate, thin, veiny; flowers in axillary, peduncled, mostly simple and secund racemes, nearly sessile, about 6 mm. (¼ in.) long, the calyx bilabiate, in fruit becoming closed and developing a large helmet-shaped crest, the corolla deep blue, bilabiate, the stamens didynamous; fruit of four depressed, globose, papillose nutlets.

So called "Western scutellaria," more or less rough gray-hairy and with much larger flowers, in terminal panicles, is not of this species.

Skullcap contains a very little volatile oil, and its bitter principle has been called *scutellarin*.

The Scutellarias have had from time to time some transient or popular reputation in medicine for the cure of mad-dog bites, chorea, epilepsy, or other nervous diseases; also as tonics, antiperiodics, etc. The official species is considerably used by the eclectic school of practitioners and in home medication. It is reputed to be antispasmodic, anticonvulsant, etc., and is given for restlessness and wakefulness. It certainly possesses bitter tonic and mildly laxative properties.

W. P. Bolles.

SLEEP. See *Drowsiness.*

SLEEP. DISORDERS OF. See *Insomnia.*

SLEEPING SICKNESS.—DEFINITION.—Sleeping sickness, or negro lethargy, is a disease of the central nervous system—a meningo encephalomyelitis—endemic in Western equatorial Africa; characterized by gradually increasing drowsiness and lethargy, both mental and physical; and, after a period of about a year, terminating in death.

SYNONYMS.—Negro Lethargy, Sleeping Sickness of West Africa, Sleeping Sickness of the Congo, Congo Sickness, African Lethargy, Sleeping Dropsy, Lalaregolo, Lalangolo, Manungina, Nélavane, Ntolo, Dâdane, Somnolenza, Hypnose, Hypnosie, Maladie du Sommeil, Maladie des Dormeurs, Die Schlafkrankheit der Neger, Enfermedad del Sueno.

GEOGRAPHICAL DISTRIBUTION.—This disease is endemic on the western coast of Africa, between the River Senegal in the north and Loando in the south, a distance of about fifteen hundred miles. It is found on the coast, inland, and on the islands; how far inland it spreads has not been ascertained, but it may be safely said to be endemic in the whole of the region drained by the Senegal, the Niger, and the Congo. Outside of this region it has never been known to originate. Those who have resided within this area, and have left it, are liable to be attacked by the sleeping sickness at any time within six or seven years, so long is the latent period that has been assigned to this disease. Those cases of sleeping sickness that have been reported from other parts, as the Bahamas, Brazil, British Guiana, the French West Indies, etc., either have been imported from the endemic region or else are not sleeping sickness at all, but most probably ankylostomiasis. Thus "Guérin in an experience of one hundred and forty-eight cases at Martinique never saw the disease in a negro who had not been imported from Africa, nor in one who had been resident on the island for more than ten years" (Manson, in "Allbutt's System of Medicine"). Within the area of its endemicity sleeping sickness rages in certain places and at certain times as an epidemic. The spots thus unfortunately visited are selected with a capriciousness that defies all explanation. Settlements, villages, or garrisons are suddenly attacked with the epidemic; all who can, leave the infected place; the others remain—and die. Other spots in the neighborhood are passed by, at any rate for the present; later on their turn comes, and another district is desolated and decimated. Further, some districts are constantly attacked; and others, in fairly close proximity, as constantly and inexplicably escape. Epidemics are very frequent in the Lower Congo region, while at Stanley Pool and at the mouth of the Congo they are almost unknown. From recent accounts it would seem as if the disease was spreading. Dr. Cook (*Jour. of Trop. Med.*, iv., p. 236) reports cases occurring at Uganda on the Upper Nile; and Dr. Castellani has witnessed it raging among the natives in the Victoria Nyanza district. According to this observer, fifty thousand natives died of this disease in one year (see also the London *Hospital* of December 27th, 1902). Sleeping sickness is almost entirely confined to the negro race; the mulatto and the Moor have been attacked, but it has not yet been observed in a European. Whether this is due to hygienic precautions and conditions, or to something inherent in the disease, is at present unknown, and is likely to remain so until the etiology of sleeping sickness is settled.

ETIOLOGY.—The cause of sleeping sickness is not known. The disease has, in turn, been attributed to a variety of causes, some of which need only be mentioned to be rejected. For example: 1. *Sunstroke* has been put forward as the cause; but whether the sun was hotter or the negro's skull thinner in the endemic region was never explained; nor were the peculiar epidemic outbreaks so characteristic of the disease. If sunstroke had been the exciting cause, sleeping sickness would have had a much wider area of distribution. 2. Various *foods* and *intoxications*, as fungus, hemp, maize, the bitter manioc or cassava. When properly cooked these are said to be non-injurious; but when eaten raw it is claimed that they are liable to produce the disease. But these plants are found outside of this region, and are just as liable to be eaten uncooked in other districts; hence as an etiological factor they have not much value, although some analogy may be claimed to pellagra and lathyrism. 3. *Emotional causes*, such as nostalgia, pining under ill-treatment when away from home; and yet it has never been asserted, much less proved, that the negro from western equatorial Africa was either worse treated than others, or that he was more tender-hearted than his brother from other parts. 4. Various *microbes* have, of course, been suggested, but, unfortunately, the observers do not agree among themselves.

Bettencourt thinks that the cause of the sleeping sickness is a micrococcus; Cagigal and Lepierre did not find the micrococcus, but report a bacillus; Dr. Broden also found a bacillus. Marchand thinks that the disease is due to the pneumococcus; Drs. Mott and Bulloch found no micro-organisms at all; but, of course, this does not preclude the possibility of the disease being due to a specific organism, for, as in the case of syphilis, the organism may be there, but so far may have eluded the bacteriologists.* 5. Among the *parasites* that have been put forward as the probable cause are *Filaria perstans* (Manson), *Rhabdonema strongyloides* (Le Dantec), and *Ankylostomum duodenale* (Ferguson). Of these, Manson's suggestion of the Filaria perstans is by far the most probable. Manson has shown that the geographical distribution of the Filaria perstans is the same as that of the sleeping sickness; and further, the Filaria perstans has been found in an exceedingly large proportion of the cases in which any proper examination has been made; the latent period and the peculiar endemicity are both capable of explanation on this theory. Probably there is something else requisite besides the Filaria perstans, for many negroes have this latter and yet escape the sleeping sickness; so far, Manson only puts it forward as a hypothesis, but it is quite the most reasonable that has appeared. 6. "Like all tropical pathological puzzles, sleeping sickness has been attributed to *malaria*—that blessed cloak for ignorance—but there are none of the clinical or pathological marks of malaria about the disease" (Manson, *Jour. of Trop. Med.*, i., 125). 7. Dr. Andriezen has pointed out how very similar the symptoms of sleeping sickness are to those produced by destruction of the pituitary gland. Whether the pituitary gland is a causative factor in sleeping sickness is not known. 8. Crombie suggests that the deep cervical glands, which receive the lymph from the brain, may, by becoming obstructed by the Filaria perstans or its ova, cause sleeping sickness. 9. The virus, whatever it may be, is said to be conveyed by the saliva, the negroes using their fingers to eat with out of a common dish.

SYMPTOMS AND COURSE OF DISEASE.—Before describing the symptoms of sleeping sickness it may be well to remember that the negro is naturally prone to sleep. To those who have lived for any length of time in the tropics, the following quotation from Scheube's "Diseases of Warm Climates" will appear to be a remarkably mild statement of fact: "The negro works—when forced to—but with frequent interruption; he eats and drinks, sings, laughs, perspires; he capers and dances with ex-

* As this goes to press, Dr. Castellani, an Italian physician residing at Uganda, claims to have discovered the microbe of the disease, viz., a new variety of streptococcus. This same observer has since reported the finding of a species of Trypanosome in the blood and cerebro-spinal fluid of patients suffering from sleeping sickness. This has also been verified by Colonel Bruce, who found a trypanosome in the blood of twelve out of thirteen cases of sleeping sickness, and in the fluid obtained by lumbar puncture in every one of thirty-eight cases. ("Brit. Med. Jour.," 1903, i., 617 and 1218.)

Sleeping Sickness.

treme gayety—or he sleeps. When unemployed he cannot keep himself awake without a noise. It is therefore customary in the negro schools of the West Indies to oblige the unemployed half of the scholars to sing hymns while the other half receive instruction. If this were not done half of the scholars would be asleep" (Junker von Langegg). Neither *sex* nor *occupation* has any influence either as regards liability to the disease or immunity from it; all *ages* are susceptible to it, chiefly the young and vigorous adult from about fifteen to twenty years; in infants, and in those over forty years of age, the disease has not been noted.

Sleeping sickness begins very gradually with general weakness and languor, enfeebled powers of endurance, debility both muscular and intellectual, a more than ordinary disinclination to work coupled with an almost irresistible longing to doze or sleep, and this latter shows itself not only during the hours of labor, but even at meal-times. With this muscular fatigue and weakness there is also a corresponding mental dulness and vacuity, so that in place of his usual vivacious disposition the afflicted negro gets morose and silent, does not initiate conversation and talk for the mere love of talking as is his wont; but at first he will only answer questions, then only in monosyllables and when pointedly and repeatedly interrogated; later on, it is only after considerable lapse of time that an answer can be extracted from him, thereby showing the slowness and impairment of the mental processes. Headache is often one of the prominent early symptoms, though it is by no means an invariable one; when present, it is generally occipital.

Vertigo is often present. The patient has a shuffling, staggering gait, as if half asleep. The face is puffy; the upper eyelid droops, though whether as the result of drowsiness or from paralysis of the levator palpebræ superioris is not known. The lower lip also droops, showing the lower teeth and allowing the saliva to dribble and almost flow out of the mouth. The state of torpor increases, sometimes punctuated by brief snatches of seeming improvement which are not only short-lived, but generally lead to worse relapses, so that work of any kind becomes absolutely impossible and the patient does little but sleep; food is taken if brought to the patient, and if he is kept awake while eating it; otherwise he is very liable to fall asleep while a bolus is making its way from his tongue to the œsophagus. He lies around anywhere and in any position, even the most uncomfortable, and sleeps. If left alone now he would starve. Even now under proper care and attention it is more than probable that nutrition will fail, bedsores form, and diarrhœa and epileptiform seizures come to add to his generally miserable condition. The skin is generally cold, though the temperature may rise to 101° or 102° F., or even higher. There is enlargement of the lymphatic glands, chiefly the cervical; but the supraclavicular and occipital glands are often noticeable too. These enlarged glands vary in size from a small bean to a walnut, are tender on pressure, are discrete, do not adhere to the skin, and have no tendency to suppurate. The skin suffers from loss of the peculiar gloss and lustre which is noticed in health; it is also liable to be covered with an eruption, either papular, vesicular, or pustular; sometimes it may have the appearance of an exanthem. Such eruption is most common on the chest and abdomen. There is a very pronounced pruritus, and the consequent scratching leaves whitish lines of abraded epithelium on all accessible parts of the skin. Muscular tremors and light fibrillar twitchings are noticed.

Sensation is not much affected, except toward the end of the disease, when it may be diminished. The secretions are fairly normal, except the saliva, which constantly flows or dribbles out of the mouth; but whether it is a hypersecretion or inability of the patient to swallow, is not settled. Insanity is apt to supervene before the end. The superficial reflexes are normal and the knee-jerk is normal or increased. Choreic attacks have been observed, with tonic or clonic convulsions, and in severe cases epileptiform attacks. Muscular spasms are most apt to affect the flexors of the limbs and the sterno-cleido-mastoid. The above are the chief symptoms that have been noted, but it must be understood that no case presents *all* the symptoms, and there is considerable variation in their presentation.

Duration.—The disease may last anywhere from three months to three years; about one year is the average time.

Diagnosis.—There ought to be but little difficulty in diagnosing sleeping sickness; the geographical distribution, the progressive somnolence and bodily weakness, and the pruritus present a complex that is not afforded by any other disease. It has been confounded with beriberi, but the following table, compiled from Manson (Allbutt's "System of Medicine"), will show the differences:

Sleeping Sickness.	Beriberi.
1. Diseases of the central nervous system.	1. Disease of the peripheral nerves.
2. Progresses slowly.	2. Progresses rapidly.
3. Nearly always fatal.	3. Rarely fatal.
4. Limited endemic distribution.	4. Extensive distribution.
5. Not a peripheral neuritis, and not associated with marked œdema, although in the earlier stages there may be puffiness of the face, and in the later stages puffiness of the feet.	5. Has all the signs of a peripheral neuritis, and generally is accompanied with more or less œdema.
6. Muscular atrophy of rapid development, palpitations, abolished knee-jerk, and hyperæsthesia of muscles not found.	6. Torpor, tremor, insanity, and itching papular eruption not found.

Prognosis.—The disease is almost invariably fatal. Guérin reports 148 cases with 147 deaths; Gore 179 cases with 132 deaths; Forbes 13 cases with 11 deaths (and the termination of the other two not known).

Pathology and Pathological Anatomy.—Although sleeping sickness has been known for a little over a century, it is only in the last few years that anything has been learned about its pathology. Among the few notices that make any direct reference to the pathological anatomy, there is one that stands quite alone for its completeness and utility; this is a report of two cases (including autopsy) by Dr. F. W. Mott, director of the Pathological Laboratory of the London County Asylums. We here quote from his report in the *British Medical Journal* for 1899, i., p. 1108:

"The brain and spinal cord, pituitary body, and spinal ganglia were examined. To the naked eye the tissues in Case I. presented but little change beyond some slight thickening of the pia-arachnoid. The cerebral convolutions were complex and not atrophied; the brain weighed fifty-four ounces. The two hemispheres were of equal weight and there was no excess of fluid. In Case II. (the younger patient) the dura mater was found adherent to the calvaria. A considerable quantity of cerebrospinal fluid was present. The pia-arachnoid was somewhat thickened and opaque over the convolutions. The base of the brain likewise showed thickening and opacities of the pia-arachnoid. The weight of the brain was thirty-six ounces. Neither of the brains showed flattening of the convolutions, erosions on stripping the membranes, or dilated ventricles with granular ependyma. The nervous tissues before mentioned were removed so soon after death as to avoid post-mortem fallacies. Portions of different parts of the hemispheres, cerebellum, pons, medulla, and cord, as also the spinal ganglia, were stained by the Nissl, Marchi, and Marchi-Pal methods after suitable fixation. The microscopical examination of these sections exhibited in both instances similar conditions. There was a leptomeningitis and an encephalomyelitis. Throughout the whole central nervous system, but especially in the medulla and base of the brain, sections showed all the perivascular limits distended with mononuclear leucocytes. . . . Sections were also stained for micro organisms by Gram's, Pfeiffer's, and other methods, but with negative results. . . . The general and special appearance of the nerve cells was as follows: In Case I. the outline of the nerve cells and their arrangement appeared fairly normal; neither was it considered that the neuroglia cells were markedly increased. The columns of Meynert in the cortex cerebri were distinctly evident, thus contrasting with the appearance of the brain in general paralysis. The cells themselves throughout the whole nervous system showed a uniformly dull, diffuse, staining reaction, and in none of the cells were the Nissl granules evident. This change was undoubtedly due to the hyperpyrexia during the last hours of life. In Case II. the cells for the most part presented a normal outline and exhibited Nissl granules on the dendrons and in the body of the cell. In the medulla, however, a considerable number of cells showed chromolytic changes, and to a less degree changes were found in the motor cells of the anterior cornua The cells in the left hemisphere showed degenerative changes in sections of the motor area, Meynert's columns were not distinctly visible, and many of the cells seemed atrophied and broken up. Fibres: Sections of the brain and cord were stained by Marchi and Marchi-Pal methods. Nothing abnormal was found in Case I. except perhaps that the tangential fibres were not so numerous as in the normal cortex cerebri. In Case II. there was obvious wasting of the tangential fibres in both hemispheres, but especially of the left. There was slight sclerosis of the crossed pyramidal tracts of the cord, more marked on the right side, and also a number of recently degenerated fibres were exhibited by the Marchi method. The arteries of the central nervous system exhibited no trace of endarteritis. In the choroid plexus there were numerous microscopical psammomata. The central canal of the spinal cord was filled up with proliferated glia tissue. The posterior spinal ganglia showed the same appearances around the vessels, but the ganglion cells in Case I. only showed the diffuse staining of hyperpyrexia, and in Case II. exhibited a fairly normal appearance. . . . The symptoms which were, however, present in both patients, and characteristic of the disease—namely, progressive drowsiness and lethargy, and the progressive weakness in body and mind, without any distinct paralysis or mental disability—could best be accounted for by supposing that the metabolism or functional activity of the neurons as a whole was affected injuriously by some toxic product either circulating in the blood or existing in the cerebrospinal fluid; that this toxic agent, whatever it might be, occasioned great proliferation of mononuclear leucocytes beneath the pia-arachnoid and in the perivascular lymphatics. It might, however, be supposed that the functions of the nervous system were affected by an interference with their nutrient lymph supply, owing to the perivascular lymphatics being filled with leucocytes. The liver, kidneys, lungs, pituitary body, spleen, lymphatic glands, and duodenum were also examined. The results were for the most part, with the exception of the duodenum and lymphatic glands, negative. The lymphatic glands were much enlarged owing to great increase of lymphocytes. Sections of duodenum showed a large number of lymphocytes, and a proliferation of the same in the lymphoid nodules."

In addition to the above, Dr. Mott furnished a much fuller report, with illustrations, to the *British Medical Journal* for December 16th, 1899. To this the reader, in search of further details, is referred

TREATMENT.—This has, so far, been most unsatisfactory Purgatives, tonics, quinine, and arsenic have all been tried, but without much effect on the death rate. Among the newer suggestions are: (1) Hypodermic injections of testicular extract; (2) venesection of about one-fourth of a litre per week, followed by injection of an artificial serum, the object being gradually to free the blood from the Filaria perstans; (3) thyroid extract; (4) electricity over the spine. Probably the best that can be done will be found along the lines of hygiene, nursing, and feeding. *R. J. E. Scott.*

SMALLPOX.—DEFINITION.—Smallpox is an acute, contagious, febrile, exanthematous malady, characterized by an eruption which passes through four stages of development, *i.e.*, macule, papule, vesicle, and pustule. The initial symptoms are, ordinarily, chill, fever, headache, lumbar pain, and vomiting. The fever disappears when the eruption appears, and recurs when the latter has reached the pustular stage. The period of incubation varies from seven to twenty-one days.

HISTORY.—Though an ancient disease, its origin is unknown. DeHaen, Willan, Moore, and Barron contend that it was known to the ancient Greeks and Romans; Friend, Mead, Good, and Adams deny this assertion. Rhazes, an Arabian physician, who practised medicine about the year 910 A.D., was one of the most celebrated of the earlier writers on smallpox. When we consider the date of his writings and the state of medical knowledge at that time, it will be seen that he delineated the natural history of the disease with remarkable accuracy. Rhazes contends that Galen was familiar with the malady, and cites extracts from his first, fourth, ninth, and fourteenth books as evidence of the fact. He also mentions Ahrún, of Alexandria, and Mesue, of Bagdad, among the other early writers on variola. It is, however, commonly agreed among historians of medicine that this disease cannot with certainty be traced to a period anterior to the Christian era. Since smallpox first attacked mankind it has never wholly disappeared, and from Europe and Asia has been carried all over the world. It appeared in England in the first part of the thirteenth century, and in Germany in the latter part of the fifteenth. It was imported into the United States soon after the discovery of America. It reached Mexico in 1527. Smallpox is a malady to which the human race is wellnigh universally susceptible, probably not more than one in a thousand persons being naturally immune. In consequence of the universal susceptibility of unvaccinated persons, and the neglect of vaccination in almost all communities, smallpox smoulders in different localities, and at varying periods breaks loose from these endemic foci and assumes epidemic proportions in municipalities, States, and nations.

Like all other contagious maladies epidemics of smallpox differ markedly one from another, not only in the amount and character of the eruption, but in the character and intensity of symptoms, and in mortality as well. For centuries prior to Jenner's discovery of vaccination (1796) smallpox was regarded as the king of fatal diseases. M. de La Condamine, writing of this malady, says that it was the cause of one-tenth of all the deaths among mankind. He also says: "Among those who outlive it, many, either partially or totally, lose their sight or hearing; many are left consumptive, weakly, sickly, or maimed; many are disfigured for life by horrid scars, and become shocking objects to those who approach them. Immense numbers lose their eyesight by it." Black, Frank, and other reputable writers on this disease state that it caused half a million deaths annually in Europe prior to general resort to vaccination. The great English historian Macaulay, in speaking of this malady in England, says: "The havoc of the plague had been far more rapid, but the plague visited our shores only once within living memory, but the smallpox was always present, filling the churchyards with corpses, leaving on those whose lives it spared the hideous traces of its power, turning the babe into a changeling at which the mother shuddered, and making the eyes and cheeks of the betrothed maiden objects of horror to her lover."

Rosen says that one-tenth of the deaths in Sweden resulted from smallpox. Simon says that this disease concurred with fire, and sword, and famine to depopulate St. Domingo.

In an epidemic of smallpox in Mexico in the sixteenth century 3,500,000 of the inhabitants died in a few years, leaving in some places scarcely enough people alive to bury the dead. Prescott ("Conquests of Mexico," vol. vi) describes this epidemic as "sweeping over the land like fire over the prairies, smiting down prince and peasant, leaving its path strewn with the dead bodies of natives who perished in heaps like cattle stricken with the murrain." Smallpox invaded Brazil in 1653, and in some instances whole races of men died of the malady.

In a few years the Province of Quito lost 100,000 of her Indian population by this disease. Iceland had been invaded by smallpox seventeen times prior to 1707, and desolation and ruin followed in its wake for years, causing in the year 1707 the death of 18,000 out of a total population of 50,000. The terrible fatality of the disease in Greenland in 1707 is evidenced by the following extract from Crantz's "History of Greenland": "Empty, depopulated houses and unburied corpses, some within and some without the houses, were commonly encountered. In one island they found one girl with the smallpox on her, and her three little brothers; the father, having first buried all the people in the place, had laid himself and his smallest sick child in the grave, raised with stones, and ordered the girl to cover him." In 1734 Greenland lost two-thirds of her population from smallpox. From authentic sources it is learned that in one epidemic of this malady one-sixth part of the inhabitants of Ceylon died. Siberia had a similar experience, and Kamchatka has suffered in like manner. Captain Cook ("Voyages to Pacific Ocean," 1785), speaking of the first appearance of smallpox (1767) in Kamchatka, describes it as "marking its progress with ravages not less dreadful than the plague, and seeming to threaten their extinction." M de La Condamine says that prior to vaccination one-tenth of all the deaths in France were from smallpox. In 1805 M. Laborde says: "I had been a witness of the variolous epidemic which had, in 1792, swept off one-fourth of the population of the Isle of France." North America has been fearfully scourged by smallpox; whole tribes of our Indian population were almost literally extinguished by it. McKenzie says of the disease among the Indians: "It was as a fire consuming the dry grass of the field. The infection spread with a rapidity which no flight could escape, and with a fatal effect which nothing could resist." Godfrey says that 2,000,000 of the inhabitants of the Russian empire died of smallpox in a single year. Sir Gilbert Blaine says: "When there was no vaccination in our navy, one-fifth of all the men enlisted died of smallpox." Mr. Makena describes an epidemic of this disease in the Argentine Confederation from 1846–48, as "sweeping with the wings of death over that enormous tract of country from the seaboard of the Atlantic on the East to the cordillera of the Andes on the West." Alexander Wheeler, of England, an ardent antivaccinist, says: "In 1875 smallpox carried off 101,397 inhabitants of India." Hirsch says that between 1866 and 1869 smallpox killed 140,000 natives in Bombay and Bengal. In the whole of India (1873–74) 500,000 inhabitants died of this disease.

An exhaustive account of the various epidemics of smallpox is, of course, not to be expected in a limited article. The instances above quoted are presented in order to show how malignant smallpox commonly was in prevaccinal times, as well as the present, in a population unprotected by vaccination. The instances cited are entirely authentic, and justified Macaulay in styling smallpox "the most terrible of all the ministers of death." It, however, would be wholly erroneous to contend that all epidemics of smallpox had been as pernicious as the ones above cited. It is an incontestable fact that throughout the entire written history of this malady individual epidemics have differed markedly one from another, not only in mortality, but in the quality and quantity of the eruption and the other attendant symptoms. In some epidemics a large percentage, and in others the largest percentage, of cases of smallpox were of the mildest type—varioloid as it is called—and this resulted, not, as some text-writers assert, in consequence of previous vaccination or a prior attack of smallpox, but from an inexplicable partial natural immunity of populations more general at one period than at another, for this disparity of different epidemics as to mortality, quality, and quantity of eruption, and other symptoms was noted prior to vaccination. I cite three instances from a number at hand. George Cleghorn, M.D., in his book on the "Epidemic Diseases of Minorca," says: "The smallpox were twice epidemical in Minorca while I resided there, viz., in 1742 and 1746. About the middle of March, 1742, the smallpox broke out in Minorca, to the great consternation of the natives who had not seen them since the year 1725, but well remembered the destruction which they then occasioned. During the first six or eight weeks (1742) the distemper was favorable and seldom proved fatal; but its virulence increased with the heat of the weather, so that in June and July it was not uncommon, both at Mahon and Ciudadella, to bury ten or twelve a day. Nevertheless, in proportion to the numbers not many died, and what mortality there was happened chiefly among children at the breast and the common soldiers." Of the epidemic of 1745–46 he says: "Then they (the smallpox) travelled northward to Ciudadella, and disappeared in the spring, having carried off almost all of the children who survived the chincough and the summer fevers. It was, however, very remarkable that the longer the infection continued in the island the milder it became, so that there was much less mortality in the northern part than in the southern, where it first broke out." He then cites the fact that in 1846 at St. Phillip's Castle three-fourths of the smallpox patients died.

In the early part of 1898 smallpox appeared in several of the Southern States. The first case in this city (Augusta, Ga.) was detected May 5th, 1898 the patient having contracted the disease in South Carolina. The malady spread from one State to another until it invaded all sections of the United States. The disease is said to have been brought to this country from Cuba, it having been prevalent there during the Spanish-Cuban war. In a large number of communities it assumed epidemic proportions by reason of the fact that physicians failed to recognize its nature until it had attacked a large number of the inhabitants. Cases of the disease were observed by me in citizens of twelve counties in Georgia and four counties in South Carolina. In each and all of the communities in which I encountered the disease it was, in my experience, unprecedentedly mild and irregular both as to constitutional symptoms and quantity and quality of eruption, and equally strange was the further fact that while perhaps one-sixth of the cases were either confluent or semiconfluent in type, the vast majority of discrete and semiconfluent cases went on to and through the purulent stage without secondary or maturation fever. This fact was ascertained by repeated daily observations with the thermometer. Again, not more than five per cent. of confluent cases terminated fatally. In the confluent and semiconfluent cases pitting of the face was in about the percentage usually attendant on severer epidemics. The disease was confined almost exclusively to the unvaccinated. No one of the four hundred and twenty-nine cases coming under my observation during the last four years had a typical vaccine scar. Ten of them had a scar, and claimed to have been vaccinated from ten to twenty years previously, but in no one of them could I say from the cicatrix that the patient had undergone vaccinia.

The initial symptoms of the malady were headache, lumbar pain, chill, fever, and vomiting, and these symptoms were as commonly complained of by those having the disease mildly as by those who had the severer types. In those who had the disease mildly, *i.e.*, about two-thirds of the cases, the constitutional symptoms disappeared wholly when the eruption appeared, and these patients then went to work or visited their friends. I found a large per cent. of them at work in the fields, shops, and other industrial pursuits while the eruption of smallpox was in full bloom on them. Two of these patients after remaining at home three days resumed their work of delivering ice to our citizens. Others were apprehended on the public thoroughfares or in houses where they were visiting. These individuals claimed that their disease was chickenpox, and in not a few instances had been so informed by their physicians. In one case the total number of pustules on the patient's body was six, yet this patient gave rise to an epidemic of smallpox in the jail in our city. Another patient had only twelve pustules, another twenty-four, another thirty-five, another forty-four, others had from fifty to sixty, others from seventy-five to one hundred, while still others had several hundred.

The disease attacked entire unvaccinated families, and it was a common experience to find all numerical grades of eruption from fifty to one hundred on to discrete, semiconfluent, and confluent cases in one unvaccinated family. Several of the confluent and semiconfluent cases were in direct traceable connection with those who had respectively six, twelve, thirty-five, and fifty pustules. That the disease in America has been for the last four years unprecedentedly mild, when judged by fatality, is shown by the statistics of the United States Marine Hospital Service. The reports of this service show the following facts: 1899, total number of cases of smallpox 11,136, deaths 553; year 1900, cases of smallpox 20,362, deaths 819; six months ending June 13th, 1901, cases 28,257, deaths 486; from December 28th, 1901, to June 13th, 1902, cases 36,373, deaths 1,154. While the statistics above quoted are imperfect in that they do not represent the total number of cases nor the total mortality occurring in America, they are valuable in that they are made up from data furnished from all parts of the United States, and accurately show the mortality rate in the various localities from which these reports were obtained. The report of the Marine Hospital Service shows that for the term ending June 13th, 1902, smallpox was in existence in forty-three States and Territories in the United States. Of the 129 cases which occurred in this county during the last four years only 6 resulted fatally.

That the course of the disease was altogether atypical is shown by the fact that the initial symptoms constituted the major part of the attack of smallpox in nine-tenths of the cases observed by me. Other atypical manifestations of the malady were noted as follows: In not a few cases the eruption remained globular throughout its entire course, umbilication being wholly absent. In a still greater percentage of cases, although umbilication was present, a large per cent. of the eruption continued globular through its entire course. Not uncommonly, in discrete cases, the vesicles were observed to have changed into pustules on the fourth day, and then rapidly desiccated, and in a few additional days began to drop from the body. In some instances semiconfluent cases did likewise, while in other instances, in both semiconfluent and confluent cases, the course of the eruption was as prolonged as that in severer epidemics. In semiconfluent and confluent cases pitting of the face was about in the percentage observed by me in former years, though in some cases of both of these varieties the eruption ran an exceedingly rapid course, desiccated and soon dropped off in large patches, leaving no sign of pitting. In a large proportion of the mild cases the exanthem did not pass through the various stages usually observed in the disease, but after developing in an abortive form promptly retrograded, leaving warty excrescences on the face which after several months disappeared and left no trace of disfigurement.

My experience with smallpox during the last four years may be summed up by saying that the cases of the disease varied from one another—from those showing the extreme limits of the severest and fatal types to the very mildest forms of varioloid in which but a few pustules evidenced the fact that I was dealing with smallpox. The variations in types of the malady were rarely ever sharply defined amidst the group of variolous affections ordinarily described in the books, but were rather a direct or an indirect change from one type to another, ofttimes so gradual as to be diagnosticated by general outlines rather than by sharply defined outward appearances.

Morbid Anatomy.—The only characteristic pathological lesion of smallpox is the exanthem. This passes through four stages, *i.e.*, macule, papule, vesicle, and pustule. In the white subject the macules consist of small, non-elevated red spots, which within forty-eight hours become elevated into papules, then develop into vesicles, and later into pustules. In the negro the exanthem follows a similar course except as regards the redness of the macules and papules. In the hemorrhagic variety hemorrhage occurs in the skin, in the exanthem, in the mucous and serous membranes, and in the viscera. The eruption of variola appears on the skin and on the mucous membrane of the nose, mouth, pharynx, œsophagus, the genitalia, and occasionally of the larynx and trachea. If the suppurative process of the eruption does not invade the true skin, pitting will not result; if, however, it be involved, scarring of the part is inevitable. The morbid changes in the viscera of the smallpox patient show nothing peculiar to this disease, but are such as are common to most of the zymotic affections—*i.e.*, congestive, inflammatory, and degenerative changes.

Etiology.—Smallpox is contracted by breathing a confined atmosphere infected with the virus of the malady and by contact mediate or immediate, with an infected person, clothing, bedding, etc. It is a disease *sui generis*, and therefore can be propagated only by its own specific virus. (In regard to the nature of this, consult the article on *Protozoa* in Vol. VIII.) The contagious element is given off from the infected body by the breath, exhalations, secretions, and exanthem. Attempts to produce the malady by inoculations with the blood and secretions of smallpox patients have in some instances resulted negatively. The disease is, however, transmissible by inoculation of an individual with the contents of the pustule, yet this virus may be rubbed upon the skin with impunity unless the skin be abraded. If it comes in contact with the mucous membrane of an unvaccinated individual variola results. It has been claimed that smallpox is transmissible through the atmosphere. From long experience with the disease I am convinced that it never is air-borne. Our smallpox hospital has been for years located within one thousand feet of two populous blocks of our city, yet we have had but one case of the disease develop on these two blocks, and it was traced to an extraneous source. I am convinced that in every instance where it has been claimed that smallpox was disseminated through the atmosphere, it resulted from infected fabric having been scattered from time to time through the community, or from contact with individuals having the malady so mildly as to escape detection. I recently intercepted an individual having an extremely mild case of smallpox in the pustular stage, who, the whole night previous to his detection, had attended a ball. These extremely mild cases are frequent sources of dissemination of the disease. The virus of smallpox is tenacious of life when attached to fabrics, and when these have been packed away it has been known to retain its vitality for a year or more. It is therefore portable. Indeed, infected clothing, bedding, and other fabrics are frequent sources of extension of the disease. The contagion of smallpox infects an individual by passing into the system through the respiratory tract.

The character of an attack of variola as to lightness or severity varies with the then constitutional condition or degree of susceptibility of the individual. If an unvaccinated person be exposed to varioloid so mild that there may not be more than six pustules on the body, he may contract malignant smallpox therefrom, while, on the other hand, one who had never been vaccinated may be exposed to a malignant case of variola and only contract varioloid. This inequality of individual predisposition has been observed from the earliest period embraced in the recorded history of the disease. A fractional part of mankind seems to be wholly insusceptible to smallpox. I have met with two physicians who had never contracted the disease, although repeatedly exposed to it, and they possessed equal immunity to vaccination, as shown by failure of repeated efforts to inoculate them with vaccinia. These individual instances of immunity to smallpox and vaccinia are among the rarest of medical experiences, are in fact clinical curiosities, for it is a proven fact that susceptibility to both infections is well-nigh universal in man. Occasional instances are met with demonstrating that some individuals possess remarkable susceptibility to smallpox. I have encountered seven instances of second attacks of this malady. Three of them were cases of recrudescence; in the other four, all of whom were pockmarked by the first attack, a long number of years intervened between the attacks of smallpox, and two of these patients died. I have a photograph of one of the cases of recrudescence plainly showing the marks of the first attack while the pustules of the second infection were still adherent to the body of the patient. Second attacks of variola are, however rare, though a few cases are on record in which physicians have reported cases of third and even fourth attacks of the malady in the same individual.

A successful vaccination in the vast majority of instances is protective against smallpox during life, though in a minority the protective effect of vaccination decreases, and in some cases wholly disappears, in from ten to twenty years after it was done. I have never observed a case of smallpox or varioloid in a person with a typical scar of vaccination made within ten years, and I have carefully searched for such instances. The wife and six children of the superintendent of our smallpox hospital were successfully vaccinated, and though in constant contact with the patients they have never contracted smallpox. No vaccinated employee or officer of our hospital has ever contracted variola in any of its forms. In my experience a recent successful vaccination (*i.e.*, one made within five years) is as fully protective against smallpox as a previous attack of this disease is against a second one. If vaccination be done in infancy and repeated at puberty, such patient will prove immune to smallpox, though it would only be prudent for such a one to be promptly revaccinated if directly exposed to the former disease. I was vaccinated in infancy, and though I have repeatedly in the last thirty years made attempts at revaccination of myself, every such effort has failed.

Incubation.—The period of incubation varies from seven to twenty-one days. Ordinarily it is about twelve days. I have, however, repeatedly observed it to be as long as eighteen and twenty-one days. This latter fact is important in that it demonstrates the necessity of detaining suspects in isolation for a period of twenty-one days.

Types of Smallpox.—The Chinese described forty varieties of this disease. While the eruption of smallpox shows itself under a number of modifications from the several types ordinarily described by modern writers, it is not deemed necessary to describe the twenty or more varieties presented by the old writers. I shall describe the following types of the disease:

Discrete Smallpox.—*Symptoms and Course.*—The initial symptoms of this variety are chill, fever, vomiting, headache, and lumbar pain. Ordinarily the temperature reaches 102° or 103° F. on the first day of the attack, 103° or 104° F. on the second day, and on the third day it may be 105° or more. With the elevation of temperature the pulse becomes full and frequent, beating 120, 140, or even 160 per minute. Photophobia and sore throat now set in. The patient becomes restless or even delirious in consequence of the febrile movement and other constitutional disturbance. Convulsions are of frequent occurrence in children. The face becomes flushed, the conjunctivæ congested, and the carotids throb. Redness and swelling of the tonsils and soft palate take place at the end of the second day; this may extend to the larynx and cause hoarseness, and a shrill, harsh cough. At the end of the third day the fever and other constitutional disturbance have attained their maximum. At this time the eruption appears, and, as a rule, the fever and pulse-beats fall to the normal. The initial symptoms are usually quite severe, though their intensity is not always indicative of the grade of the attack, for it is frequently observed that the initial symptoms of extremely mild cases are of considerable intensity. At this stage of the disease no symptoms are present by which it may be diagnosticated. The severe lumbar pain is, however, so characteristic that its presence should lead the physician to suspect the nature of the disease.

Stage of Eruption.—At the end of the third day of the fever the eruption commences on the face, scalp, neck, and wrists. When it first appears it is macular, *i.e.*, consists of red spots which simulate the exanthem of measles, and at this stage cannot be diagnosticated from measles. During the succeeding day it spreads over all parts of the body. It commences on the mucous membrane of the throat before it attacks any other part of the body, but it is rarely first detected in this situation owing to the slight local disturbance which it causes in its incipiency. On the third day the macules have changed into papules. The papules on the surface of the body impart to the sense of touch a feeling similar to that of shot beneath the skin. If the efflorescence be copious in the mouth it causes increased flow of saliva; in the pharynx it causes difficulty in swallowing; in the larynx, hoarseness and cough; on the conjunctivæ, lachrymation and photophobia. The papules persist for two days and, by elevation of the epidermis over the site of each papule, develop into vesicles. The individual vesicles are about the size of a split pea, contain a lactescent fluid, and become umbilicated. On the sixth day of the efflorescence the vesicles begin to lose their umbilicated appearance, rapidly assume a globular shape, and by the eighth day have changed into pustules. The skin surrounding the pustules becomes red, swollen, and œdematous, each pustule has a broad base, and in cases of confluent or semiconfluent smallpox is closely set against or runs into its fellows. During this stage, in a full case of discrete smallpox, and in all cases of the confluent and semiconfluent varieties, the patient suffers from profuse salivation, swallowing is accomplished with great difficulty, the nose is filled with pustules, the voice is husky or inaudible, the cough croupy and distressing; the eyes are red, discharge a muco-purulent matter, and are extremely sensitive to light. When the exanthem covers the face, as it not infrequently does when the eruption is discrete on all other parts of the body, the face is swollen into a shapeless mass, the eyes are closed, and the features are so distorted as to render it impossible to recognize the patient. Secondary fever sets in upon the stage of pustulation being reached, a chill having preceded the fever. The fever is distinctly remittent in type, reaching its acme in the evening. The temperature in this stage is higher than in the initial fever, not infrequently reaching 106° F. when the fever is at its highest point. The pulse increases in frequency simultaneously with increase of temperature, ranging from 120 to 140 or 160 beats per minute. At this stage the patient is in the most critical period of the disease. The fever and other constitutional perturbation continue until the stage of desiccation has been completed. A subsequent marked elevation of temperature is suggestive of some complication, and its cause and significance should be promptly ascertained.

Stage of Desiccation.—The process of desiccation ordinarily commences on the twelfth day of the efflorescence, and follows in the order in which the eruption appeared. The desiccative process usually occupies from eight to fourteen days, the length of time being governed by the extent and degree of pustulation. The desiccative process on the palms and soles in some instances extends from four to six weeks. Just prior to or at the commencement of the desiccative process many of the pustules rupture and the exuded fluid dries into a yellowish or brown crust. As desiccation advances the swelling of the skin decreases and the constitutional disturbance abates. Cicatrization advances beneath the pustules or crusts, and ordinarily when these are thrown off there remains at the site of each pustule a reddish-brown or violet color in white subjects, and a white or black spot on negroes, with elevated margins and depressed centre. If only the superficial layer of the skin has been invaded these blotches sooner or later wholly disappear; if, on the other hand, the true skin has been invaded by the suppurative process the face will be permanently pockmarked. This description is an outline of discrete smallpox as it is ordinarily encountered among unvaccinated patients. Individual cases, however, present the widest differences in severity and character under different constitutional conditions of patients, and in numerous instances during every epidemic the malady is so light in the amount of eruption and character of the symptoms that those suffering from it present but few if any of the typical symptoms of the malady, and may not even suspect the true nature of the disease. If such patients perchance consult a physician, he, unless practised in smallpox, diagnosticates the malady to be chickenpox or some other light affection, and the patients continue to attend to business throughout the entire course of the disease, and thus scatter it abroad in the community.

Confluent Variola.—This type differs from the discrete in that the eruption and constitutional symptoms are much more severe than in the latter. The initial fever is more intense and of shorter duration, usually lasting not more than two days. The initial fever frequently reaches 106° F. and then falls to 103° or 104° and continues at this height until secondary or maturation fever occurs. The fever of confluent smallpox is of the remittent type, and when the suppurative process is reached, not infrequently registers 107° or 108° F. The development of the eruption in this type occurs from twelve to eighteen hours earlier than in the discrete variety, and spreads over the body more rapidly, frequently appearing simultaneously on the face, trunk, and limbs. In the severest cases the eruption is so thickly set upon the entire body that each vesicle coalesces with its fellows. The skin is intensely swollen and the eruption may cover the entire body as a mask. Suppuration rapidly ensues in the vesicles, and the eyes, lips, nose, cheeks, ears, scalp, hands, feet, and genitalia present one horrid mass of deformity. Ordinarily, however, where there is a complete coalescence of the exanthem on the face it is semi-confluent on the other parts of the body. It may be stated as a rule that pustulation on more than one-half of the body results fatally. Confluent variola is a formidable malady, the mortality ranging from fifty to seventy-five per cent. In its onset, and throughout the entire course of the disease, the confluent type shows a marked difference from the discrete variety in intensity and character of all of the symptoms. In addition to the more violent fever and delirium the nervous and muscular systems show greater depression of vitality. The mucous membrane of the air tracts is attacked with greater severity, the eruption in the mouth and throat is confluent, and frequently a diphtheritic exudate covers the soft palate, tonsils, pharynx, and nasal cavities. The larynx is occasionally invaded by the exanthem and the severity of this invasion is not infrequently evidenced by the occurrence of submucous abscesses, necrosis of the cartilages, or œdema glottidis. The eyes, too, are more severely affected in this type; the eruption usually invades the ocular conjunctivæ, giving rise to inflammation of the lids, and frequently results in keratitis with perforation and loss of eyesight. In the mouth the severity of the disease is manifested by profuse salivation, by great difficulty in swallowing, and not infrequently by inflammation of the parotid glands. Confluent variola is prone to a number of complications, such as bronchitis, pneumonia, pleurisy, pericarditis, diarrhœa, albuminuria, abscesses, etc. So intense is this variety of variola that some patients die before the eruptive period has arrived, but the majority of those who die survive until the stage of desiccation has been reached, death resulting at this time usually from exhaustion, or from one of the numerous complications which beset this type of the disease. In those who survive, the process of desiccation is slowly accomplished, often extending over a period of four or five weeks. In this variety but few patients escape permanent disfigurement of the face from pockmarks. Convalescence, too, is quite slow, the patient often being troubled with boils and abscesses for several weeks after the exanthem has been thrown off.

Hemorrhagic Varioloid.—The difference between this and the other types of smallpox consists mainly in the character of the eruption, the spoliation of the blood, the course of the fever, and the constitutional symptoms. It is simply a modification of variola vera. The hemorrhage into the eruption takes place under various circumstances. In some cases the exanthem becomes hemorrhagic upon the appearance of the papules, in others when the vesicular stage is reached, and in still others only when the pustules are fully formed. In some cases the entire exanthem is hemorrhagic, while in others one-half or even a very small portion of it is hemorrhagic. As a rule it begins in the eruption on the lower extremities. Petechiæ and ecchymoses usually appear between the efflorescences, and livid spots or patches are to be found on the mucous membrane of various parts of the body, particularly in the mouth and throat. Diphtheritic exudates frequently form on the tonsils, pharynx, and nasal cavities. The gums become spongy and bleed as in scurvy. Hemorrhages occur from the nose, stomach, lungs, kidneys, rectum, or uterus. The amount and persistency of the hemorrhage vary in different cases. There is no means of diagnosticating this variety of variola until the hemorrhage has occurred. The initial fever is ordinarily mild, and throughout the subsequent course of the disease the temperature rarely exceeds 102° F. When the hemorrhage has been profuse the temperature falls to or below the norm. There is a marked contrast between the temperature and the pulse rate. While the temperature is but slightly above, at, or below the norm, the pulse is beating from 120 to 160 per minute. The breathing is rapid, the countenance pinched and sunken, and occasionally there is delirium, though as a rule the intellect remains clear. This is a very fatal form of the disease; fully ninety-five per cent. of the cases end in death.

Modified Variola.—Under this head are embraced all varieties of smallpox which depart materially from the course pursued by variola vera. These departures from type may consist in variations in the character and course of the eruption, or in the symptoms of the malady, or in both; in a word, it embraces all abortive forms of smallpox. These varieties are usually designated varioloid. Varioloid may be defined smallpox modified by a previous attack of the disease, by a previous attack of vaccinia, or by an unusual degree of personal insusceptibility. There is no ground whatever for the old claim that varioloid is essentially different from variola vera. Varioloid, it is true, is milder in its course and shorter in duration than variola vera, and presents many striking departures from the ordinary course of the latter disease. That it is, however, the same disease as variola vera is constantly being demonstrated by the fact that individuals contract all other grades and varieties of smallpox by contact with individuals affected with varioloid. The duration of the initial fever of the latter variety is rarely beyond two days and the temperature seldom exceeds 102° F., falling, as a rule, to the norm at the end of the second day. With the disappearance of the initial fever the patient is convalescent and generally able immediately to return to business. In rare instances the initial fever is as high as in variola vera, yet it persists for only two days. Secondary fever is extremely rare, and when present seldom continues beyond twenty-four hours. The eruption differs in its character and development from that of unmodified smallpox. In varioloid the efflorescence appears simultaneously on all parts of the body, and it rarely passes through all the stages characteristic of variola; it may not go beyond the vesicular stage and then rapidly desiccate. Not infrequently the eruption goes on through the pustular stage, but the pustules are dwarfed, and while they are surrounded by a red areola the skin is neither tense nor swollen, and the pustules rapidly dry up and fall from the body. Desiccation usually commences from the fifth to the seventh day of the eruption. Pitting is rare in varioloid, but in some instances the face is left pockmarked. When the eruption of varioloid passes through all the stages of variola it is differentiated from the latter by the milder constitutional symptoms and by the smaller number and abortive forms of the pocks of varioloid. Varioloid is devoid of fatality.

Several other varieties of varioloid are encountered in every epidemic of smallpox. These are mainly: (1) Variola verrucosa. In this variety the eruption does not go on to well-formed pustules of smallpox, but stops with the development of solid papules with a vesicle at their summit, and on the site of each of which, after desquamation, a warty elevation of the skin is left. (2) V. pemphigosa. In this type the exanthem progresses regularly to the vesicular stage, when the vesicles become irregular bullæ with sero-purulent contents. (3) V. miliaris. In this form, while a portion of the eruption is that of regular and fully developed smallpox, the largest part consists of vesicles slightly larger than millet seeds. These vesicles, which are filled with a yellow fluid, progress no further than the vesicular stage, dry up and fall off. (4) V. siliquosa. In this variety the eruption develops regularly to the pustular stage, when the contents of the pustules are absorbed, leaving them with the appearance of empty shells. This variety is less often encountered than the three previously described.

Curschman, in discussing varioloid, has summed up the philosophy of the matter as follows: "It is generally conceded at the present time that varioloid is nothing more than a form of smallpox with a milder course and shorter duration, and, this view being accepted, it is readily seen that between varioloid and variola vera no absolute line of distinction can be drawn. During every epidemic of any considerable extent a number of cases are found which show a transition from one to the other form, and which, when we have followed their entire course, leave us in doubt as to whether we shall call them cases of variola or varioloid. The quantity or quality of the eruption is as far from being a good criterion in determining the nature of the affection as the presence or absence of the suppurative fever, which some consider decisive in this respect. This latter does not even depend entirely upon the intensity of the disease, but upon personal peculiarities, and particularly upon the sensibility of the person attacked. As regards the peculiar conditions under which varioloid occurs, it is important in the first place to observe that many persons who have never had smallpox nor have been vaccinated are only attacked by this form, on account of a natural slight susceptibility to the smallpox contagion. We accordingly find frequent mention made of cases in which the disease runs an extremely mild course."

Differential Diagnosis.—In diagnosticating smallpox in any of its varieties time is an important factor. The chill, fever, headache, vomiting, and lumbar pain constitute a group of symptoms which should put the prudent physician on his guard when smallpox exists in the locality, yet the occurrence of this symptom complex would not justify him in committing himself unqualifiedly to the diagnosis of smallpox, even though it were known that the patient had never been vaccinated and had been exposed to the disease. Under such circumstances he should make a provisional diagnosis, isolate the patient, and await the development of the disease to a stage at which it can be diagnosticated, *i.e.*, the vesicular stage. The wisdom of this course is attested by the experience of all hospital physicians. Marson, of the London Smallpox Hospital, says on this subject: "Upward of twenty diseases have been mistaken within the last few years, in the early stage of the disease, for smallpox, and the patients have been sent as having smallpox to the smallpox hospital." Under such circumstances the physician is guilty of malpractice, and can be held liable for damages. Such mistakes show ignorance or carelessness on the part of their authors. When the characteristic exanthem of smallpox has appeared, there are but few diseases liable to be confounded with it. These are chickenpox, pustular syphilis, pemphigus, impetigo contagiosa, and measles.

Diagnosis of Smallpox from Chickenpox.—A few modern writers contend that variola and varicella are one and the same disease, yet in the whole domain of medicine no proposition is better established than that each of these is a disease of its own kind, having its own specific cause. By reason of the frequency of atypical cases of variola the differential diagnosis of such cases from varicella is at times quite difficult, and in all cases demands the exercise of prudence and judgment. While they are essentially different diseases they generally prevail simultaneously, and the vesicles of each counterfeit those of the other, yet when judged in connection with the symptoms and course peculiar to each disease they can be differentiated readily by one familiar with them. Smallpox is generally ushered in with a chill; varicella is not. Varicella is ordinarily unattended by an initial fever, and when it occurs it is very slight and disappears in twenty-four hours; but in variola, even in the lightest and most atypical cases, the fever reaches 102° F. and persists for two days. The initial stage of smallpox is attended by intense pain in the lumbar region; in varicella it is absent. Vomiting is a constant symptom in the early part of the attack of smallpox, and is rarely, if ever, present in varicella. It is, however, in the character of the eruption that the difference between these two diseases is most strikingly manifested. The smallpox eruption passes through four stages, *i.e.*, macule, papule, vesicle, and pustule; the macule persists for from twenty-four to forty-eight hours before being converted into a papule; the papule remains as such for forty-eight hours before being converted into a vesicle; the vesicle continues to retain this form for four or five days prior to becoming a pustule. In varicella the eruption is fully vesicular within twenty-four hours after the efflorescence first manifests itself. The vesicles of smallpox contain a lactescent fluid and appear to be deeply seated in the skin; those of varicella contain a serous-looking fluid and appear to be quite superficial. Indeed they present the appearance of having been produced by spattering hot water on the skin. In smallpox all of the pocks have a prominent red base, while in varicella the red base is slight if at all present. All smallpox vesicles develop into pustules, whereas in cases of chickenpox not more than one in fifty or one hundred does so. Umbilication occurs in the vast majority of smallpox vesicles, while but a small percentage of vesicles of varicella become umbilicated. Some text-book writers contend that umbilication never occurs in varicella. This is a mistake. Of the hundreds of cases of chickenpox observed by me I have never encountered one case in which a fractional part of the vesicles were not umbilicated; on the other hand, I have encountered cases of smallpox which never at any stage of the disease became umbilicated. Some writers contend that chickenpox never attacks an adult. This, too, is a mistake. I have repeatedly observed undoubted chickenpox in adults. I have, however, never known chickenpox attack a whole family of adults. This is an important diagnostic point in differentiating modified smallpox from chickenpox. Again, the eruption of chickenpox appears in several successive crops, while in smallpox there is but one. In varicella the major part of the eruption is upon the body, the back particularly, while it is sparse on the face and limbs. This rule is reversed in smallpox. It is well, however, to remember just here that in rare instances chickenpox is observed to be copiously scattered over the entire body. A few months ago I saw in consultation a case of chickenpox in a child about six years old in which the eruption was semiconfluent over every part of the entire body except the palms of the hands and soles of the feet; these were devoid of eruption. All of the children of this family had been vaccinated the previous year, and all of the others had light cases of varicella.

Diagnosis of Smallpox from Syphilis.—Occasionally it becomes necessary to differentiate smallpox from syphilitic eruptions. As health officer of this city (Augusta, Ga.) I have repeatedly been called upon to discharge this duty. With care and patience these diseases can be readily separated. Papular, vesicular, and pustular syphilides counterfeit the exanthem of smallpox. In either of these varieties of syphilitic eruption fever may coexist. Papular syphilides are devoid of the shotty feel of variola. I have encountered a syphilitic vesicular eruption which was distributed over the surface of the body; a portion of the vesicles were umbilicated, and they closely simulated variola in the vesicular stage. I have also observed pustular syphilides which bore a close resemblance to the pustular stage of smallpox. Such cases are to be differentiated from smallpox by the following points: (1) None of them commence with the symptom complex of smallpox, *i.e.*, chill, fever, vomiting, headache, and lumbar pain. In each of these varieties of syphilides, if fever be present, as it not infrequently is, it persists beyond the appearance of the efflorescence, while in smallpox the fever disappears immediately after the exanthem appears. Pain may be a prominent symptom of syphilis, but it is never confined to the lumbar region as in smallpox. In any and all forms of syphilitic exanthem it will be found that the syphilides, whether papular, vesicular, or pustular, have persisted as such far beyond the time limit of either variety of the smallpox eruption. Again, the eruption in any variety of smallpox is of uniform size, while in syphilis it is of various sizes. The eruption of smallpox consists of one crop, while that of syphilis is commonly observed to be in various stages of development, thereby showing a succession of crops. In doubtful cases the diagnosis is easily cleared up by isolating the patient and awaiting the development of the exanthem.

Diagnosis of Smallpox from Pemphigus.—When pemphigus is scattered over the body it may for the first few days simulate the vesicles of smallpox. Pemphigus commences as minute red spots upon which vesicles form. The vesicles present a clear citrine or yellow color, in whites, owing to the fact that the translucency of the epidermic covering allows their serous contents to shine through it. When fully developed the vesicles are tense and firm to pressure. The fluid in them changes from a serous to a milky color. In some instances the exanthem attacks all parts of the body, but ordinarily it is confined to the limbs. The palms and soles are rarely invaded. When the eruption reaches the vesicular stage the vesicles are of uniform size, about the size of a split pea, though at a later stage a majority of the vesicles develop into bullæ of sizes varying from that of a chestnut to that of a split walnut. By reason of the thinness of their covering the vesicles and bullæ easily rupture and fold over on the adjacent sound skin, leaving a superficial raw surface on the site of those which have been broken. The major part of the eruption does not rupture, and the walls of the unbroken ones become progressively shrunken and flattened until the tops of the vesicles and bullæ sink down on the underlying layer of skin. The exanthem develops in crops and sooner or later all sizes of vesicles and bullæ will be represented. Pemphigus pursues a chronic course. Pitting does not occur in this malady. The eruption may attack the mucous membrane of the mouth, conjunctivæ, and genitalia. Fever attends the majority of cases of pemphigus in which the eruption is extensive. As a rule the fever will be in proportion to the extent and intensity of the exanthem. Four years ago I attended a case of pemphigus in which the eruption was scattered over all parts of the body. When I saw this patient the case was in the acute stage. For the first two days the vesicles counterfeited those of variola, but on the third day many of them formed bullæ varying in size from that of a chestnut to that of a guinea egg. The fever ranged from 105° to 108° F., and continued until the death of the patient on the eighth day after I was called to see him. This case in its eruption pursued the typical course of pemphigus. In cases of pemphigus which in their incipiency simulate smallpox, the diagnosis is arrived at by the following points of difference: Pemphigus is devoid of the symptom complex of smallpox, *i.e.*, chill, fever, headache, vomiting, and lumbar pain. The vesicles of pemphigus do not umbilicate; umbilication is common in variola. When fever attends pemphigus it persists for days after the eruption has appeared; this rule is reversed in smallpox. The exanthem never, in pemphigus, goes through the four stages of macule, papule, vesicle, and pustule common to variola.

Diagnosis of Smallpox from Impetigo Contagiosa.—Inasmuch as many physicians claim that the recent epidemic of smallpox was impetigo contagiosa, I give the following sketch of the malady. It is a contagious disease occurring mostly among children, and at times as a quasi-epidemic. The initial symptoms are malaise, chilliness or chill, and fever, though not infrequently these symptoms are absent. As a rule the eruption commences on the face around the mouth, on the chin, cheeks, alæ nasi, forehead, and about the eyes. The exanthem commences as small vesicles, which soon contain a turbid serum; the exanthem then extends peripherally, and assumes the character of flat, somewhat flaccid bullæ containing a sero-purulent fluid, and surrounded by an inflammatory areola of greater or less intensity. As the bullæ expand and flatten, the contained fluid dries, and in a few days a yellowish-green or straw-colored crust covers each bulla. This crust becomes dry and of a papery consistence, and has the appearance of having been stuck on its site. When it becomes detached at its margins it curls up and finally falls off; the underlying site seems superficially excoriated. After desiccation a shiny epithelium of a pinkish-red color is left on the site of the eruption, but this gradually fades to the normal color of the skin. The fully formed bullæ vary in size from that of a split pea to that of a silver three-cent piece. The eruption lacks uniformity in size, and commonly appears in small crops. After the exanthem has gradually developed over the face it attacks the abdomen and extremities in successive limited advances. As a rule the force of the disease is expended on the face, only a few scattered spots appearing on the other parts of the body. To the physician practised in smallpox it is readily seen that impetigo contagiosa bears no resemblance of any kind whatsoever to any variety of smallpox, and that these two diseases ought never to be confounded by any physician who has even a limited acquaintance with smallpox.

Diagnosis of Smallpox from Measles.—Up to the vesicular stage of smallpox its eruption simulates that of measles so closely that it is impossible positively to differentiate these diseases prior to the appearance of the vesicles of variola. If the physician awaits the vesicular stage of variola, as he should invariably do before committing himself unqualifiedly to the diagnosis, he will have no difficulty whatever in separating these two diseases. The catarrhal symptoms of measles should put the physician on his guard as to the probable nature of the malady, and the fact that the fever persists after the eruption has appeared, while it disappears in smallpox, gives added strength to the probability of the case being one of measles. Yet these two points in diagnosis, together with the difference in the initial symptoms of each malady, do not justify the physician in committing himself to a positive opinion as to the disease, inasmuch as neither these two nor all of the symptoms are pathognomonic. His duty to the public will be fully discharged by isolating the patient until the time has passed for the appearance of the vesicular stage of the exanthem. If the patient presents the initial symptoms of smallpox, has never been vaccinated, and is known to have been exposed to the former disease, the physician is justified in making a provisional diagnosis of smallpox and reporting the case as a suspicious one, reserving the right to amend his opinion thereon should the course of the disease demand it. Suit for damages has been sustained in a number of instances in which physicians reported the disease as smallpox, the patient on this diagnosis having been sent to the smallpox hospital and subsequent events having demonstrated that the diagnosis was erroneous.

Diagnosis of Smallpox from Febrile Lichen.—Febrile lichen bears a close resemblance to the efflorescence of variola in the papular stage. The exanthem of the former appears as small, slightly red papules, ordinarily of the size of millet seeds. In differentiating these two maladies time is an important factor. The eruption of lichen follows within twenty-four to forty-eight hours after commencement of the initial symptoms, and it never passes through the four stages characteristic of smallpox. In lichen the eruption is practically devoid of fluid contents, and even when it is present it is so unlike that of variola that after the vesicular stage of the latter has appeared it is impossible for the trained observer to mistake the one disease for the other.

Finally it may be said that the eruption of smallpox is the only one of all the various eruptions which passes through the four successive stages of macule, papule, vesicle, and pustule. This, then, is a crucial test of smallpox.

PROGNOSIS.—The type of the disease largely determines the rate of mortality. If a large number of cases extending over a period of many years be taken, so that epidemics of mild and severe types shall be represented, the mortality from the several more important types will be about as follows: Hemorrhagic, 95 per cent.; confluent, 50 per cent.; semiconfluent, 10 per cent.; discrete, 7 per cent.; varioloid, 0. In individual epidemics characterized by marked virulence of the disease the mortality will greatly exceed that above given, while in epidemics of marked mildness, like the one in this country for the last four years, the mortality will fall below it. Marson, from the records of the London Smallpox Hospital from 1836 to 1851 inclusive, reports that of the 2,654 cases of confluent, semiconfluent, and discrete types of variola there were 996 deaths, being a mortality of 37 per cent. Welch, from the records of the Municipal Hospital of Philadelphia, Pa., shows that from 1870 to 1894 the total number of cases of smallpox was 5,000; total number of deaths, 1,562; mortality per cent., 31.24. So much for general considerations. Several other circumstances must be considered in estimating the result in individual cases. They are mainly as follows:

Vaccination.—In the vast majority of individuals vaccination performed in infancy confers immunity from smallpox during the remainder of life, yet it is a proven fact that in some persons the protective power of vaccination decreases after a greater or less number of years, and thereby fails fully to protect these individuals from smallpox. It is also a demonstrated fact that even in those cases in which vaccination fails wholly to protect against variola, it markedly decreases the mortality from this disease. The mortality from post-vaccinal smallpox varies with the length of time intervening between the attack of vaccinia and that of variola. Marson, of the London Smallpox Hospital, claims that the mortality in post-vaccinal smallpox is greatly influenced by the number of insertions of the vaccine virus. After examining into 4,896 cases of post-vaccinal variola he says that the percentage of mortality was as follows: Having one vaccine cicatrix, 7.73 per cent.; two vaccine cicatrices, 4.70 per cent., three vaccine cicatrices, 1.95 per cent.; four or more vaccine cicatrices, 0.55 per cent.

My experience does not agree with that of Marson. In this locality vaccination is made by only one puncture, and I have never observed a fatal case of variola in a patient having a typical vaccine scar. Marson shows by elaborate statistics that the death risk from smallpox in the unvaccinated is as three to one compared with the most defective vaccination, and as seventy to one after the best vaccination.

Constitutional Condition.—The constitutional condition of the patient markedly influences the prognosis in this disease. Intemperate and debilitated patients show a greater mortality than those who are in full health and of robust constitution.

Age and Sex.—The age of the patient influences the prognosis. Among infants the mortality often reaches ninety per cent., and the same is true of those at the other extreme of life. Sex has no influence on the mortality of smallpox except in cases of pregnant females in whom abortion or miscarriage results during the attack of variola.

Complications.—The complications of this disease will be referred to under the head of treatment.

TREATMENT.—The treatment of variola embraces two important though widely divergent indications, viz. (1) Prophylaxis. (2) Therapeutics.

Prophylaxis.—In the whole range of preventive medicine prevention and control of smallpox can be more certainly accomplished than in any of the other contagious diseases, provided measures for the attainment of this end are wisely planned and faithfully executed. Vaccination, isolation, and disinfection constitute the measures necessary to be applied in prevention and control of this malady.

Vaccination.—No fact is better established than that vaccination, when duly and efficiently performed, is a full and efficient preventive of smallpox. It is equally true that vaccination, properly performed and properly cared for, is devoid of danger to health or life. In the twenty thousand vaccinations made by me, or under my personal supervision, no one of these individuals ever had any trouble other than the mild fever and pain in the arm which constitutes the vaccine disease, except a small number who contracted erysipelas or developed an abscess at the point of insertion of the vaccine virus. In every instance in which erysipelas or an abscess complicated the vaccine disease it was due to lack of care to prevent infection of the vaccinal site, and in nowise to vaccination. The subject of vaccination has been assigned to another writer, and therefore I will dismiss the subject with the following general statement: In view of the prophylactic power of vaccination every citizen should be vaccinated, and it should be deemed a solemn duty on the part of authorities of cities, counties, and States continuously to provide gratuitous vaccination for indigent citizens. When smallpox threatens a community the authorities should resort to universal vaccination, and, in needful cases, to revaccination. Every unvaccinated person is liable to contract variola if exposed to it; therefore all such persons should be excluded from schools, hospitals, asylums, and other public institutions. The same rule should be applied to all employees in business enterprises wherein large numbers are assembled. Compulsory vaccination should be resorted to where citizens are known to have been exposed to smallpox.

No matter how absolute the protection conferred by vaccination, there will always be great and insurmountable difficulties in the way of enforcement of this measure in America, where individual ignorance and prejudice are allowed to contravene public welfare, and for this reason isolation and disinfection must be added to vaccination. If a case of smallpox be introduced into a community it cannot be disseminated if the patient be promptly isolated and all infected materials disinfected.

Whenever a case of variola is encountered the patient should be promptly isolated and provided with an immune nurse if the case is not to be moved to hospital. All unvaccinated persons in the domicile, together with all outsiders who have been in contact with the patient, should be immediately vaccinated. If any of them have been previously vaccinated the procedure should be repeated. The patient should be removed to hospital, unless he can be isolated in perfect safety to the inhabitants of neighboring houses and unless the necessary nurses, guards, and medical service can be provided. When a patient is allowed to remain at home the sanitary authorities should, at the patient's expense, furnish reliable guards to compel isolation of the patient and household and compliance with all necessary sanitary precautions. When a case of smallpox is moved to hospital, all fabrics of every kind whatsoever should be thoroughly disinfected, together with the entire domicile. The fabrics in the patient's room should be taken to the public disinfection station for treatment, and, after having been thoroughly disinfected, they should be returned to the owner. It is indispensable in waging warfare against smallpox that every community should be provided with a properly located and equipped hospital, detention buildings, and a disinfection room located on the same premises. Persons who have been directly exposed to the disease should be taken to the detention building, vaccinated, and kept there for twenty one days, and at the expiration of this time they should be sent home if free of smallpox. A community which attempts to treat smallpox without a hospital and detention buildings will do so in a haphazard manner, and thereby prolong the existence of the disease among its citizens. A suitable detention building is as necessary as a hospital in attempts to stamp out smallpox in a community. Of the three hundred and seventeen persons who were taken to the detention apartments after they had been exposed to smallpox, fifty nine contracted the disease and were transferred to hospital. But for the prompt removal of these suspects to detention buildings, they would have constituted that additional number of centres of smallpox in our community The fabrics of smallpox suspects should be disinfected as carefully as if it were known that their owners were affected with the disease. Smallpox patients and their fabrics should be taken to hospital in a closed conveyance used exclusively for that purpose.

The origin of every case of smallpox should be vigilantly traced. It is equally important to ascertain the name and residence of every person who has been in the presence of the patient or has entered the house. Every such individual should be promptly apprehended and vaccinated, forcibly if necessary Those who have been in only momentary contact with the disease can, after being vaccinated, be detained at home until the period of incubation of smallpox has passed; in the mean time a sanitary officer should visit and inspect every suspect every second day in order promptly to detect any who may fall ill of variola Suspects detained in their homes should undergo detention for three weeks

Among our servant class of population (negroes) it is necessary to exercise the closest possible supervision, inasmuch as they habitually conceal the disease in their families. They also commonly go from their infected houses to their duties in the families of their employers, while others of them carry on their work in the household, as washer-women, during the full bloom of variola, and deliver this washing without the owners suspecting that their clothing had been in the midst of the disease and was being returned without being disinfected. In scores of instances I have found the clothes of white families being done in a room occupied by a patient in the full bloom of smallpox.

Disinfection.—The contagious element of smallpox resides in the eruption, exhalations, secretions, and excretions of the patient. These contaminate the sick room and adhere to all fabrics therein. The vitality of the poison of variola persists for a long time when contained in fabrics which are laid away in closed receptacles. By intelligent use of germicidal agents every particle of contagion in houses and fabrics can be destroyed. To do this the germicide must be used in sufficient quantity, and of sufficient potency, and the fabrics must be opened so that the disinfectant can come in immediate contact with every particle of the contagion. Fabrics in bundles cannot be disinfected even by boiling. Gaseous disinfectants are to be relied upon only for surface disinfection. Every discharge which passes from the patient's body, mouth, nose, kidneys, or bowels must be received in suitable receptacles containing a potent germicidal solution The discharges from the nose and mouth are best disposed of by being received upon bits of old cloth, which should be burned as soon as soiled. Every handkerchief, towel, every article of bed or body linen, should be thoroughly saturated in a germicidal solution prior to being sent from the patient's room. All articles of crockery and utensils of every kind whatsoever used in the sick room must be disinfected before being sent from it. In order, as far as possible, to confine the contagion to the patient's room, all communicating doors, except the one leading to the hall, should be securely sealed by pasting paper over all joints, and a sheet saturated with a germicide should be hung on the hall side of the door. The nurse should wear a washable suit, and the physician should put on a linen duster which covers his entire body when he enters the room. The patient should be detained in isolation until desquamation has been completed on every part of the body. The epidermis being thicker on the palms and soles, desquamation is slower on these parts than on the remainder of the body.

After desquamation has been completed the patient should be given a general sponge bath charged with creolin or carbolic acid, and then, dressed in a fresh suit of clothes, just brought into the room, may be allowed to mingle with the household. The nurse should take similar precautions as to bath and fresh clothing before leaving the room. As soon as the room has been vacated, it, with its contents, should be disinfected. The first step is to stop up all openings in the apartment, then to open and hang all unwashable fabrics on furniture or wires, and fumigate it with sulphur or formaldehyde. Formaldehyde fumigation is preferable by reason of its greater convenience and economy and because it does not injure household articles. Sulphur fumigation is, however, equally efficacious. After fumigation the room should remain closed for twenty-four hours, when all fabrics which are washable should be wrung out in a hot germicidal solution and subsequently boiled for half an hour. It is extremely difficult, if indeed it be possible, to disinfect pillows and mattresses except by placing them in a chamber and subjecting them to superheated steam. Inasmuch as few municipalities are provided with this apparatus, it will be found cheapest and safest to burn such articles. All stuffed furniture in the infected room should be stripped and the stuffing burned. If a carpet is on the floor it should be thoroughly scrubbed with a solution of bichloride of mercury (1 to 5,000), then removed from the floor and hung in the air for a week or more. All unwashable fabrics, after having been fumigated, should be hung in the open air for several days. After the room has been fumigated and the carpet and other fabrics have been removed therefrom, the floor and woodwork should be scrubbed with a germicidal solution, the walls carefully swept, and the apartment thrown open for atmospheric disinfection for a period of two weeks, after which it may be safely reoccupied. Where mattresses, pillows, and other articles belonging to citizens are destroyed, they should be replaced at public expense, inasmuch as they were destroyed for public protection.

It should be remembered that it is impossible to disinfect an inhabited room, and that there should be no such thing as partial disinfection. Disinfection must be perfect in all of its details or it will prove a failure. To demonstrate that disinfection can be made a perfect success, I cite the fact that the fabrics of fully eight hundred smallpox patients and suspects have been disinfected, as above outlined, in Augusta, Ga., and in no instance have these fabrics spread the disease after having been so treated by our chief sanitary inspector

In fatal cases of smallpox the body should be thoroughly washed in a strong disinfectant solution and subsequently enveloped in a sheet charged with a solution of chloride of zinc, bichloride of mercury, or undiluted commercial formaldehyde. Under no circumstance should public burial be permitted, nor should the corpse be transported in a public conveyance. The body should be carried to the grave in the smallpox ambulance, but if no such conveyance is available, the vehicle in which the corpse is so transported should be disinfected under the supervision of the sanitary authorities immediately after it has been used.

Therapeutics.—There is no known curative treatment of smallpox. It is wholly symptomatic and must be adapted to the case in hand with a view to mitigate the severity of the symptoms Vaccination, if successfully performed within three days after exposure to smallpox, will in some cases prevent, in others abort, and in still others markedly modify the course of smallpox. In a number of instances I have vaccinated individuals from three to five days after they had been exposed to smallpox, and these individuals failed to contract the disease notwithstanding the fact that they continued to occupy the room of the smallpox patient. Some of them continued to sleep in the same bed with a case of the disease, yet remained immune. I have known five infants to be successfully vaccinated three days after the eruption of variola commenced on the mothers, and although they continued to nurse the breast of these mothers, they nevertheless remained free from the disease. I recall three instances of individuals who had been vaccinated five days after exposure to smallpox, and who had continued to nurse relatives affected with the disease. In each of these individuals, who in due time contracted smallpox, the disease was ushered in with a severe chill, high fever, vomiting, headache, and lumbar pain, and from the severity of the initial symptoms I expected them to develop severe cases of variola, yet the entire crop of eruption consisted of one vesicle. In other instances, under like circumstances, I have counted only ten or twelve vesicles on the entire body. In still other cases I have seen the vaccine disease and smallpox affect the patient at the same time, neither malady at first seeming to interfere with the other, but in whom at a later period the eruption rapidly dried up and the crusts soon dropped from the body. On the other hand, I have observed several cases in which individuals, who had been known to be exposed to smallpox, were vaccinated for the first time after such exposure and promptly developed vaccinia; then, twelve days after this exposure to smallpox, they contracted the disease, and the two diseases, smallpox and vaccinia, pursued typical courses, apparently travelling together in the patient's system as harmonious companions. That vaccination, even after persons have been exposed to smallpox, has a marked power to prevent the latter disease is shown by facts observed in the smallpox hospital of Augusta. Within the last four years three hundred and seventeen persons, who had never previously been vaccinated, but who were known to have been exposed to smallpox, were vaccinated and taken to the detention hospital, and yet only fifty-nine of them contracted variola. It would not, in my judgment, be fair to claim that this favorable result was wholly due to vaccination, inasmuch as a certain number of these individuals—exactly how many cannot be determined—doubtless escaped because they were separated at an early moment from the smallpox patients. I regard smallpox as but slightly contagious up to the vesicular stage. It is most actively contagious in the pustular stage. In view of the proven fact that vaccination, done even a few days after exposure of individuals to smallpox, has the power to prevent, abort, or mitigate the latter disease, it is important that every such exposed person should be promptly vaccinated. The character of the vaccine virus is a matter of importance. The vaccine should be used in that form which will most promptly and certainly produce vaccinia. Glycerinized lymph possesses both of these requisites. In my hands glycerinized lymph from approved propagators has succeeded in producing typical vaccine vesicles in from ninety-five to ninety-nine per cent. of primary vaccinations; and the vaccinia appeared from two to four days earlier than when dry lymph on points was used. In my experience glycerinized lymph in capillary tubes is infinitely superior in all respects to dry lymph on points. I have used glycerinized lymph in vaccinating about ten thousand individuals.

As soon as the patient has contracted smallpox he, if he is to remain at home, should be isolated in a well-ventilated room, preferably on the upper floor of the house. All unnecessary clothing, bedding, furniture, carpeting, and other household effects should be immediately removed from the room, disinfected, and stored away. In the winter season the temperature of the sick-room should be maintained at or near 72° F. When the patient has a chill he should be warmly covered, and a mustard plaster should be applied to the spine for twenty minutes. When the fever is high it should be treated by hot foot baths and if need be by general warm baths, repeated as indicated. The fever being the result of the toxins of the smallpox infection in the patient's system, the chief indication for treatment of the pyrexia will be met by opening up the emunctories of the body. This is to be accomplished by administering such agents as will induce free diuresis, diaphoresis, and catharsis, as indicated by the case in hand. It should be remembered that children are liable to convulsions during the febrile period of smallpox, and when they are so threatened hydrate of chloral and bromide of potassium should be administered in suitable doses. After the eruption has appeared the initial symptoms disappear. As a rule, fever returns when the pustular stage of the malady is reached. This is best combated by general warm baths followed by enveloping the patient in blankets in order to induce free sweating. In treating fever on the above plan, the warm baths, besides producing active diaphoresis, will induce free action of the kidneys and allay the patient's restlessness. The exanthem in the mouth and throat causes discomfort and difficulty in swallowing. To alleviate these symptoms glycerinized astringent gargles are indicated. The diet of the patient should consist mainly of milk, soup, eggs, beef-tea, gruel, oatmeal, stewed fruit, etc., during the early course of the disease; while in the later part of the attack the food may consist of almost anything which the patient's appetite may call for. In severe cases of smallpox the patient's strength will be severely taxed, and for this reason it is important that suitable food should be freely administered. In these severe cases the conjunctivæ are commonly invaded. The lids become swollen from the eruption on them, and not infrequently purulent conjunctivitis sets in, the secretion causing temporary adhesion of the eyelids, which necessitates their forcible opening so that the pent-up secretion may be removed and the eyes treated. If this be not done a diffuse keratitis may set in, and it may go on to ulceration and perforation of the cornea. In cases attended with intense swelling of the eyelids the vesicles thereon should be emptied immediately upon their reaching that stage. The lids must be frequently opened and the eyes wiped out with absorbent cotton, and at least every six hours a suitable astringent solution should be instilled between the lids. In all cases the physician must carefully watch for iritis, keratitis, and ulceration. As soon as the inflammation appears atropine should be instilled into the eyes, and iced compresses applied over the lids.

The eruption on the surface of the body is often the source of extreme discomfort. This may be alleviated by brushing it over several times daily with a solution of two grains of carbolic acid to an ounce of glycerin or linseed oil. Various plans of treatment looking to prevention of pitting of the face have been advocated. I have tried all of them and have found them to be utterly useless. If, as previously stated, only the superficial layer of the skin be involved, the patient will escape being pockmarked. If, on the other hand, the true skin be involved, pitting is inevitable. I have encountered cases of all varieties of variola unattended by pitting, although no local treatment had been used.

In some cases of variola sleeplessness is a prominent and distressing symptom. This should be overcome by the use of morphine or of a mixture of chloral and bromide. In cases of variola attended by profuse expectoration opiates should be given with caution. Constipation should be overcome by saline purgatives. When diarrhœa is present it should be controlled by astringents and careful feeding.

Abscesses not infrequently form in the subcutaneous tissues during the course of smallpox. The scalp is a favorite seat of these abscesses, and when they first appear they are of small size, but they continue to enlarge and show but little disposition to point. Whenever they form they should be promptly laid open. As soon as it is known that a patient has smallpox the hair on the scalp ought to be shaved, inasmuch as the eruption is commonly copious on the head, and if this be not done the hair will become matted and the mass putrescent. Boils over various parts of the body are of common occurrence, and these frequently terminate in foul ulcers.

Boils should be promptly lanced and both they and the abscesses should be carefully watched and treated. Wherever suppuration is present it calls for treatment with quinine, iron and strychnine, wine, and full nourishment.

Complications such as erysipelas, laryngitis, pleurisy, pneumonia, nephritis, etc., are to be treated on general principles.

In severe cases of smallpox the heart muscle usually undergoes fatty and parenchymatous changes. This fact suggests the necessity of guarding the patient against heart-strain by rest in bed and, when needful, by the administration of cardiac tonics, such as strychnine and alcoholic stimulants. Delirium, restlessness, weak and rapid pulse, shrunken features, with great prostration, demand free, even bold administration of alcoholic stimulants and strychnine. The amount of alcoholics and strychnine to be administered in adynamic states of smallpox must be decided by the degree of vital depression to be combated. Convalescence is protracted in those who have had a severe type of smallpox. During this period marked benefit will be derived from taking Aitken's pills of arsenic, iron, strychnine, and quinine, with full feeding and alcoholic stimulants in moderate doses.

Eugene Foster.

SMELL, SENSE OF. See *Olfactory Nerve.*

SNAKEROOT, CANADA, or *Wild Ginger*, is the rhizome of *Asarum Canadense* L., and that of *A. reflexum* Bicknell has probably been more or less used for and with it. These plants are natives of rich woodlands in the Northeastern United States. The rhizomes lie very near the surface of the soil, may become a foot or more in length, branch rather freely, and bear few coarse roots. The leaves are long petioled, kidney-shaped, and sometimes reach a breadth of six inches. The solitary flower is terminal, cup-shaped, three-lobed, about an inch broad, and of a deep purple color. The dried rhizomes are quadrangular or two-edged, longish-jointed, deep-purple, lightly curved, and about as thick as matchsticks. The odor and taste remind one strongly of ginger. With some resin, starch, gum, and sugar, Canada snakeroot contains an unknown bitter principle and 1.5 to 3.5 per cent. of a volatile oil. An alkaloid is also thought to be present. It is an excellent aromatic bitter, the aromatic element predominating, and a carminative and diaphoretic. The dose is from 1 to 2 gm. (gr. xv.–xxx.), the tincture being the preferable form of administration. The volatile oil is also known to commerce. Its active constituent is *asarol* ($C_{10}H_{16}O$). Under the name "*asarabacca*," the rhizome of *A. Europæum* L. has long been employed similarly. It is now very little used. Its oil contains *asaron* instead of asarol, and it is distinctly emetic, or even purgative in the dose above specified for the other species. Its ordinary dose is only one-tenth as large.

Henry H. Rusby.

SNAKEROOT, VIRGINIA, OR TEXAS.—(*Serpentaria*, U. S. P.; *Serpentariæ Rhizoma*, B. P.) The dried rhizome and roots of *Aristolochia Serpentaria* L. (True Virginia Snakeroot or Serpentaria) or of *A. reticulata* Nutt. (Texas Snakeroot or Serpentaria) (fam. *Aristolochiaceæ*). These are perennial herbs, a foot or so high, from knotty, horizontal, aromatic rhizomes; stems slender, flexuose, branching at the base; leaves of various shapes between ovate and narrowly lanceolate, with heart- or halberd-shaped base, petiolate, entire; flowers lateral, on slender, straggling, crooked peduncles in the axils of bracts near the surface of the ground, about an inch long, consisting of a dull-purple, single perianth (calyx), whose curved tube has a wasp-like constriction near the middle, and a very oblique, spreading, three-lobed border; stamens six, short, connected with the style in three pairs; ovary three-celled, many-ovuled, inferior. The first named is a native of the Eastern United States, especially of Pennsylvania, Virginia, and Kentucky, where much of the drug is collected. The second named, of Texas and the adjacent region, is somewhat larger and coarser.

FIG. 4320. Virginia Snakeroot. About one-half natural size. (Baillon.)

DESCRIPTION.—*Virginia Serpentaria.*—Rhizome of oblique growth, 1 to 3 cm. (⅖ to about 1 in.) long and 1 to

2 mm. ($\frac{1}{25}$ to $\frac{1}{12}$ in.) thick, crooked and somewhat branched, bearing on the upper surface approximate, short stem bases, and underneath a dense tress of long, thin, branched roots, which are straightish, except as they are bent and doubled by pressure; dull yellowish-brown, internally whitish, the wood-rays of the rhizome longest in the lower side; fracture of both rhizome and roots weak; odor strong, aromatic, and camphoraceous; taste warm, aromatic, bitter.

Texas Serpentaria is larger, coarser, of a more gray color, and the roots are fewer.

CONSTITUENTS.—Serpentaria owes its aromatic properties to a volatile oil, existing to the extent of from one-half to one per cent., of which *borneol* is the important constituent. Associated with this is five or six per cent. of resin, the greater portion of it soluble in petroleum ether. Tannin, starch, gum, and sugars also occur. The bitter principle is not well known, but is believed to be, in part at least, a very small amount of the alkaloid *aristolochine*, extracted by Hesse from *A. Argentina* Griseb. The amaroid *clematitin* ($C_9H_{10}O_6$), obtained from *A. Clematitis* L., is believed to be identical with a constituent of serpentaria which has been called *aristolochin*, also *serpentarin*, and which is poisonous; but the relationship of these to the alkaloid named above is not known. Hesse also describes *aristinic*, *aristidinic*, and *aristolic acids* from *A. Argentina*, and these are believed also to be present in serpentaria.

ACTION AND USE.—Although aristolochin has been found, as stated above, to be poisonous when pure, it is present in the drug in such small amount that the latter is not poisonous in any ordinary doses. Neither has serpentaria any specific properties, although such have been ignorantly ascribed to it. Its action is merely that of an excellent aromatic bitter and its antiperiodic and antirheumatic reputation is doubtless due entirely to its indirect effects as a general tonic. The dose of serpentaria is 1–4 gm. (gr. xv.–lx.); of the official fluid extract, 1–4 c.c. (♏xv.–lx.). The Pharmacopœia provides also a ten-per-cent. tincture, of which the ordinary dose is 4–16 c.c. (fl. ʒ i.–iv.). Like other bitter stomachics, serpentaria is far better taken in small doses, of the weaker preparations, a short time before eating.

The genus contains a large number of species, many of which have been similarly used in their own homes. Some of them are far more active than serpentaria, large doses acting as emetico-cathartic poisons.

Henry H. Rusby.

SNAKES AND SNAKE-POISON. See *Poisonous Reptiles*.

SOAP.—When natural fats or oils are decomposed by treatment with salifiable bases, they split up into the alcoholic body *glycerin* on the one hand, and a series of *acids* on the other—principally oleic, palmitic, and stearic acids, in varying proportions, according to the nature of the fat, which acids then unite with the base used in effecting the decomposition of the fat, to form salts—oleates, palmitates, or stearates, or all combined, as the case may be. Such salts are generally called *soaps*, but in common parlance the name soap is applied only to the fatty salts of the alkali bases—potassa, soda, and ammonia—which, in contradistinction to the soaps derived from earthy and metallic bases, are soluble in "soft" water and in alcohol. Of the alkali soaps, furthermore, ammonia soap is used only in the preparation called *ammonia liniment*, or *volatile liniment* (see *Ammonia*), so that the soaps in common use as such are narrowed down to soda and potassa soaps.

Between soda soaps and potassa soaps, as distinct classes, the broad distinction is that soda soaps tend to be comparatively hard, and potassa soaps soft, so that the phrase *hard soap* is applied generically to soda soaps, and *soft soap* to potassa soaps. But the consistence of soaps is also markedly affected by the nature of the fat used in the manufacture, in the way that fats rich in olein, as is the case with oils, tend to yield softish soaps, whereas those rich in stearin and palmitin, typified by the solid fats, such as tallow, furnish soaps of greater consistence.

Soaps are bodies of a well known characteristic odor and disagreeable alkaline taste. They dissolve in alcohol and in "soft" water, but in "hard" waters they suffer decomposition by the calcic salts present, and the resulting lime soap floats in insoluble flocculi on the surface of the water. Soaps are, in general, decomposed by acids, by earthy bases and salts of the earths, and by the heavy metals. The useful property of soaps is that they attack grease, dirt, and dried animal débris, probably by virtue of their free alkalinity, and so affect those substances as to render them soluble in water, and thus readily removable.

The kinds of soap official in the United States Pharmacopœia for use in technical medicine are as follows: Under the simple title *Sapo*, Soap, is recognized "soap prepared from soda and olive oil." Such a soap corresponds to what is commercially called *Castile*, or *Spanish*, soap, and is an opaque, white substance, hard, but when fresh easily to be cut. It has the simple, characteristic smell of soap and an unpleasant alkaline taste. It dissolves readily in water and in alcohol. If the soap, as first separated in the making, be not purified, it presents a marbled appearance from contaminating streaks of an insoluble iron soap. This unpurified soap is stronger than the purified, white soap, since in the process of purification the soap combines with more water.

Castile soap is locally detergent, and, by virtue of its free alkalinity, mildly irritant to tender surfaces. Taken internally, it is innocent in moderate quantity, and tends only to relax the bowels and neutralize acid in the *primæ viæ*. Locally, free ablutions of soap and water are beneficial in certain forms of skin disease, such as acne, and, as regards internal giving, the principal application of soap is as a ready and innocent alkali to administer in cases of poisoning by any of the strong acids. A strong aqueous solution—one part of soap to four or five of water—should in such cases be very freely administered pending the arrival of more powerful and appropriate alkaline antidotes. Soap and water is also much used as a cathartic enema, but in sensitive conditions of the rectum may irritate. Pharmaceutically, soap is much used as an excipient in pill composition, but due regard must be paid to its chemical susceptibilities, as above detailed. From Castile soap are made the following official preparations: *Emplastrum Saponis*, Soap Plaster, is compounded of soap, one part, and lead plaster, nine parts, mutually incorporated when in the fluid condition, and the product evaporated to the proper consistence. Soap plaster is a feebly active plaster, devoid of specific medicinal properties. *Linimentum Saponis*, Soap Liniment, is compounded of soap and camphor with a little oil of rosemary, made into a liniment with dilute alcohol. This preparation makes an excellent gently stimulant embrocation, and takes the place of the *camphorated soap liniment*, or so-called *opodeldoc* of older revisions of the Pharmacopœia, an article substantially the same in composition as the present, but prepared from the common white soap made of animal fat, instead of from Castile soap.

The second variety of official soap is entitled *Sapo Mollis*, Soft Soap, and is made from potassa and linseed oil. It is a soft, unctuous substance of a brownish-yellow color. "*Green soap*" or "*German soap*" is a soft soap made in Europe and formerly imported into America. Its greenish color is due to impurities in the oils from which it is made.

Soft soap is more strongly alkaline, and therefore more detergent on the one hand, and more irritating to sensitive tissues on the other, than the hard soda soaps. Severe pain is easily excited upon tender surfaces, such as that of an eczematous patch of skin, by applications of soft soap. The medicinal use of the soap is as a detergent and "alterative" application in certain forms of skin disease, notably in *eczema rubrum*. The part is com-

monly washed with the soft soap, and afterward dressed with some bland substance, such as ointment of zinc oxide.
Edward Curtis.

SOAP BARK.—(*Quillaia*, U. S. P.; *Bois de Panama*, Codex Med.) The dried inner bark of *Quillaia Saponaria* Molina (fam. *Rosaceæ*). This bark is derived from a large evergreen tree, native and abundant in Chili. After the removal of the corky layer, the bark is usually flattened out and pressed tightly into bales, in which form it reaches the market. It is imported in considerable quantities for various purposes connected with manufacture—sizing, cleansing, etc.—and has found a not very commendable place in syrups for aërated waters, and in beers, to make them hold their froth.

Description.—In large, flat pieces, 3-8 mm. ($\frac{1}{8}$–$\frac{1}{3}$ in.) thick; outer surface brownish-white, often with larger or smaller patches of the dark brown outer layer adhering, otherwise smoothish or lightly striate; inner surface pale yellowish or whitish, nearly smooth, or often with longitudinally elongated blister-like elevations; fracture tough and strongly splintery, the laminæ oblique to each other; transverse section checkered with pale brownish bast fibres embedded in the white tissue; inodorous, but the powder highly sternutatory; taste persistently acrid. The infusion foams like soap water.

The active constituent of soap bark is saponin (from eight to ten per cent.), which is in turn resolvable into several distinct substances, all of them poisonous. Sapotoxin, the more important of these, is soluble in water but not in alcohol, and is precipitated by basic lead acetate. It is the principal irritating constituent. Quillaic acid is soluble in alcohol and water, not in ether, and is precipitated by the neutral as well as the basic lead acetate.

Uses.—Soap bark, or an infusion or tincture made from it, is useful as a detergent in washing fine linens, laces, etc., cleaning the surface of paintings, and other fine work of that kind. It is also an ingredient of some cosmetic preparations—lotions, hair washes, etc. Its use in syrups has been referred to; it has been further employed to a small extent as an emulsifying agent. Physiologically it is a pretty active substance, paralzying voluntary muscles with considerable rapidity, and producing local anæsthesia. It is also a local irritant. These properties have not, however, been put to therapeutic use. As an expectorant, in small doses, it has been recommended, also as an alterative in place of sarsaparilla, but its value is at least doubtful.
Henry H. Rusby.

SOAP ROOT.—*Soapwort.* "Bouncing Bet." (*Saponaria officinalis*, Cod. Med.). The dried root of *Saponaria officinalis* L. (fam. *Caryophyllaceæ*). This plant is a well-known European perennial herb, freely naturalized in North America, and often a troublesome weed around the edges of gardens, along roadsides, and in rich waste places. It is about two feet high, with ovate, opposite, usually sessile, three- or five-nerved leaves, and cymes of large whitish or pink flowers terminating the branches. All parts of the plant, but especially the roots, contain saponin in large amount, and its properties are very similar to those of soap bark, considered above, though it is scarcely so active as that drug. It is commonly employed in the household in the form of a viscous, suds-like solution for washing or sizing. It is also more or less employed, though less than formerly, as a stimulating expectorant, like senega, or as an alterative, like sarsaparilla. The ordinary dose is from 2 to 8 gm. (ʒ ss.–ij.) and it is mostly employed in the form of the decoction, one ounce to the pint.

Levant soap root, from various species of *Gypsophila*, of the same family, occurs in pieces of a large root, often two inches in thickness, of a pale yellowish- or brownish-white color. Its constituents, as well as its properties and uses, are similar to those of the ordinary soap root. It is rather more active, however, than the latter. Many other related plants have a similar composition and use.
Henry H. Rusby.

SODIUM.—I. General Medicinal Properties of the Compounds of Sodium.—From the close chemical alliance between sodium and potassium, theory would assign to compounds of sodium physiological properties similar in kind to the corresponding potassic compounds, but less strongly pronounced. The prediction is true in that the sodic effects, such as they are, are potassic effects weakened; but an inference that all the potassic effects, in kind, will be reproduced to some degree in the action of sodium, will not hold. The notable potassic effects are irritation, catharsis, cardiac paresis, general motor paresis, oxidation quickening, and, toxicologically, general toxæmia. Sodium, in comparison, is irritant, salt for salt, in decidedly less degree; is purgative in only slightly less degree; paralyzes heart and motor function so very little that the action appears only at all in excessive dosage in animal experimentation; scarcely seems to quicken oxidation at all, nor, even in high dosage, to impoverish the blood after the manner of potassium. So far, however, as concerns those compounds of sodium that are alkaline in reaction, or which, as in the case of citrates, acetates, and tartrates, are converted into an alkaline compound in the blood, the degree of alkalinity is but little less than that of the analogous potassic compounds, and hence the effects that follow simply from the fact of such alkalinity are, with sodic compounds, well pronounced. But yet, therapeutically, so far as constitutional alkalizing is concerned, the diseases calling for alkaline medication are also specifically benefited by the specific potassium effects, so that in their case sodic salts, though strongly alkaline, still cannot compete in curative power with their potassic rivals.

II. The Compounds of Sodium Used in Medicine.—As in the case of potassium, those compounds only will be discussed here whose effects are either *sui generis* to the compound, or are determined mainly by the basic radical. Such salts, official in the United States Pharmacopœia, are the following: *Hydroxide* (hydrate), *carbonates*, normal and acid, (pyro-) *borate*, *acetate*, *potassio-sodic tartrate*, *sulphate*, *phosphate*, *pyrophosphate*, *nitrate*, and *chlorate*. Of these the potassio-sodic tartrate (Rochelle salt) will be found discussed under the title *Potassium*. Other sodic salts, whose properties are derived mainly from the acid radical of the composition, are treated of under the title of such radical. Such pharmacopœial salts are the following: *Arsenate*, see *Arsenic*; *benzoate*, see *Benzoic Acid*; *bromide*, see *Bromides*; *chloride*, see *Chlorides*; *hypophosphite*, see *Hypophosphites*; *hyposulphite*, see *Sulphites*; *iodide*, see *Iodides*; *nitrite*, see *Nitrites*; *salicylate*, see *Salicylic Acid*; *silicate*, see *Silicates*; *sulphite*, see *Sulphites*; *sulpho-carbolates*, see *Sulpho-carbolates*.

Sodium Hydroxide (Hydrate): NaOH.—This substance, commonly called *Caustic Soda*, is official in the United States Pharmacopœia, in solid condition, under the title *Soda*, Soda, and in about five-per-cent. aqueous solution, as *Liquor Sodæ*, Solution of Soda. Soda is a white, hard, opaque substance, occurring either in lumps or in moulded cylindrical pencils. It is odorless, but has an intensely acrid, caustic taste. It deliquesces in moist air, but becomes dry and effloreseent in dry air. It dissolves freely in water and alcohol. It should be kept in well-stoppered bottles made of hard glass. Soda is commonly made by evaporating an aqueous solution of the substance, until the water is driven off and the hydroxide remains in a state of fusion, and then either pouring the viscid fluid into cylindrical moulds or allowing it to harden *en masse*. Solution of soda may be made by dissolving soda in water, but is commonly prepared from the carbonate by decomposition with lime in the presence of water. Calcium carbonate precipitates, and the solution of soda, clarified by straining and settling, is separated by siphonage. Solution of soda is "a clear, colorless liquid, odorless, having a very acrid and caustic taste, and a strongly alkaline reaction. Specific gravity about 1.059" (U. S. P.). The solution should be kept in green glass bottles, glass stoppered, and the stoppers should be coated with vaseline or paraffin.

Soda and its solution are powerfully alkaline and caustic, like potassa, but to a somewhat inferior degree. Soda is available as a caustic, to be used after the manner of potassa, but potassa, being the stronger agent, is generally preferred. Solution of soda is possible as a local alkali for the skin or the stomach, but the carbonates are almost always used in preference. If given internally, the dose of solution of soda would range from 1 to 4 gm. (♏ xv.-lx.), largely diluted. In considerable quantity, undiluted, solution of soda would prove a caustic poison, with symptoms generally similar to those of poisoning by potassa.

Normal Sodium Carbonate: $Na_2CO_3.10H_2O$.—Sodium carbonate in crystals or effloresced powder is official in the United States Pharmacopœia as *Sodii Carbonas*, Sodium Carbonate; and the effloresced powder, baked at a temperature of about 45° C. (113° F.) until its weight is reduced to a fixed standard, is also official under the title of *Sodii Carbonas Exsiccatus*, Dried Sodium Carbonate. Sodium carbonate is the salt commonly called *sal soda* or *washing soda*, and is obtained in part from natural deposits—"native soda," so called—in part from the ashes of certain plants growing in or near the sea, the impure yield of which constitutes *barilla* or *kelp*, and in part by artificial making from sodium chloride, sodium sulphate, or the mineral *cryolite*. Sodium carbonate occurs as large, colorless, monoclinic crystals, which effloresce in dry air and fall into white powder. The salt has no odor, but has a harsh, alkaline taste. It dissolves freely in water, but is insoluble in alcohol. The dried salt of the Pharmacopœia, a fused mass as first prepared, finally presents itself as a white powder. Both forms of the carbonate should be kept in well-stoppered bottles.

Sodium carbonate combines, very purely, strong alkalinity with absence of specific qualities of any kind except the irritation or even causticity in concentrated application which is inherent in a powerful soluble alkali. Its uses are solely those of a local alkali, and are practically confined to external employment in lotion or ointment in skin affections. Lotions average two per cent. in strength, and ointments between two and ten, the basis being lard. For internal use, the acid carbonate, next to be described, is preferred, because of its more agreeable flavor and milder action. In considerable quantity and strong solution the normal carbonate is a corrosive poison.

Acid Sodium Carbonate: $NaHCO_3$.—This salt, the well-known *cooking soda*, so called, occurs in two grades of purity. One, corresponding to 95 per cent. of the pure salt, is the commercial *bicarbonate of soda;* the other, purified to represent 98.6 per cent. of the pure salt, is what is used in medicine, and is official in the United States Pharmacopœia under the title *Sodii Bicarbonas*, Sodium Bicarbonate. This salt is a white powder, permanent in the air, without odor, and of a not unpleasant taste, cooling, mildly saline and alkaline. It dissolves in 11.3 parts of cold water (15° C. = 59° F.), but is decomposed by hot water, losing carbon dioxide, and becoming the normal carbonate. It is insoluble in alcohol.

Sodium bicarbonate is purely alkaline, like the normal salt, but to a less degree, and by reason of that fact is far less irritant. In all ordinary dosage it is indeed practically free from danger. Its taste also is mildly mawkish only, instead of harshly alkaline. For these various reasons this salt is a favorite one for stomachic alkalizing, as in acid dyspepsia or diarrhœa. It is also much used to make alkaline lotions for the skin. Internally from 1 to 4 gm. (gr. xv. to lx.) may be given at a dose in water, and externally washes or ointments may be made in the same manner and of the same strengths, as in the case of the normal carbonate. Both of the carbonates are incompatible with acids and acidulous salts, lime water, ammonium chloride, and salts of the metals and metals of the earths.

Troches of the bicarbonate—*Trochisci Sodii Bicarbonatis*—are official in the United States Pharmacopœia, each troche containing 0.20 gm. (gr. iij.) of the salt. The salt is also an ingredient of the pharmacopœial preparations, *Mistura Rhei et Sodæ*, for which see *Rhubarb*, and *Pulvis Effervescens Compositus* (Seidlitz powder), for which see *Potassio-Sodic Tartrate*, under *Potassium*.

Sodium (Pyro-) Borate: $Na_2B_4O_7.10H_2O$.—This salt—the familiar substance *borax*—is official in the United States Pharmacopœia as *Sodii Boras*, Sodium Borate. It occurs in colorless, transparent, shining, monoclinic prisms, which effloresce in dry air. The crystals are odorless, and of a mild, cooling, and somewhat sweetish taste. The effloresced powder has a more pronounced alkaline flavor. Borax dissolves in sixteen parts of cold water, and freely in boiling water. In alcohol it is insoluble. Borax occurs native in Persia and adjacent neighborhoods as a saline efflorescence on the borders of lakes, and in California as a crystalline deposit at the bottom of a small lake. It is also made from other native borates.

Borax is locally bland and constitutionally innocent, and its medicinal virtues seem to reside in the combination of feeble alkalinity with a fair degree of antiseptic power derived from its acid radical. Borax works well as a mild detergent alkali in skin diseases or catarrhs, and ulcerations of mucous membranes, particularly of the mouth. A lump held in the mouth and slowly sucked seems to excite the secretions of pharynx and larynx, and in case of huskiness from dry catarrh of these parts temporarily restores something of the natural quality to the voice—an important matter to a singer or speaker affected with a cold. Internally, borax may be used as a feeble alkali, and it has been accredited also with a power to promote menstruation, correct dysmenorrhœa, and excite uterine contractions—a power which until better substantiated than at present should not be trusted in an emergency. Borax may be given internally in doses of from 1 to 3 gm. (gr. xv. to xlv.), and, externally, may be applied in lotions ranging from one to six per cent. in strength (limit of solubility in water), or in ointment of thirty-per-cent. strength. Borax has been experimented with, among a host of other substances, for the purposes of "antiseptic surgery," and has been found experimentally to prevent the development of microzymes in aqueous solution of from one-half to one-per-cent. strength.[1]

What is practically a soluble form of borax is the *tetraborate* that forms when borax and boric acid are boiled together in water. Sodium tetraborate makes a fine white powder, of greasy feel, which is freely soluble in water. It may be used locally for the purposes of borax, and is convenient for the making of antiseptic borate solutions. Solutions ranging in strength from two to fifty per cent. have been used.[1]

Sodium Acetate: $NaC_2H_3O_2.3H_2O$.—The salt is official in the United States Pharmacopœia as *Sodii Acetas*, Sodium Acetate. It occurs in large, colorless, transparent monoclinic prisms, efflorescent in dry air. It is odorless, with a bitter, saline taste; dissolves in 1.4 parts of cold water, and freely in boiling water; in 30 parts of cold alcohol and in 2 parts of boiling water. It is rarely used in medicine. Its purpose would be as a constitutional sodic alkali, its acid, as in the case of other alkaline acetates, undergoing conversion, in the blood, to carbonic. It may be administered in doses of from 2 to 4 gm. (gr. xxx. to lx.).

Potassio-sodic Tartrate. (See under *Potassium*.)

Normal Sodium Sulphate: $Na_2SO_4.10H_2O$.—This salt, commonly called *Glauber's Salt*, is official in the United States Pharmacopœia as *Sodii Sulphas*, Sodium Sulphate. It occurs in large, colorless, transparent, monoclinic prisms, rapidly efflorescing on exposure to air, and ultimately falling into a white powder. It is odorless, with a cooling but bitter saline taste. It dissolves in 2.8 parts of cold water (15° C. = 59° F.); in about 0.25 part at 34° C. (93.2° F.), and in 0.47 part of boiling water. It dissolves also in glycerin, but is insoluble in alcohol. The salt should be kept in well-stoppered bottles. Sodium sulphate is formed as a by-product in the manufacture of many chemicals. It is a salt of low diffusion power, and hence in full dose, in comparatively strong solution, is a purgative. As such it is powerful in action, like the other alkaline sulphates, producing watery stools, with nausea and griping. From its sickening taste it has been almost wholly superseded by the less disagreeable magnesium sulphate (Epsom salt). From 15 to 30 gm. (℥ ss.–i.) is a full purgative dose, to be taken in aqueous solution, aromatized or slightly acidified to disguise the nauseous bitter taste of the salt. Sodium sulphate is a purgative ingredient of many mineral waters.

(*Di-*) *Sodium* (*Ortho-*) *Phosphate*: $Na_2HPO_4.12H_2O$.—This salt, the common tribasic phosphate, so-called, or *tasteless purging salt*, is official in the United States Pharmacopœia as *Sodii Phosphas*, Sodium Phosphate. It occurs in large, colorless, transparent, monoclinic prisms, which, on exposure to air, effloresce rapidly and become opaque, losing five per cent. of their water of crystallization. The salt is odorless, with a cooling, saline, and slightly alkaline taste. It dissolves in 5.8 parts of cold water and in about 1.5 parts of boiling water. It is insoluble in alcohol. Sodium phosphate is made from the calcium phosphate of calcined bone, by decomposition by sulphuric acid. It should be kept in well-stoppered bottles in a cool place.

Sodium phosphate is a bland salt, of low diffusion power, whose prominent physiological properties are to purge mildly, and, as animal experimentation has shown,[2] to excite quite notably the secretion of bile. At the same time it is feebly alkaline, and possessed of a clean, non-nauseous, salty taste, quite like that of common salt. Therapeutically this phosphate may be used for the general purposes of the milder saline purges, and, more specially, has also proved of avail, even in non-purgative doses, to correct bowel derangements associated with acidity and assumed sluggishness of the liver. From its mildness and not unpleasant taste it is particularly convenient for giving to young children. Mixed with foods, such as soup, in lieu of common salt, it may be administered in moderate quantity without suspicion. As a purge the dose for an adult is about 30 gm. (℥ i.); but for corrective purposes, much less—even so little as 0.65 gm (gr. x.)—given a number of times through the day, may suffice.

Normal Sodium Pyrophosphate: $Na_4P_2O_7.10H_2O$.—The salt is official in the United States Pharmacopœia as *Sodii Pyrophosphas*, Sodium Pyrophosphate. It is not used in medicine, and is official for pharmaceutical purposes only to prepare ferric pyrophosphate.

Sodium Nitrate: $NaNO_3$.—The salt is official in the United States Pharmacopœia as *Sodii Nitras*, Sodium Nitrate. It occurs in colorless, transparent, rhombohedral crystals, which deliquesce in moist air. It is odorless, with a cooling, saline, slightly bitter taste. It dissolves in 1.3 parts of cold water and in 0.6 part of boiling water. It is slightly soluble only in cold alcohol, but dissolves in 40 parts of boiling alcohol. It should be kept in well stoppered bottles. Sodium nitrate is the salt called *cubic nitre*, and is obtained from South America, where it occurs native. It is a salt of high diffusion power, and in its physiological relations closely resembles ordinary nitre (potassium nitrate), except that it is, of course, devoid of the characteristic properties of a potassium salt as such. Its use in medicine has so far been an empirical employment in dysentery, in which disease 30 gm. (℥ i.) of the salt has been given divided in frequent doses throughout the day, in dilute aqueous solution. It is not a standard medicine.

Sodium Chlorate: $NaClO_3$.—The salt is official in the United States Pharmacopœia as *Sodii Chloras*, Sodium Chlorate. It occurs in colorless, transparent tetrahedrons of the regular system, permanent in dry air. It is odorless, with a cooling saline taste. It dissolves in 1.1 parts of cold water, and readily in boiling water. It is sparingly soluble only in cold alcohol, and dissolves in about 40 parts of boiling alcohol. If mixed with organic substances or with readily oxidizable chemicals, such as sulphur or phosphorus, trituration or concussion may cause a dangerous explosion, as in the case of the allied salt potassium chlorate. Sodium chlorate should be kept in glass-stoppered bottles. Sodium chlorate has the peculiar medicinal properties of the potassic salt of the same acid, except in regard to the effects of potassium compounds as such. It is important only because of its excess of solubility as compared with potassium chlorate. The medicinal uses are the same as those of the latter-named salt, which see under *Potassium*.

Edward Curtis.

[1] Sternberg: Am. Journal of the Med. Sciences, April, 1883, p. 334.
[2] Rutherford: The Practitioner, vol. xxiii., p. 414.

SODIUM DITHIOSALICYLATE.—This is the sodium salt of an acid formed by the reaction that occurs when salicylic acid and sulphur chloride are mixed together in molecular proportions at a temperature of 120° to 150° C. A large isomeric series is possible, but only two are utilized, the sodium salts of which are known as sodium dithiosalicylate I., and sodium dithiosalicylate II. The acids themselves are not employed for any therapeutic purposes, the sodium salts only being used. No. I. has not been used to any extent except in veterinary practice, in which two-and-a-half and five-per-cent. solutions are used in the treatment of foot-and-mouth disease. No. II. is the salt usually employed. It is a grayish-white powder, very hygroscopic, and entirely soluble in water. On the addition of acids a precipitate of yellow viscid drops is formed consisting of dithiosalicylic acid.

This salt is said to be superior to the salicylates in the treatment of acute and gonorrhœal rheumatism. It is given in doses of three grains, twice a day in mild cases, and more frequently when the attack is severe.

Beaumont Small.

SODIUM OLEATE. See *Eunatrol*.

SODIUM PARA-FLUORO-BENZOATE is a white powder soluble in water and used in tuberculosis in dose of 0.5 gm. (gr. viij.) three times a day. *W. A. Bastedo.*

SODIUM PERSULPHATE. See *Persodine*.

SODIUM SULFORICINATE. See *Polysolveol*.

SOILS IN THEIR RELATION TO HEALTH.—Under this heading we will consider, along with the soil more strictly speaking (that is, the débris of various kinds of rocks and the organic matter from animal and vegetable life forming what is ordinarily called soil), the influence exercised by vegetation.

Soils influence health: (1) Directly, by their component parts and immediate products being taken into the organism; (2) indirectly, by their influence in modifying other surrounding conditions.

(1) The direct influence of soils above alluded to may be exerted (*a*) chemically; (*b*) by introducing pathogenic micro-organisms; (*c*) by acting mechanically on the tissues.

(*a*) Gases and particles of organic matter taken into the organism in various states of chemical change may act by lessening its vitality or by introducing toxic material. The commonest example of this will be found in what are called "made soils." Holes and depressions in the surface of the soil are frequently filled up by street scrapings, garbage, bodies of dead animals, and other refuse, mixed, it may be, with earth, ashes, etc. These after a time are covered with grasses or other forms of vegetation, and eventually may become portions of streets and building sites. In the latter case it will readily be seen how noxious gases may be generated and carried up by the ascensional air of the houses built in and over such sites. Soil so made may also be ground up into dust and inhaled. The same is true in regard to various forms of animal and vegetable organic matter, scattered upon the surface of the ground, especially in our roads and streets.

In the case of houses built on made soil, or soil rich in organic matter, the cellar walls should be made impermeable to gases by the use of cement or other impervious material. A ventilated air space around the foundation wall will be serviceable in this regard, as well as for securing dryness of the walls. All cellar floors should be built of a sufficient depth of concrete or other similar material.

In those soils which contain a large amount of organic matter, the danger will be increased if they are underlaid with a stratum of impermeable marl, clay, or rock. The decomposing material will be retained in the soil. The writer placed on record, in the previous edition of THE REFERENCE HANDBOOK, in the article on *Sewage Disposal*, a remarkable instance of this in connection with the yard of one of our public schools, and also another instance in which filth had travelled laterally one hundred and forty feet over a substratum, saturating the earth in its course.

(*b*) With regard to *pathogenic micro-organisms* contained in the soil and taken from it directly into the organism, there has been and still is much speculative discussion among bacteriologists, but it may be looked upon as quite certain that some diseases are produced in this way.

It has been pretty well established that the germs of *typhoid fever* may be introduced by this method. The writer was one of a committee charged with investigating the causes of the spread of an endemic of typhoid fever in a small village. By a process of exclusion the committee came to the conclusion that some of the cases were due to the germs from typhoid washings drying upon the soil, being wafted in the dust, and inhaled by those who were attacked.

It is the generally received opinion that *tetanus* is caused by the germs finding their way from the soil into wounds and abrasions. It is also supposed by some that *malignant œdema* is caused in the same manner.

Anthrax, as has been established by frequent observations, is taken from the soil of pasture lands by cattle grazing upon them, and there are numerous instances where men have been attacked from the germs on the surface of the soil or from streams running through these pasture lands. We have not been able to collect data which would enable us to form an absolute decision, but there is no reason to doubt that with carelessness the anthrax germs may be taken into the system from the soil by man as well as by other animals.

By some, *diarrhœa* and *dysentery* are believed to be caused by the dust of infected soil. Dr. E. W. Hope,[1] of Liverpool, is quoted by Harrington as having made some important investigations in this connection. It has been noticed by many observers that a period of long-continued dry hot weather, followed by heavy rains, has been succeeded by endemics of diarrhœa and dysentery among children and others. This has been interpreted differently by different observers, as will be noticed hereafter, but Hope states that the highest death rate from these causes, during a period of twenty years, "occurred in the year whose summer had the least rainfall, and the lowest in that in which the summer rain was greatest in amount, and that the fourteen years with average dry summers, in which the mean June to September rainfall was 10.9 inches, averaged about fifty per cent. more mortality during the quarter than the six average wet summers with a mean rainfall of 13.8 for the corresponding period." Hope believed that the absence of showers allowed an accumulation of dust and filth in the streets, roofs, and elsewhere, and that this floating in the atmosphere was the cause of the increased disease and mortality.

So general is the opinion as to the germs of *tuberculosis* being carried from the soil into the human organism through the respiratory passages and other channels, that it is now enacted in most communities that spitting in streets and other public places shall be prohibited. A case came under the notice of the courts in Toronto in connection with our public schools: A lad who had scrofulous sores was excluded from school, and the action of the school authorities in thus excluding him was upheld by the court, one of the reasons being the probability of the germs being conveyed in the dust of the school-room and premises into the lungs of the other scholars.

Much experimentation and discussion are going on regarding the conduct of many other pathogenic bacteria in the soil and the influence of the soil upon them. These cover too wide a territory and the conclusions are still too uncertain to be profitably taken up in this article.

(*c*) *Mechanical irritations* of certain tracts of the organism are produced by particles of the soil taken in from the air or mixed with drinking-water or other media. Sharp particles in the form of dust inhaled into the respiratory passages give rise to *bronchitic affections*; those blown into the eyes cause *conjunctivitis*. The action of such dust on the respiratory passages is well known where it has been caused in connection with the soil of mines and also in the prosecution of some trade or employment such as stone-cutting, grinding of agricultural implements, etc. When similar effects arise from the natural disintegration of the soil it is more difficult to trace them to this specific cause, inasmuch as it is accompanied by other influences.

The inhalation of coal dust and its deposit in the lungs of miners give rise to the disease known as *anthracosis*.

The mechanical irritation of the mucous membrane of the intestines from sand conveyed in drinking-water is well known, and is more properly considered in connection with the subject of water.

2. (*a*) The *ground water* is very largely influenced by the structure of the soil for receiving, holding, and retaining water, and not only by the structure of the superjacent soil but also by that of the subsoil, and by the configuration of both the soil and the subsoil. It will readily be seen that sandy or gravelly soil will be best adapted for receiving water and allowing it to run through it, and that such percolation of the water would be lessened if it had beneath it an impermeable subsoil, as of clay, marl, or shale, with a flat or concave surface.

Clays and marls are least adapted to allow water to pass through them, and hence retain their dampness for a greater length of time.

These conditions of soil in regard to the water in them influence health in various ways. In the first place, habitually wet soils act by increasing the humidity and coldness of the air at their surfaces, and it has been found by long experience and observation that such soils are conducive to *rheumatism, diphtheria*, and *tuberculosis*.

With regard to the last-named disease, statistics were collected by Dr. Henry I. Bowditch,[2] showing that the disease is much increased by dampness of the soil, and is notably lessened by drainage. Similar observations were made independently by Dr. Buchanan in England.

While the Klebs-Loeffler bacillus of *diphtheria* is aërobic and does not flourish in water, it has nevertheless been a matter of repeated observation that diphtheria is more prevalent in the presence of cold, wet soils. Whether this may not be due to a condition of the respiratory mucous membrane produced by such soils, is a suggestion.

We have spoken above of the condition of a concave, impermeable subsoil underlying a more porous structure. To depressions of this kind in an exaggerated form the term "punch bowl" has been applied, and such situations are particularly unhealthy. The condition of a stagnant body of water filling the interspaces of the soil here comes into play.

By similar conditions on a more extended scale marshes are formed, and in addition to the insanitary effects already alluded to they become breeding-places for mosquitoes, and consequently under suitable conditions give rise to *malarial affections, yellow fever*, and, it may be, other diseases.

The bad effects of damp soils on habitations may be lessened by the use of weeping drains so constructed and protected as to prevent the introduction of gases through them when there is no moisture in the soil which they are supposed to drain. Air spaces around the foundation walls have been alluded to when speaking of the means for preventing polluted air and noxious gases gaining entrance into houses. A damp proof course of slate or similar material should also be interposed through the whole thickness of the wall at or above the level of the surface of the ground. Unless such precautions be adopted dampness is likely to strike through and up the walls.

The influence of wet soils in interfering with outdoor living and exercise will be apparent.

(*b*) Before leaving the subject of the influence of soil upon water we must not lose sight of the fact that *water supplies* receive from the soil substances which have a decided influence upon health, both from the chemical and from the bacteriological standpoint. In this connection there is one aspect in which loose soils may, from accident or carelessness, become detrimental to health, and that is the ease with which they will allow pathogenic bacteria, such as the bacilli of *typhoid* and of *cholera*, to be carried for a considerable distance through their interspaces into wells and watercourses. It is highly probable that the colon bacillus is carried in the same way, giving rise to *diarrhœa* and *dysentery*. It has often been noticed that typhoid is very prevalent at that season of the year when the level of water in wells becomes low, an indication of the washing of bacteria into the wells. Instances of contamination in this way from and over the surface of the soil are also on record and must be laid to the account of the more impervious soils.

Soils rich in organic matter will, of course, yield much of this latter to the waters percolating through them. Some of these must contain toxic material, while all of them are more apt to serve as culture media for the growth of micro-organisms.

The chemical additions received by water from the soil are various. The analysis of our mineral waters is abundant evidence of this, and for this part of the subject the reader is referred to the article entitled *Water* and to the articles which treat of the different mineral springs. The prevalence of *calculus, goitre, and cretinism* in certain districts has been attributed to the presence of limestone formations and similar conditions of soil, but the evidence is very conflicting and does not seem to warrant the assumption.

Some observers consider that the absence of minerals in drinking-water is injurious, and as proof of this have cited the less hardy condition of French recruits coming from districts in which rain water is almost exclusively used for drinking purposes.

It has also been concluded, from analyses of river waters made before and after flowing through certain mining districts, that mineral additions taken up from the soil are sometimes of service in lessening the amounts of organic impurities.

(*c*) The *ground air* also is influenced by the structure and consequent porosity of the soil. The movement of the air will follow the movement of the water, and in addition will be influenced by barometric pressure, by the action of winds, and by temperature. While these forces will influence the movement of the air, it will be acted upon in respect to its humidity by the capacity of the soil particles for holding water by the force of attraction, and in respect to its chemical composition it will be modified by the chemical constituents of the soil. In this way, for example, the relative amounts of oxygen and of carbon dioxide will be modified.

It will readily be seen how great a difference in this respect there will be between the ground air, and consequently the air close to the surface of the soil, in arid, sandy soils, and that in soils rich in humus. For example, in and above a soil which is rich in humus, and which therefore contains large quantities of organic matter, the air will, other things being equal, be poorer in oxygen. On the other hand, it is very reasonable to suppose that the absence of such organic matter is one of the causes of the suitability, for tuberculous patients, of some of the arid health resorts, such as certain districts of Arizona. That other factors also play a part in rendering these resorts so beneficial will of course be apparent to the student of climatology.

The prevalence of diarrhœa and dysentery after a period of long-continued dry weather has been referred to in connection with the observations of Dr. Hope, who attributed this prevalence to some "infective agent . . . blown about in the dust of the air." It has also been stated that others have considered it to be due to the accumulated infective material being carried into depleted wells. By others again it has been attributed to the ground air, laden with this "infective agent" during a long period of inaction, being suddenly driven out by a downpour of rain, which, by providing moisture, favored at the same time a certain amount of decomposition and germ growth.

(*d*) The *temperature* of the air, besides being influenced by altitude, is largely modified by certain characters of the soil. The influences of the ground air and ground water on the temperature have been alluded to. The color and structure of the soil play an important part in determining to what extent the rays of the sun shall be reflected and to what extent they shall be absorbed by the latter. Thus, for example, soft loamy soils, and those containing a good deal of humus of a dark color, have a much greater capacity for absorbing heat and then parting with it later when the air above them becomes cooler. Hence the temperature in such districts is more equable, and the changes will be less rapid. The direction of the slope of the soil also acts by reflecting the rays of the sun more or less perpendicularly. If the ground slopes in a southerly direction, the rays are reflected more perpendicularly and consequently the temperature is increased. The movements of the air will, as a consequence, be affected by the same conditions which modify the temperature on the surface of the soil.

(*e*) *Insolation*, while largely dependent upon altitude and other associated atmospheric conditions, will also be modified by the influence exerted by the soil. Reflection of the rays of the sun, just now alluded to, is one of these factors. Another is the absence or presence of dust, which is shown to be largely dependent upon the condition of the soil. This absence of dust, very noticeable in some districts, was brought very forcibly under the notice of the writer in the district of Muskoka. Having occasion to ascend to an open attic floor in a cottage in Muskoka, after a year's absence, he was surprised to find that it was almost entirely free from the dust which would have accumulated in a similar position in most other districts, and especially in our cities or in the vicinity of country roads. The condition observed in the case of the cottage is to be attributed to three factors: that there is very little loose surface soil, the ground being composed principally of rock; that there are no roadways nor wagon roads in the vicinity of this cottage, travelling being effected in boats; and that the soil in the neighborhood is covered with trees and mosses. These conditions make such localities very desirable for the treatment of diseases of the respiratory organs.

(*f*) The influences of the *configuration* of soils have been alluded to in some of their aspects, such as slope and direction of slope both of the soil and of the subsoil. Some other influences under this head remain to be considered.

Valleys and *ravines* have an influence on temperature and also in the determination of the direction of the wind. The positions of the ends of valleys influence their temperature and the character of the wind blowing through them. As an example of the former, the writer has been told by botanists that the valley of the Desjarnins Canal, near Hamilton, Ontario, contains plants which on open ground are not to be found farther north than the isothermal line of Virginia.

The question of *altitude* belongs to the article on *Climate* (*q.v.*), but the altitude of a particular locality in relation to surrounding localities—whether situated on hill, valley, or plain—will have a determining effect on its temperature, humidity, and immediate atmosphere. An elevated spot may be unhealthy by relative depression.

A plain situated at the foot of a range of hills will be influenced by the circumstance whether it is on the north or the south side of the range. Vegetation is also likely to be influenced by such situation.

(g) The influence of *vegetation* must be further considered. It will depend upon the quantity and kind of vegetation. Low scrub and brush-wood are injurious by preventing a free circulation of air on the surface of the soil, and by favoring the accumulation of organic deposit which is likely to decompose slowly and to vitiate the air. Such vegetation should not be disturbed during the existence of a camp in its immediate neighborhood, inasmuch as this removal tends for the time being to increase the unhealthy condition of the atmosphere by the rapid liberation of the vitiated air. This kind of vegetation is also a harboring place for the lower forms of insect life, including mosquitoes, the injurious action of which has already been considered.

The tendency of forests is to equalize temperature, cooling the atmosphere by evaporation from their leaves during hot weather, and also by shielding the ground from the rays of the sun. They also tend to keep up a more equable supply of water in the streams of the locality. Evergreen trees are supposed to have an additional beneficial effect by the exhalation of resinous vapors. Belts of trees are sometimes of service in sheltering localities from bleak winds, and have been supposed to be of service in warding off malaria. In former days rows of sunflowers were planted for this latter purpose of shielding a locality against the malarial "miasm," as it was termed. According to our present knowledge, it may be that these effects were due to these trees and plants forming barriers or receiving-places for the winged bearers of infection.

To the above remarks regarding the health of forests there are exceptions. In some places the influences described keep the soil in a permanently wet condition; as, for example, in the tamarac and mangrove swamps, of temperate and tropical regions respectively. Again, in other forests, through lack of sun and air no opportunity is afforded for the disposal of the decomposing vegetation, which is sometimes very luxuriant.

Wm. Oldright.

[1] Public Health, July, 1890.
[2] Topographical Distribution and Local Origin of Consumption in Massachusetts, Transactions, 1862.

SOLVEOL is a neutral solution of cresol in aqueous sodium cresylate. It contains 23.6 per cent. of cresol.

W. A. Bastedo.

SOMNAL.—Introduced as an hypnotic by Radlauer, of Berlin, in 1889. He described it as a true chemical compound formed by the direct combination of chloral alcoholate with urethane.

It is properly a clear, colorless crystalline powder, with a hot burning taste, and very deliquescent, but is supplied in the form of a liquid on account of its instability. It is an alcoholic solution, one part in three. It has also been described as a solution of chloral hydrate and urethane in alcohol.

It is used solely as an hypnotic, the dose being from twenty to thirty minims for adults. *Beaumont Small.*

SOMNAMBULISM. See *Consciousness, Disorders of.*

SORREL. See *Poisonous Plants.*

SORREL WOOD. See *Oxalidaceæ.*

SOUTH DAKOTA HOT SPRINGS.—Fall River County, South Dakota.

Post-Office.—Hot Springs. Numerous hotels and cottages.

Access.—Viâ Freemont, Elkhorn, and Missouri Valley Railroad (branch of the Chicago and Northwestern system), or viâ the Chicago, Burlington, and Quincy Railroad (Burlington route) direct to Hot Springs, arriving at the same depot by either route.

This attractive new spa is located in the heart of the Black Hills, at an elevation of 3,400 feet above the sea level. Hot Springs is the county seat of Fall River County, and is located about seventy miles south of Deadwood. The town has a permanent population of about 1,500 and a summer population of 3,000. Its proximity to extensive pine forests, in addition to the favorable features of location above mentioned, assists in preserving a mild and agreeable climate, and has brought the resort into much favor with persons afflicted with hay fever, asthma, and incipient phthisis.

The advantages of Hot Springs as a health resort are numerous. First, as to topographical features. The scenery in and adjacent to the place is varied and delightful. The lofty pine-clad hills, grand canyons, rippling streams, and beautiful falls of the Minnekahta and Cheyenne, make up a group of attractions difficult to excel. Second, as to climate. By reason of certain peculiar circumstances of location this resort is favored by very mild, equable atmospheric conditions. Summer days are followed by evenings of delicious coolness, while the autumns are unusually pleasant. During the winter months the temperature has observed an average of 42° F. above zero for the last four years. Situated in the Minnekahta Valley and sheltered on all sides by heavily timbered hills, this resort is almost perfectly exempt from cold winds and sudden changes of temperature. The winter temperature in the valley is from 20° to 25° F. higher than it is in localities only a dozen miles distant. It is said that the protection afforded by the hills is supplemented in no small degree by the millions of gallons of hot water flowing through the valley. During the winter of 1892-93 Dr. C. W. Hargens, of Hot Springs, kept a record of the temperature for five months, beginning with December 1st and ending with April 1st. This was the coldest winter this country has had for many years. We make the following extracts from his notes:

December, 1892. Snowed once; fall of snow three-quarters of an inch. Five cloudy days.

January, 1893. Three cloudy days. No snow during the month; average temperature for the month, 40° F. (for the last two weeks of the month it was 50.2° F.).

February, 1893. One day and a half cloudy. Snowed four times, with total precipitation nine-sixteenths of an inch.

March, 1893. Two and one-half days cloudy. Snowed twice. Total precipitation, two-fifths of an inch. Average daily temperature, 50.3° F.

April, 1893. No snow. No storms of any kind. Mild, pleasant weather throughout the month.

The visitor will find excellent accommodations. The largest hotel, the Evans, is constructed and equipped throughout in accordance with the latest and most approved methods. Other excellent hotels are the Gillespie, the Hot Springs, the Catholicon, the Davis, and the Parrott House. Cottages are also at hand for those who desire them. The hills afford attractive spots for camping out. Adjoining the Evans House is the Evans Sanitarium, containing sixty bathrooms and embracing all varieties of baths. The Stewart Sanitarium, recently completed, also affords falcilities for all kinds of bathing. The Catholicon Sanitarium, now under construction, will add another to the list of the sanitaria of Hot Springs. The springs at this resort are eight in number. The name, the "Minnekahta," is given to a great Indian spring, the word being a synonym for health, pleasure, and recreation. It is said that the waters of this spring were in use by the Sioux and other tribes long before the approach of civilization. The natural temperature of this spring is 98° F. It furnishes the drinking fountain of the Evans House, the Evans bath house, and the Minnekahta bathhouse. An analysis by Prof. Charles B. Gibson, of Chicago, resulted as follows: One United States gallon contains (solids): Magnesium sulphate, gr. 4.32; sodium sulphate and potassium sulphate, gr. 25.62; sodium chloride and potassium chloride, gr. 13.79; calcium sulphate, gr. 16.32; silica, gr. 2.46, and a trace of iron peroxide. Total, 62.51 grains. The waters are perfectly clear, have a decidedly alkaline reaction, and contain no organic matter.

A second spring, known as the Mammoth Mineral

Spring, furnishes a water which is still richer in solid constituents. The analysis shows that one United States gallon contains (solids): Sodium sulphate, gr. 23.26; potassium sulphate, gr. 5.63; calcium sulphate, gr. 36.11; calcium chloride, gr. 5.59; magnesium chloride, gr. 4.11; magnesium carbonate, gr. 3.51; organic and volatile matter, gr. 12.11; and very small quantities of ammonium chloride, magnesium nitrate, magnesium phosphate, iron sesquioxide, alumina, and silica. Total, 92.71 grains.

The analysis of the water of the third spring, known as the Lakatah Spring, shows that one United States gallon contains (solids): Sodium sulphate, gr. 8.82; potassium sulphate, gr. 3.33; calcium sulphate, gr. 16.29; calcium chloride, gr. 8.50; magnesium chloride, gr. 3.14; magnesium carbonate, gr. 3.04; organic and volatile matter, gr. 8.05; and very small quantities of ammonium chloride, calcium phosphate, magnesium nitrate, iron sesquioxide, alumina, and silica. Total, 53.79 grains.

According to the report of the National Association of Railway Surgeons, which visited this resort in 1893, "treatment by the Hot Springs water may be said to stimulate all the secretions and organic functions, to promote digestion and assimilation, and to favor tissue metamorphosis and excretion, thereby relieving internal congestions, stimulating blood-making, increasing the appetite, and favoring new and healthy tissue at the expense of the old and inactive." This treatment may therefore be confidently recommended in "gout and rheumatism after the inflammatory stage; in neuralgia, especially when depending upon gout; in metallic or malarial poisoning; in paralysis not of organic origin; in neurasthenia; in the early stages (only) of Bright's disease; in syphilis; in functional diseases of the liver; in dyspepsia, not of organic origin; in catarrhal affections of the respiratory tract; . . . and in chronic skin diseases, especially of the squamous variety."

James K. Crook.

SOZOIODOL.—(Di-iodo-para-phenol-sulphonic acid.) An acid base which was introduced in 1887 as an antiseptic. It contains forty-two per cent. of iodine, twenty per cent. of carbolic acid, and seven per cent. of sulphur. The acid itself is not employed, but it forms salts which possess all the properties of the acid. The potassium and sodium salts are the ones most employed. They resemble one another in physical characters, forming in colorless, well-defined prisms, soluble in water, the potassium compound in fifty parts and the sodium in fourteen.

The use of these compounds is in all those conditions in which iodoform is likely to be proved useful. It is said to be preferable, as it is soluble in water and glycerin, does not decompose when exposed, readily combines with other substances, and is free from irritating action and disagreeable odor. The zinc salt has been specially recommended for gonorrhœal discharges. It is soluble, one part in twenty of water. All the solutions should be freshly prepared and not exposed to the light, as they are decomposed and free iodine is liberated.

The mercurial salt is a lemon-yellow powder, soluble in about five hundred parts of water. It is mainly employed in the treatment of syphilitic affections. It has been recommended as the most suitable form of mercury for hypodermic injections. The injections should be made in the gluteal regions, alternately on the right and on the left side. It causes a little pain, but the local effects are said to be much less than with any other mercurial salt. The dose is one grain and a half, and one injection a week is equal to three of other forms of mercury. The absorption of the drug is rapid, and the gums have to be carefully watched, as its action is very marked.

Beaumont Small.

SOZOL.—(*Paraphenol-sulphonate of aluminum.*) It occurs in brownish granules of a strong astringent taste and faint carbolic odor. It is very soluble in water, glycerin, and alcohol, and forms very stable solutions.

It is not a powerful antiseptic or bactericide, but has been found to be a very serviceable application to wounds, ulcers, etc., as it possesses an astringent action in addition to its antiseptic properties.

Beaumont Small.

SPARKLING CATAWBA SPRINGS.—Catawba County, North Carolina.

Post-Office.—Sparkling Catawba Springs. Hotel and cottages.

Access.—Viâ Western North Carolina Railroad to Hickory, sixty miles west of Saulsbury; thence six miles by carriage to springs.

The location of the Sparkling Catawba Springs is within the shadow of the Blue Ridge Mountains, 1,150 feet above the sea level. This part of the State, known as the "Piedmont Section," has long been famous for its bracing climate, pure air, and uniform temperature. The springs are three in number, and gush from the ground in a shaded valley surrounded by a circular range of timbered hills and within one mile of the banks of the Catawba River. No analysis has been made, but the springs are said to be blue and white sulphur and chalybeate in character. The new hotel and cottages afford comfortable accommodations for about four hundred guests. We are informed by Dr. E. O. Elliott, of the springs, that the waters possess well-marked alterative and tonic properties, and generally increase the appetite, assist the digestion, and promote the assimilation of food. A very complete and comfortable bathing establishment is at hand.

James K. Crook.

SPARTA MINERAL WELLS.—Monroe County, Wisconsin.

Post-Office.—Sparta. Hotel.

Access.—Sparta is a station on the Chicago, Milwaukee, and St. Paul Railroad, two hundred and fifty-five miles from Chicago. Bulletin 32 of the United States Geological Survey reports twelve mineral wells in Sparta, only two of which appear to have been analyzed. We present the following analysis of the Magnetic Well, made by J. M. Hirsh in 1876: One United States gallon contains (solids): Magnesium carbonate, gr. 3.35; iron carbonate, gr. 11.94; and very small quantities of manganese carbonate, calcium carbonate, ammonium carbonate, lithium carbonate, strontium carbonate, barium carbonate, potassium sulphate, sodium sulphate, calcium sulphate, sodium chloride, calcium chloride, sodium phosphate, aluminum phosphate, sodium iodide, and silica. Total, 19.25 grains. This analysis shows an almost pure chalybeate water, the remaining ingredients being all of a secondary character.

James K. Crook.

SPASMS. See *Convulsions.*

SPEARMINT.—*Mentha Viridis. Brown, Garden, Lamb,* or *Mackerel Mint.* "The dried leaves and tops of *Mentha spicata* L. (fam. *Labiatæ*)." U. S. P.

Spearmint is a native of Europe and Asia, and has spread widely through nearly all temperate regions, where it is also cultivated to a large extent, and shows a high degree of variation in characters. It usually covers quite large patches, propagating by slender runners. The quadrangular, slender, frequently purplish stems are prostrate below, one to two or three feet long, and much branched. The drug is thus described:

Sparingly and obscurely hairy, the hairs short and stout, without menthol crystals in their cells; branches quadrangular, slender, usually pale green, rarely purplish; leaves opposite, exstipulate, very shortly petioled, the blades usually less than 5 cm. (2 in.) long and about one-third as broad, lanceolate, or lance ovate, rounded at the base, acuminate and acute, sharply serrate, thickish, and rigid, deep and usually dark green; flower spikes usually appearing clustered at the summit, interrupted, elongated, and acute, about 5–8 mm. ($\frac{1}{5}$–$\frac{1}{3}$ in.) thick; flowers about 3 mm. ($\frac{1}{8}$ in.) long, the calyx tube nearly equally five-toothed, ten-nerved, the corolla light purple, nearly equally four-lobed, the stamens four, nearly equal, rather long; odor characteristic, aromatic, rather heavy; taste characteristic, pungent.

It is readily distinguished from peppermint by the elongated, slender, and acute flower spikes, the relatively longer stamens and style, and the ranker odor. As seen under the microscope, its hairs never exhibit menthol crystals.

The only important constituent of spearmint is about one per cent. of volatile oil, with which there is associated a little tannin. This oil, although quite similar in properties, is very distinct in composition from the closely related peppermint oil. It contains no menthol, nor apparently any other crystalline substance. Its important constituent appears to be carvone (see *Caraway*). Pinene and limonene also exist.

The action and uses of spearmint are almost identical with those of peppermint. It is somewhat milder in action, on account of which it is often preferred for administration to infants.

Powdered spearmint is often given in doses of 1–2 gm. (gr. xv.–xxx.). The infusion is also popular. The best form of administration is the oil (*Oleum Menthæ Viridis*), dose one to five minims, or one of its two preparations. The spirit or essence (*Spiritus Menthæ Viridis*) contains ten per cent. of the oil and one per cent. of spearmint, and the dose is 0.3–1 c.c. (♏v.–xv.). The water (*Aqua Menthæ Viridis*) has a strength of 0.2 per cent. and the dose is 15–60 c.c. (fl. ℥ ss.–ij.). *Henry H. Rusby.*

SPECTACLES—from *spectare*, to view; French, *besicles*,* *lunettes*; German, *Brille*;* Dutch, *bril*;† Italian, *occhiali*; mediæval Latin, *perspecillum*, *conspecillum*, *ocularius*—are first mentioned about the close of the thirteenth century.‡ Seneca mentions the fact that "letters, however minute and indistinct, appear larger and clearer when viewed through a glass globe filled with water."[9]

The first mention of a lens, properly so called, is attributed to the Arabian mathematician Alhazen (*obt.* 1038),[10] who describes the magnifying property of a segment of a sphere of glass.[11] Roger Bacon (*circa* 1267) mentions the magnifying property of convex lenses, and suggests the benefit to be derived from their use by old persons with weak sight.[12] The step from the use of a convex lens, as a magnifier, to the construction of binocular eyeglasses or spectacles, to be worn by presbyopes in reading, implies a considerable development of the optician's art, in the direction of grinding lenses of relatively long focus. The invention of spectacles is variously attributed to Salvino degli Armati, a Florentine (*obt.* 1317),[13] and to Allessandro della Spina, a Dominican friar of Pisa (*obt.* 1313). The use of concave glasses, as a help to myopes in distant vision, must have followed at no very long interval; the date of their first employment is, however, unknown. The necessity for the selection of lenses of different focal length for different persons, as well as for the same person at different periods of life, must also have been very early recognized; but there is no reason for believing that the choice was made in any better way than by trying them at random, until a pair was found which appeared to be suited to the kind of work for which they were to be used.* Certain it is that spectacles had been in use for from two to three centuries before the theory of their action was explained,† and it is only since the middle of the nineteenth century that anything like a complete understanding of the subject has been reached.

Spectacle lenses, as late as the second half of the eighteenth century, were generally, so far as is known, of the plano- or double-convex, or of the plano- or double-concave form.[16] Both the plano-convex and the plano-concave glasses appear to have been mounted, sometimes with the plane surface and sometimes with the curved surface next the eye. Concavo-convex lenses were used to some extent in the eighteenth century, but with varying practice as regards the side turned next the eye.‡[17] Under the name of *periscopic* spectacles, concavo-convex lenses, with the concave surface turned toward the eye, were brought into use by Wollaston (1804).[18] A special construction of double-convex and double-concave spectacle lenses, made by grinding the two surfaces of the glass to cylindrical curves of equal radii, but with crossed axes, was introduced (before 1830) by Galland de Cherveux;[19] such lenses are still manufactured in limited quantity, but, aside from certain inherent defects, they offer no compensating advantage over the several forms of lenses with spherical surfaces; their existence in commerce made it possible, however, to furnish a cylindrical surface, on demand, at a time when plano-cylindrical lenses were not yet readily obtainable. Cylindrical lenses proper, as used for the correction of astigmatism, were first employed by G. Airy, Astronomer Royal (1827),[20] who was himself the subject of compound myopic astigmatism. Airy discussed the relative advantages, in compound astigmatism, of a bicylindrical lens of unequal radii of curvature, and a spherico-cylindrical lens. The common use of cylindrical spectacle lenses dates from the special study of astigmatism by Donders.[21] Since 1884 it has been possible to have spec-

* From the old French form *bericle*, diminutive of *berille*; Latin, *berillus*, *beryllus*; βήρυλλος, the beryl[1]; *cf.* the derivation of "brilliant"—French, *briller*, etc.—from *berrylus*.[2]

† From *berillus*, *beryllus*, βηρυλλος, the beryl; "the colors of the beryl range from blue through soft sea-green [aquamarine] to a pale, honey yellow, and in some cases the stones are entirely colorless";[3] *ocularii vitri aut berillorum*: Guy de Chauliac (1363).[4] The most available material for spectacle lenses, excepting glass, is rock crystal or quartz, and it is highly probable that this mineral, still largely used under the name of pebble, was utilized by the older opticians.

‡ Spectacles, both convex and concave, were in common use by the Chinese before the opening of commerce with Europe. They were made of a transparent stone, of a color like that of a strong infusion of tea, called *schu-chi* (tea-stone), and were tied upon the head by silken cords.[5] Chinese spectacles are now made of rock crystal, and are mounted in thick frames of tortoise shell or of metal, evidently borrowed from old European models.

The common use of some form of magnifying glass by the ancients is wellnigh proved by their perfect workmanship as displayed in the engraving of gems. On the other hand, it appears certain, from the notices on presbyopia and myopia, by Paulus Ægineta (seventh century A.D.),[6] and by later as well as earlier writers, that they had not applied lenses to the relief of persons laboring under these disabilities.

Pliny's description of the visual defect of the Emperor Nero[7] strongly suggests a case of myopia or of compound myopic astigmatism. The statement of Pliny - Nero princeps gladiatorum pugnas spectabat in zmarugdo[8] — taken in connection with what is said of this gem in the same chapter, would seem to be best explained upon the supposition that the emperor possessed a large and highly polished emerald, or gem of like color, most probably of unequal curvature in its two principal diameters, and that he viewed the combatants, in the strong light of the amphitheatre, by reflection from its convex surface. This theory would imply that the use of the gem for this purpose was the result of an observation made by Nero himself, who may, therefore, be accredited with the discovery of an optical device suited to the correction of myopia, or of compound myopic astigmatism; the invention would appear to have died with the inventor.

* Bartisch (1583) protests earnestly against the widely spread abuse of spectacles.[14]

† "Maurolicus, in his treatise '*de lumine et umbra*' (1554), considers the crystalline as the principal instrument of vision, and as transmitting to the optic nerve the images of objects; and he explains why some persons are long-sighted and others short-sighted, according to the less or greater convexity of the surfaces of the crystalline, showing that in the former case the rays have not been converged to a focus when they reach the retina, while in the latter they have been converged before they reach it. He explains, also, how the convergency may be hastened in the long-sighted eye by the use of a convex glass, and delayed in the short-sighted by a concave one. These observations of Maurolicus were not known to Kepler, when it was proposed to him, as a question by his patron, Dietrichstein, in what manner spectacles assisted sight? The first answer he gave, as he tells us in his '*Paralipomena ad Vitellionem*' (1604), was, that convex glasses were of use by making objects appear larger. But his patron observed, that if objects were by them rendered more distinct, because larger, no person would be benefited by concave glasses, since these diminished objects. . . . He now gave a clear account of the effect of lenses, whether within or without the eye, in making the rays of a pencil of light converge or diverge; and explained that convex glasses assist the sight of presbyopic persons by so altering the direction of rays diverging from a near object, that they fall upon the eye as if they had proceeded from a more remote one, that concave glasses benefit the myopic by producing a contrary effect upon rays which diverge from a distant object, making them fall upon the eye as if they proceeded from a near one."[15]

‡ Aside from the misinterpretation of special optical formulæ, caprice has played its part in determining many eccentricities of practice; from the beginning, the business of selling spectacles appears to have been conducted largely under the cloak of mystery, and very often of deliberate misrepresentation.

tacle lenses ground to order with a convex or concave surface of unequal radius of curvature in its several meridians, thus producing, by means of a single curved surface, the effect usually obtained by the combination

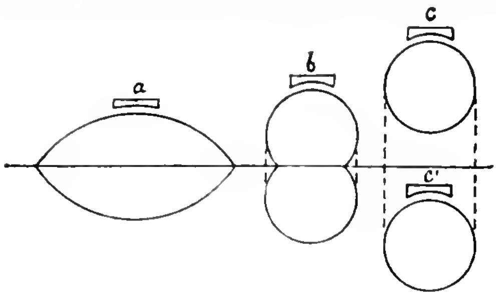


FIG. 4321.

of a cylindrical with a spherical surface.[22] The curved surface of such a convex lens represents a small area cut out from a large surface of revolution corresponding to the rounded rim of a wheel; the concave surfaces produced by this method are such as may be worked upon a

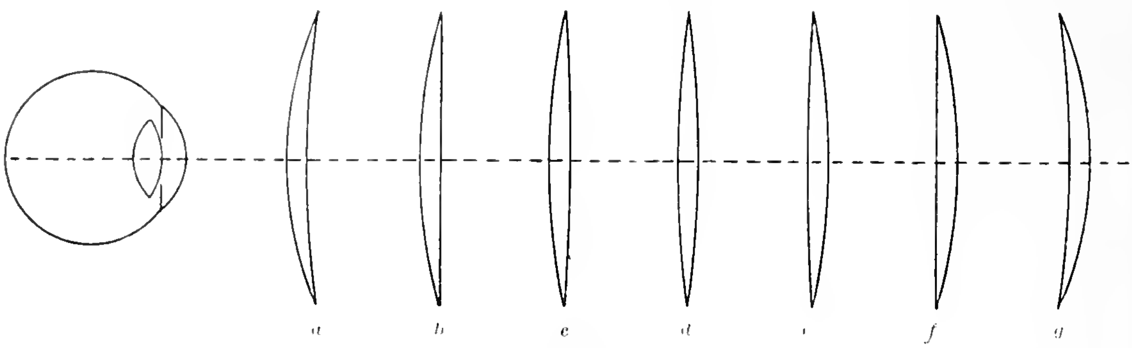


FIG. 4322.

grinding tool having the form of such a wheel.* Prismatic glasses, suggested to Donders by his colleague, Kreeke, as a possible means of re-establishing binocular vision when it has been lost through the deviation of the visual axes in strabismus, were made the subject of spe-

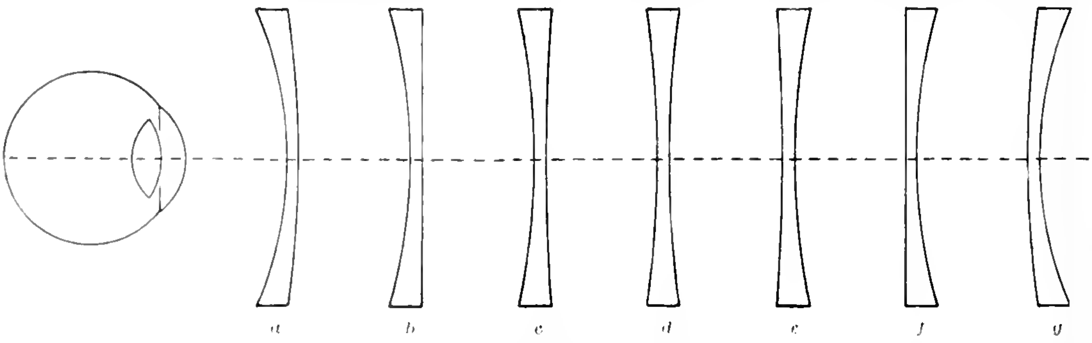


FIG. 4323.

cial study by Donders,[24] and have since held a place among the recognized means of dealing with certain conditions referable to disorders of the external muscular apparatus of the eye. The decentration of ordinary convex or concave lenses, in order to give to the combination of the two spectacle glasses some measure of prismatic effect, was also discussed by Donders.[25] Decentrated convex lenses had already been used in the dissecting spectacles of Brücke,[26] and in the refracting stereoscope of Brewster.[27] Stenopæic spectacles—from στενός, narrow, and ὀπή, a peep-hole—were also employed by Donders,[28] chiefly for the purpose of admitting to the eye such rays only as correspond to a selected limited area of the cornea or crystalline. Like the so-called *panoptic* spectacles of Serre d'Uzès,[29] they are essentially the same thing as the obsolete strabismus goggles (*Schielbrillen—louchettes*). The snow-goggles of the Esquimaux, which cover the entire front of the eyeball, with the exception of a narrow horizontal slit, may be classed with stenopæic spectacles, although designed primarily as protectives against the injurious effects of strong sunlight reflected from the snow.

In very high grades of myopia, and especially in cases of irregular myopic refraction of high degree, the best attainable visual result may often be had by looking through a small circular hole or a slit in a thin opaque card or disc of blackened metal.

The several forms of spectacle lenses, as they have been or may be mounted before the eye, are shown, for convex and concave lenses respectively, in Figs. 4322 and 4323. Of the convex lenses (of positive focus), *a* and *g* (Fig. 4322) are menisci; *b* and *f* are plano-convex; *c* and *e* are double convex, with surfaces of unequal radii of curvature; and *d* is double convex, with surfaces of equal radii. In concave lenses (Fig. 4323) we recognize the corresponding forms: –*a* and –*g*, concavo-convex; –*b* and –*f*, plano-concave; –*c* and –*e*, double concave, with surfaces of unequal radii of curvature; and –*d*, double concave, with surfaces of equal radii. Of these, *g* (positive meniscus, with the concave surface turned toward the eye), and –*a* (negative concavo-convex, with the concave surface toward the eye), are especially designated as

* The entire surface of revolution, as shown in section, takes one of the three forms, Fig. 4321, *a*, *b*, *c*, the last of which is an open ring (anchor-ring, torus); the interior of such a ring gives a surface (*c'*) convex in one principal meridian and concave in the other, and applicable, therefore, to the correction of mixed astigmatism.[23]

periscopic (from περί and σκοπέω) glasses; they offer a certain advantage when the eyes are turned so as to look obliquely and eccentrically through them, the advantage being greater according as the concave surface, as in —*a*, is of shorter radius of curvature.[30] These several forms of lenses, other than the plano-spherical, may be resolved into combinations of two lenses, each with a spherical and a plane surface, placed with their plane surfaces in contact (Fig. 4324, *a*, *b*, *c*, *d*). Inasmuch as a smaller effective area than that bounded by the usual setting is quite sufficient for many of the uses for which spectacles are worn, it is often possible notably to reduce the weight

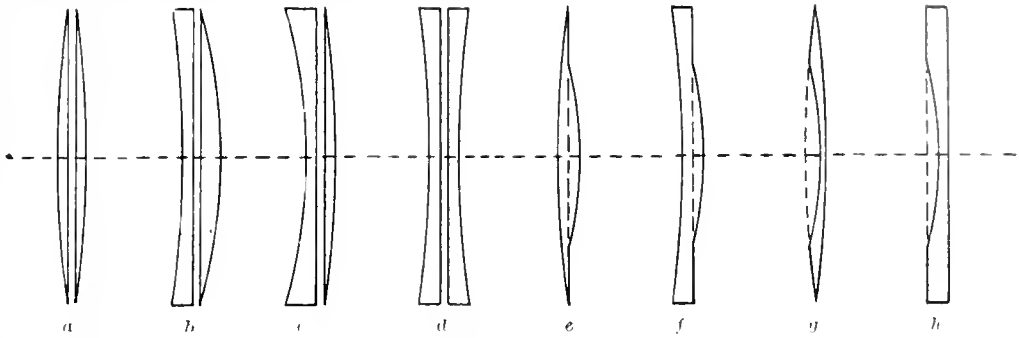


FIG. 4324.

of the glasses, when required to be of very short focus, by the adoption of forms like those shown in Fig. 4324, *e*, *f*, made by cementing a small plano-convex upon a larger plano-convex or plano-concave lens, or *g*, *h*, in which a deep concave surface is ground in a lens of any required configuration.

Cylindrical lenses are found in trade of two forms, namely, plano-convex and plano-concave (Fig. 4325, *a* and *b*); the dotted line represents an element of the cylindrical surface, which is parallel to the axis of the cylinder of which the lens-surface is a segment; they are manufactured by machinery, in different thicknesses, so that any required spherical surface, convex or concave, may be ground to order upon the plane side. The power of a plano-cylindrical lens varies, in its several meridians, from zero, in the meridian corresponding to the axis, to a maximum power (positive or negative) in the meridian at right angles to the axis. In a spherico-cylindrical lens, with both surfaces of the same kind (*i.e.*, convex or concave), the meridian corresponding to the axis of the cylinder is that of least, and that at right angles to this axis is that of the greatest (positive or negative), power. Cylindrical lenses are occasionally prescribed with two cylindrical surfaces of unequal radii of curvature and crossed axes, but the same optical effect is more easily obtained by combining a cylindrical with a spherical surface.*

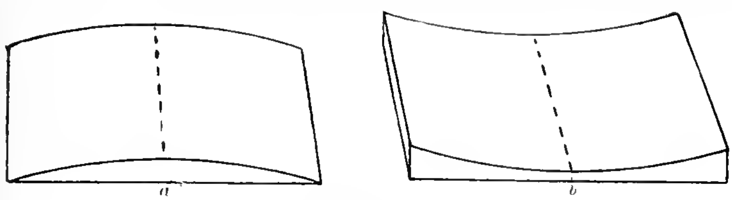


FIG. 4325.

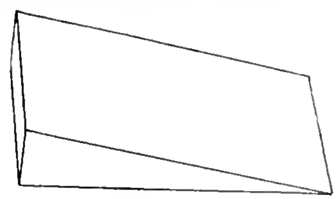


FIG. 4326.

Prismatic glasses with plane surfaces are of the form shown in Fig. 4326; any desired curvature, whether convex or concave spherical, or convex or concave cylindrical, may be given to either surface, or to both surfaces of the prism. A prismatic lens with one surface, or both surfaces, ground to a spherical curvature, is equivalent to a lens cut out from a peripheral zone of a larger spherical lens (Fig. 4327). Some degree of prismatic effect may, therefore, be obtained by the decentration of any convex or concave spectacle lens; such effects are, in fact, not infrequently produced by accident, as a result of carelessness in mounting spectacle glasses.

The stenopæic effect may be embodied in any lens by painting over some part of its surface, next the eye, with an opaque, lustreless, black varnish. A partial opacity of the cornea, or a portion of its surface presenting an abnormal curvature, may be thus excluded, more or less completely, from participation in the formation of the retinal image, with the effect, in some cases, of materially improving the definition of the object.[32]

Tinted glass is occasionally used in the manufacture of both spherical and cylindrical spectacle lenses, which, however, present an unequal density of tint in different parts, dependent on the varying thickness of the glass. In the case of concave glasses, which are thinnest at the centre, this may be an advantage; in the case of convex

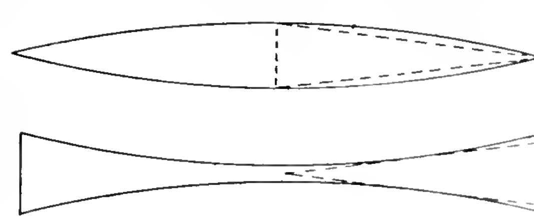


FIG. 4327.

glasses, the inequality of tint may be avoided by cementing a thin plate of tinted glass to the plane surface of a plano-convex lens by means of Canada balsam. A more elaborate device consists in cementing a thin plate of tinted glass between the plane surfaces of two plano-convex lenses, or of a plano-spherical and a plano-cylindrical lens. Amber has been used as a material for spectacle lenses, notably at Königsberg, about the end of the seven-

* Cylindrical lenses with two cylindrical surfaces, with axes at some angle other than a right angle, are sometimes prescribed. Such lenses, as well as bicylindrical lenses with crossed axes, can always be reduced to an optically equivalent combination of a spherical and a cylindrical surface.[31]

teenth century; the transparency of the amber is said to have been increased by heating in a bath of oil or sand.[33]

Tinted glasses are in common use to temper the light which reaches the eye; they are made either with parallel plane surfaces, like window glass, or with concentric curved surfaces, like a watch glass (coquilles). Green was formerly a favorite color, as assimilating the light passing through it to the color of grass and the foliage of trees; blue (the color of the sky) gradually superseded green, and is still often used. The neutral tint, known as London smoke, is, in most cases, to be preferred. Glasses of an amber color, called shooting glasses, are also to be found in the shops, generally ground to a dull surface, with the exception of a small, central area; they are intended to be used in looking at small distant objects in strong sunlight. Amber-colored and, more perfectly, red glasses, by excluding the more refrangible rays of the spectrum, improve the definition of the retinal image in very low grades of myopia; blue reading glasses, on the other hand, may render some slight degree of aid in low grades of hypermetropia and of presbyopia.[34] Tinted glasses should, as a rule, be mounted in large, oval rims, so as to cover the entire front of the orbit; the coquille form of glass affords more perfect protection than a glass with plane surfaces. Darkly tinted (London smoke) coquilles are of great use to persons who are exposed to strong light reflected from sand or from snow, or from the surface of water. Inasmuch as such reflected light is highly polarized, protective spectacles of tourmaline should render valuable service by cutting off the confusing reflected rays, while permitting the unpolarized light, by which objects are actually seen, to pass comparatively unobstructed.[35] London smoke glass, of so dark a tint as to appear black in ordinary light, is used in protective spectacles worn by workmen employed about electric arc lights, and spectacle glasses made up of several layers of glass of different colors have been found especially useful in observing the intensely brilliant scintillations attending the conversion of pig iron into steel by the Bessemer process. A glass smoked in the flame of a candle is a familiar device used in viewing sun spots or a solar eclipse.

All spectacles afford some degree of protection against mechanical injury, and in certain trades it is only by the use of special protectives that the liability to grave accidents to the eyes can be averted. Millers have been long in the habit of wearing large spectacles fitted with thick window glass when employed in the dangerous work of dressing millstones. Protective spectacles of mica[36] are especially to be recommended for miners, quarrymen, stone-cutters, boiler-makers, and others engaged in similar dangerous employments; large spectacles fitted with thick plates of glass or of rock crystal have been found effective as a protection against injury from stray pellets in bird shooting. Goggles of finely woven wire gauze are occasionally used by railway travellers and others as a protection against flying sparks; goggles made of glass bent to a cylindrical curve, and furnished with cushioned rims to fit closely around the margins of the orbits, also masks with glazed openings in front of the eyes, are made in a great variety of forms as protectives in driving automobiles.

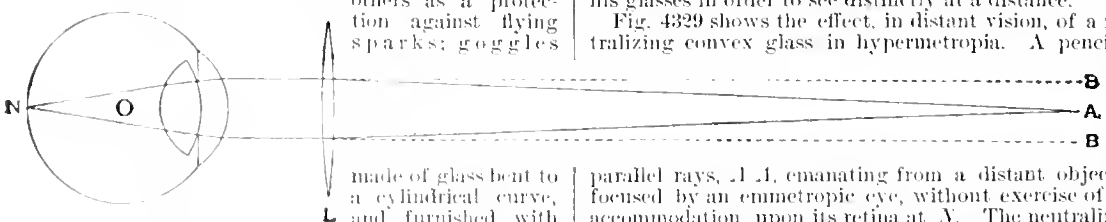


Fig. 4328.

Coquille spectacles and eyeglasses, both colorless and tinted, are made also in the meniscus form (with positive focus) and in the concavo-convex form (with negative focus); as kept in the shops, they range from about +8. dioptries to −8. dioptries. Owing to the shorter radius of curvature of the (concave) surface turned toward the eye, these glasses are more perfectly periscopic than those commonly sold under that name.

The office of spectacles and eyeglasses, other than mere protective and stenopaeic glasses, is, primarily, to supplement impaired accommodation (convex glasses, in presbyopia and in accommodative paresis or paralysis), to relieve the accommodation of an excessive burden by supplementing deficient refraction (convex glasses, in hypermetropia), to correct excessive refraction (concave glasses, in myopia), to correct asymmetrical refraction (convex or concave cylindrical or toric glasses, in astigmatism), and to relieve the external ocular muscles of strain or to overcome moderate grades of diplopia (prismatic glasses). These several effects are, moreover, often variously combined, as in the use of strong convex glasses in reading (by hypermetropes with defective accommodation); of partially correcting concave glasses, or, perhaps, of weak convex glasses, in reading (by myopes with defective accommodation); of glasses of asymmetrical refraction (in compound or mixed astigmatism, and in presbyopia or other accommodative defect occurring in connection with astigmatism); and of decentrated or prismatic glasses with spherical, cylindrical, or toric surfaces.

The action of a convex glass, as used by a presbyope, in reading, is shown in Fig. 4328. Divergent rays emanating from a printed page at *A*, at such distance from the eye, *O*, that the retinal image of the print shall be of sufficient size to admit of its being easily deciphered, are refracted in passing through the lens *L* (whose focal length must be not less than the distance *L A*), and are rendered either less divergent—as if they had originated from some point more distant than *A*—or parallel—as if coming from an infinite distance. When the focal length of the lens *L* is equal to the distance *L A*, the rays constituting the several pencils which enter the eye, *O*, from an object at *A*, are rendered parallel, and a sharply defined retinal image is formed at *N*, without exercise of the accommodation. If the focal length of the lens *L* is greater than the distance *L A*, the rays forming the several pencils emanating from the object at *A* will, after refraction by the lens *L*, be rendered less divergent, as if coming from an object at some distance greater than *L A*, and the eye, *O*, will then be enabled to focus such pencils through the exercise of less of its accommodation than would be required to focus pencils diverging from *A*. The former of these two cases represents the condition of an emmetropic eye in extreme presbyopia, or in total paralysis of accommodation; the second case is that of an emmetropic eye in lower grades of presbyopia, or in a state of weakened accommodation.

The presbyopic eye, when thus adjusted by the convex lens *L* for the reading distance *O A*, is, by the action of the lens, thrown out of adjustment for distinct vision at a distance; a presbyope wearing glasses for reading, or other near work, must therefore remove or look over his glasses in order to see distinctly at a distance.

Fig. 4329 shows the effect, in distant vision, of a neutralizing convex glass in hypermetropia. A pencil of parallel rays, *A A*, emanating from a distant object, is focused by an emmetropic eye, without exercise of the accommodation, upon its retina at *N*. The neutralizing convex lens *L* converts the parallel rays of the pencil into rays of such degree of convergence that the hypermetropic eye, *O*, focuses them accurately at *N′*; the entire accommodation is thus rendered available to meet the requirements of near vision, so that the hypermetropic eye, with its neutralizing glass, becomes virtually emmetropic.

In the case of total presbyopia or paralysis of accommodation in the hypermetropic eye, a lens equal in power to the sum of the two lenses *L* (Fig. 4329) and *L* (Fig. 4328) is required for distinct vision at the reading distance *O A*.

A hypermetrope wearing neutralizing convex glasses sees distinctly, and without conscious effort, at all distances; when, however, he becomes also presbyopic, the neutralizing convex glasses cease to afford sufficient help in reading, and stronger glasses become necessary. These stronger reading glasses are, however, too strong for distinct vision at a distance; hence, an elderly hypermetrope requires, as a rule, two pairs of convex glasses—the one, neutralizing, for distinct vision at a distance, and another pair, of greater power, for reading.

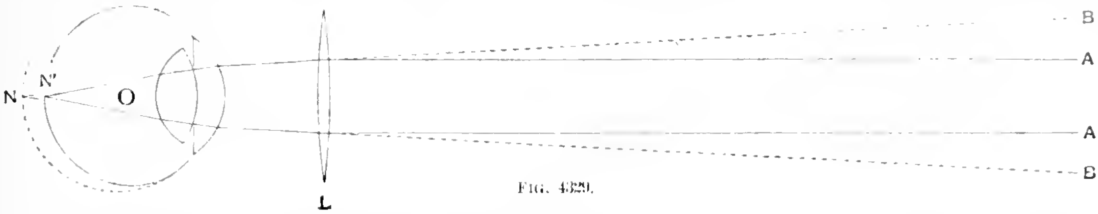


FIG. 4329.

Fig. 4330 shows the use of a neutralizing concave glass, in distant vision, in myopia. The pencil of parallel rays, *A A*, emanating from a distant object, is focused by the myopic, as by the emmetropic, eye at the normal position of the retina at *N*: the actual position of the retina, in the myopic eye, is, however, farther back, at *N'*. The myopic eye, in a state of complete accommodative relaxation, can focus only divergent rays, as from an object at some short distance, *O B*, upon its retina, and, by the exercise of its accommodation, it can also focus rays diverging from some still nearer point, somewhat within the distance of nearest distinct vision (*P*) for an emmetropic eye. The neutralizing concave lens, *L*, converts the parallel rays of the pencil, *A A*, into rays of such degree of divergence as they would have if emanating from *B*, and thus the myopic eye, *O*, is enabled to focus them upon its retina at *N'*. The farthest point of distinct vision (*r*) is thus carried off, by the neutralizing concave glass, to an infinite distance, and the near-point (*p*) is removed to the distance of the near-point in emmetropia.

When the myopic eye becomes restricted in its range of accommodation, as a result of advancing age, the neutralizing concave glasses must either be laid aside in reading or exchanged for weaker concave glasses; in myopia of a low grade it may even become necessary, in reading, to make use of convex glasses, but weaker than those which would be required by an emmetrope of the same age.

A myope wearing neutralizing concave glasses, like the hypermetrope wearing neutralizing convex glasses, sees distinctly at all distances. Only when he becomes presbyopic does he find himself compelled either to lay aside his concave glasses in reading, or to exchange them, temporarily, for weaker concave, or, possibly, for weak convex glasses.

Comparing Figs. 4329 and 4330, it will be seen that the pencil of parallel ray *A A* (Fig. 4329) is of somewhat greater diameter than the pupil, and, conversely, that the pencil *A A* (Fig. 4330) is of less diameter than the pupil. As the areas of the cross-sections of the two pencils are to each other as the squares of their diameters, it follows that there must be a considerable gain in the brightness of the retinal image in the case of hypermetropia corrected by convex glasses, and a loss of illumination in the case of myopia corrected by concave glasses. Thus, hypermetropes wearing convex glasses may see better than emmetropes by moonlight or starlight, and myopes wearing concave glasses see less perfectly under the same conditions; in high grades of myopia the disability from this cause is sometimes so great as to simulate night-blindness (hemeralopia).

Objects viewed through convex glasses appear larger than do the same objects when their images are focused by an exercise of the accommodation, and, conversely, near objects viewed through concave glasses under accommodative tension appear smaller than do the same objects when viewed without exercise of the accommodation. Hence a presbyope using convex glasses in reading sees the print not only clearer than without glasses, but larger than it formerly appeared to him under normal exercise of the accommodation. So, also, a hypermetrope wearing convex glasses sees all objects larger than when he views them without glasses, and a myope using concave glasses in reading sees the print smaller than when he reads without glasses. In uncorrected hypermetropia the actual size of the retinal image is smaller, and in uncorrected myopia it is larger, than in emmetropia.

A convex spectacle lens is increased in effective power by increasing its distance from the eye, and, conversely, a concave lens loses in effective power with every increase in its distance. The correct rule of practice is to mount the glasses as near as possible to the eyes, allowing sufficient room for the play of the eyelashes. A distance of 13 mm. from the vertex of the cornea fulfils this condition in most cases, and at the same time allows the correcting lens to be placed almost exactly at the anterior principal focus of the eye, in which position of the glass the retinal image, whether in hypermetropia or in myopia, becomes practically equal in size to the image of the same object when focused by an emmetropic eye. Whenever a hypermetrope inclines to remove his (convex) glasses to a greater distance from the eye than 13 mm., it may generally be assumed that the glasses are somewhat too weak, and, conversely, when a myope inclines to wear his (concave) glasses at a distance greater than 13 mm. from the eye, it may be assumed that the glasses are somewhat too strong. In presbyopia it is a not uncommon habit of old people to wear their spectacles far down toward the tip of the nose, in order to make a weak glass do the office of a stronger glass in improving the distinctness of the print, and also in increasing its apparent size; in this position of the glasses it is also easy to look over them at distant objects. In aphakia, after an operation for cataract, recourse may be had to the same expedient, as affording a partial substitute for the lost accommodation.

The increase or diminution in the apparent size of objects viewed through a convex or concave spectacle lens is not uniform in all parts of the visual field, but is greater at its periphery than at its centre. Thus, a large object viewed through a spherical convex lens appears more highly magnified in its peripheral than in its central portions, and the same object viewed through a spherical concave lens appears more diminished in its peripheral portions. When the (spherical) lens is accurately centred before the eye, in a plane perpendicular to the line of vision, this distortion of the virtual image is symmetrical; in all other cases it is unsymmetrical.

It has been often remarked that myopes, in selecting concave glasses, are apt to err by making choice of glasses of somewhat excessive power, which cause objects seen through them to appear very sharply outlined. This phenomenon appears to be a result of the chromatic aberration of the eye, causing the object, when viewed through a concave glass under a full correction for the more highly refrangible (blue or violet) rays of the spectrum, to be seen as if bounded by a very narrow red border, instead of by a broader violet fringe, as when the eye is focused for the less refrangible (red) rays. If a distant point of light is viewed by an over-corrected myopic eye through a piece of cobalt-blue glass, the light will appear blue, with a narrow red border; if the eye is under-corrected by its concave glass, the light will appear red, with a broader blue border.

A convex or concave cylindrical spectacle lens elongates or shortens the retinal image in a direction at right angles to its axis, thus giving rise to a change in the apparent shape of the object—a circle appearing elongated or shortened to an

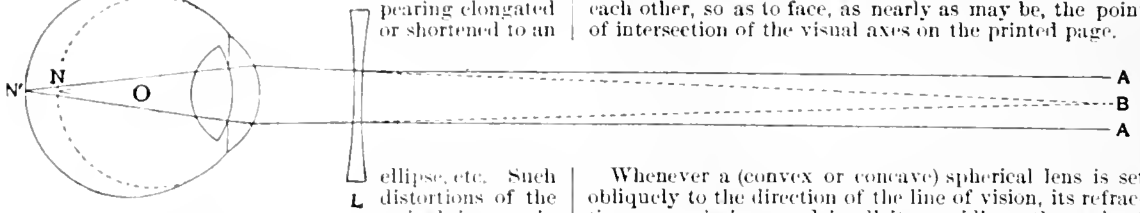


FIG. 4330.

ellipse, etc. Such distortions of the retinal image, in one eye or in both eyes, incident to the correction of astigmatism, or even a difference in the size of the two images caused by unequal spherical glasses, may give rise, in binocular vision, to a great variety of stereoscopical illusions which, until corrected by experience, may be a source of considerable annoyance.

Incidental to the action of convex and concave glasses in modifying the exercise of the accommodation is the effect which they exert upon the associated convergence. Convex glasses, by relieving the accommodation of a part of its burden (in hypermetropia), exert at the same time a positive effect in controlling the correlated convergence; hence, they rank first among the therapeutic agents at our disposal for arresting the development of convergent strabismus, and, in many cases, for its cure. Concave glasses, on the other hand, by increasing the demand made upon the accommodation in near vision, evoke increased action of the recti interni muscles (with correlated relaxation of the recti externi), and thus afford relief in many cases of muscular asthenopia and of crossed diplopia, and even of divergent strabismus (see *Asthenopia*).

Prismatic glasses with plane surfaces (Fig. 4326) may be mounted with their bases toward the nose, in which case they relieve the recti interni muscles of a part of their work in convergence, and are thus of service in certain cases of muscular asthenopia and of crossed diplopia of low grade. Mounted with their bases toward the temples, they are applicable in certain cases of homonymous diplopia dependent on insufficiency of the recti externi muscles. A prismatic glass, mounted with the base of the prism upward or downward, may be used to neutralize the effect of a slight downward or upward deviation of either eye, or the correction may be divided between the two eyes by making use of two prisms, the one mounted with its base upward and the other with its base downward. The deviation which may be thus overcome by a prism is equal to about one-half of the angle included between its two sides—*i.e.*, about 4° with a single prism of 8° angle, or 8° with a prism of 8° angle worn before each eye. Prisms of more than 10° or 12° angle are ordinarily rejected by reason of the conspicuous colored fringes due to chromatic dispersion.

The normal effect of any (convex or concave) spectacle lens is obtained only when the lens is accurately centred in front of the pupil, and the plane of the lens is perpendicular to the direction of the line of vision.* The distance between the centres of the two lenses of a pair of spectacles intended to be worn in distant vision should, therefore, be exactly equal to the interpupillary distance. In the case of reading glasses, the distance between the centres of the two lenses should be a little less than the lesser interpupillary distance when the visual axes are made to converge upon the printed page. In the case of spectacles or eyeglasses to be worn in distant vision, the two lenses should be set in one and the same (vertical) plane, perpendicular to the direction of the (parallel) visual axes, but they should be tipped forward in spectacles which are to be used in reading. In strictness, the lenses of reading spectacles should be also inclined a little toward each other, so as to face, as nearly as may be, the point of intersection of the visual axes on the printed page.

* In a plano-cylindrical lens the centre of the face of the lens is represented by a line, and the condition of accurate centration is fulfilled when this line crosses the centre of the pupil; a lens with plane surfaces, *e.g.*, a simple prismatic glass (Fig. 4326), has no centre; in general, the greater the radius of curvature (*i.e.*, the weaker the lens), the less is the error resulting from imperfect centration or from faulty direction of the plane of the lens.

Whenever a (convex or concave) spherical lens is set obliquely to the direction of the line of vision, its refractive power is increased in all its meridians, the ratio of increase being, however, greatest in the meridian corresponding to the plane of the arc through which the lens is rotated, and least in the meridian corresponding to the axis of rotation. In the case of a (convex or concave) cylindrical lens, rotated about its axis, the increase in refractive power varies from a maximum, in the meridian at right angles to the axis, to zero, in the meridian of the axis. When rotated about a line at right angles to its axis, a (convex or concave) cylindrical lens shows also an increase in refractive power, though in a lesser degree than when it is rotated about its axis. It follows that a tipped spherical lens becomes practically equivalent to a somewhat stronger spherical lens with a cylindrical lens added to it, and that, in the case of a spherico-cylindrical lens, the special effect of the cylindrical surface may be either increased or diminished, according as the compound lens is rotated about one or the other of its principal meridians. A tipped concave spherical lens may be occasionally utilized in distant vision in myopia, with astigmatism of relatively low grade, when the ocular meridian of greatest refraction is vertical or nearly vertical; conversely, a vertically mounted convex spherical lens may be given for reading, when the ocular meridian of greatest refraction is horizontal or approximately horizontal.* Again, in myopia with astigmatism, when

*A familiar instance of such a correction, in myopia, is seen in the not infrequent preference given to a tipped (concave spherical) eyeglass over glasses mounted in a vertical position, in a spectacle frame. So, also, after the extraction of cataract, a spherico-cylindrical lens, with axis horizontal, may be required to raise distant vision to its maximum, although, for reading, a spherical glass may be preferred, by reason of the increased power of the lens in its vertical meridian, incident to the oblique (downward) direction of the visual axes.

If we represent the power of any spherical spectacle lens by D, the angle through which the lens is tilted by ϕ, and the angle whose sine $= \frac{2}{3} \sin \phi$ by ϕ' (assuming the approximate value $\frac{3}{2} = 1.5$ for the refractive index of glass), the effective power of the tilted lens in its horizontal meridian will be represented by—

$$(3 \cos \phi' - 2 \cos \phi)\ D, \ldots\ldots\ldots\ldots [1]$$

and in its vertical meridian by—

$$\frac{1}{\cos^2 \phi}\ (3 \cos \phi' - 2 \cos \phi)\ D; \ldots\ldots\ldots [2]$$

the difference—

$$\left(\frac{1}{\cos^2 \phi} - 1\right) (3 \cos \phi' - 2 \cos \phi)\ D, \ldots\ldots [3]$$

representing the astigmatism of the tilted lens due to the tilting.

The following table shows the computed values of the several coefficients of D, for differences of 5° in the value of ϕ from zero to 45°.

$\phi =$	$3 \cos \phi' - 2 \cos \phi =$	$\frac{1}{\cos^2 \phi}(3 \cos \phi' - 2 \cos \phi) =$	$\left(\frac{1}{\cos^2 \phi} - 1\right)(3 \cos \phi' - 2 \cos \phi) =$
Zero.	1.000	1.000	0.000
5°	1.002	1.010	.008
10°	1.010	1.042	.032
15°	1.023	1.097	.074
20°	1.041	1.179	.138
25°	1.066	1.297	.231
30°	1.096	1.462	.366
35°	1.134	1.689	.555
40°	1.178	2.008	.830
45°	1.232	2.464	1.232
..	......	......	......
90°	2.236	Infinity.	Infinity.

By inspection of the table it will be seen that for every increase of the angle through which the lens is tilted, the astigmatism of the lens the ocular meridian of greatest refraction is approximately horizontal, the wearer of concave spherical glasses may learn the trick of looking obliquely through his glasses, to the right or to the left, in order to improve his acuteness of vision, though at the cost of acquiring an awkward carriage of the head. So, also, a hypermetrope with some measure of astigmatism, when the ocular meridian of greatest refraction is approximately vertical, may get a better correction from his (convex spherical) glasses by looking obliquely through them to one side.

A myope, wearing concave glasses of a power insufficient fully to correct his myopia, may look obliquely to one side, in order to improve his vision for the vertical lines of a distant object, and at the same time contract the opening of the eyelids, in order to improve his vision for horizontal lines; a hypermetrope, wearing convex glasses of insufficient power, is generally able to supplement their effect in distant vision by an exercise of the accommodation.

Spectacle lenses are usually mounted in oval rims, of metal or, in the case of eyeglasses, also of tortoise shell, horn, hard rubber, celluloid, etc. The rims used in mounting convex glasses are generally grooved, so as to grasp the sharp edge of the lens; concave glasses, too, are ground to an edge, and mounted in grooved rims, but it is a not infrequent practice to groove the lens itself, and to sink the rim, which is then made of (steel or gold) wire, in the groove. Convex lenses also are sometimes mounted with the rims sunken, but at the cost of making the lens needlessly thick and heavy. So-called frameless or rimless glasses have the metallic parts attached by means of screws passing through holes drilled in the lenses; concave lenses, with their thick margins, lend themselves better to this construction than do convex lenses.

Caprice has sometimes dictated the wearing of a single eyeglass, carried at the end of a riding-whip, a fan, etc., or worn suspended by a cord: in the latter case the circular glass is held in front of the eye by contracting the orbicularis muscle upon its rim. Binocular glasses may be divided, according to the way in which they are mounted, into three groups—namely, eyeglasses held in the hand (lorgnette—*face à main*); those held in place by means of a spring which pinches the nose (*pince-nez, Kneifer, Zwicker, Klemmer*), and spectacles proper, which are held in place by means of side-pieces passing above and behind the ears (*lunettes à branches, Bügel-brille*). To these three principal types may be added a fourth, still often used in the case of protective goggles, in which the glasses are held in place by means of an elastic band passing around the head.

The several parts of a pair of spectacles are (1) the rims (*cercles*), in which the glasses are mounted; (2) the bridge, or nose-piece (*arcade centrale, Bügel*), by which the rims are connected and supported upon the nose; and (3) the side-pieces (temples, bows, *branches latérales*), by which the spectacles are held in place upon the head. The size of the rims and the length of the bridge should be adjusted to the interpupillary distance, in order that the wearer may look through the centres of the glasses, and to the width of the face, so that the side pieces may touch, but not press against, the sides of the head. In the case of great width of face, larger or longer lenses are required than when the face is narrow.

The bridge should be shaped to fit the nose, and partially to encircle it; noses, however, differ greatly in prominence and in thickness, so that no single type of bridge is suited to all cases. The plain or the braced "hoop" bridge (Figs. 4331 and 4332) is one of the older forms, and is suited to noses of considerable thickness and prominence; the hoop may lie in the same plane with the glasses, or it may be turned forward at any required angle. The so-called "C" bridge (Fig. 4336) is the form most commonly found in the shops and, like the "hoop" bridge, it may be set at any required angle to the plane of the glasses. These forms serve best for reading-spectacles, but for spectacles to be worn in distant vision they often fail to support the glasses at the proper height, or at a sufficient distance from the eyes to avoid contact with the eyelashes. The "saddle" bridge (Fig. 4333), of comparatively recent invention, can be made to fit the greatest variety of noses, and when made of gold can be bent by means of pliers to meet almost any required conditions. The so-called "X" bridge (Fig. 4334), and the "K" bridge (Fig. 4335), are used principally in frames of very light weight; they are, however, of less general applicability than the other forms. The bridge should present a rather broad surface of contact with the nose, and special care should be taken to secure an accurate and comfortable fit. Bridges of the "X" and "K" patterns, when made from very thin wire, are apt to cut the nose. A gold bridge is often to be preferred, even when the other parts of the frame are made of steel, as being more easily moulded to the nose and free from liability to rust. Spectacle frames of tortoise shell were once in common use and have lately reappeared in the shops; when properly fitted to the face they are especially comfortable in reading and sewing.

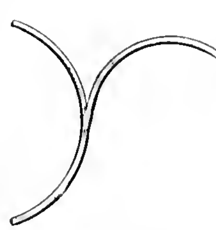


FIG. 4331.

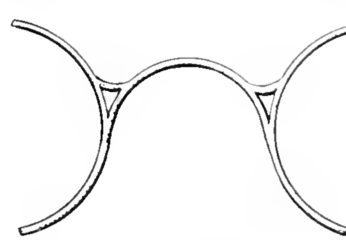


FIG. 4332.

The side-pieces (temples, bows, *branches*) should be slightly curved to fit the sides of the head, and they should be of a length sufficient to reach somewhat beyond the ears. Best of all, for spectacles to be worn constantly, are the hooked temples (Figs. 4333 to 4335) made of thin, elastic wire bent downward in a curve behind the ears.

The several parts of a spectacle frame should be nicely proportioned to each other. In the case of spectacles with straight sides the bridge should be of sufficient stiffness to maintain its shape unaffected by the lateral spring of the side-pieces. Only when hooked sides are used is it admissible to make all parts of the frame of very light weight.

(due to the tilting) increases at a much higher and progressively increasing rate. Thus, for 10° of tilting the increase in the resultant astigmatism of the lens is about four times as great as for 5°; for 20° it is 4.31 times as much as for 10°; for 30° it is 4.94 times as much as for 15°; for 40° it is 6.01 times as much as for 20°; etc. It follows that in any case in which the same spectacles are to be worn both for distant vision and in reading, as in correcting hypermetropic or myopic refraction in persons whose range of accommodation is practically unimpaired, by far the best adjustment is that in which the glasses are tilted forward through an angle equal to one-half of the difference in the direction of the visual line in distant vision and in reading (pantoscopic position).

In the case of a spectacle lens of asymmetrical refraction (sphericocylindrical, toric), with the two principal meridians horizontal and vertical, respectively, the coefficients of increase in the power of the tilted lens are the same as in the case of a spherical lens, noting, however, that D [1], which we may write Dh, now represents the normal power of the lens in its horizontal meridian, and D [2], which we may write Dv, now represents the normal power of the lens in its vertical meridian.

In the case of a plano-cylindrical (or other equivalent) lens with the axis of the cylinder vertical, we have Dv = 0 [2], the effective power of the tilted lens increasing as shown in [1]. Taking the axis of the cylinder horizontal, we have Dh = 0 [1], the effective power of the tilted lens increasing as shown in [2].

For a full discussion of the case of oblique centrical refraction through any spherical lens, see Parkinson's Optics, iv., 68; for an extension of the discussion to principal cases of oblique centrical refraction through plano-cylindrical, sphericocylindrical, and toric lenses, see two communications, by the writer, in Transactions Am. Ophthalmological Society, 1890 and 1895.

Fashion has played its part in determining the shape of spectacle glasses; the original shape was doubtless circular, but that now generally preferred is a nearly regular oval. Another and, in some respects, preferable form is oblong, with rounded angles (Fig. 4336). A parallelogram with the four corners cut off by straight lines (octagon glasses) was a favorite shape a generation or two ago, and, though rather ungraceful, is still occasionally seen. Pulpit spectacles, so called, have the upper part of the rims flattened, in order to permit the wearer to see over them in looking at distant objects; the glasses are also set, as a rule, obliquely to the direction of the side pieces, but approximately perpendicular to the direction of the visual axes in reading. In ametropia, with defective accommodation, it is often convenient to mount two half-lenses in each rim, the upper half (convex or concave) of a power suited to the correction of the actual hypermetropia or myopia; the lower half, of the power needed for reading;* a similar effect is obtained, though somewhat less perfectly, by grinding the upper and lower halves of the same lens to different radii of curvature. Bifocal spectacles and eyeglasses, generally in rimless mounting, are also made by cementing a segment of a thin convex lens upon the back of the correcting glass required for distant vision, in such position that the wearer looks through it in reading. Still more elegant is a device by which a small and very strong convex lens, made of highly refracting glass, is embedded in the lower half of the glass required for distance; the entire glass is then ground to a uniform surface, so that the reading segment becomes practically invisible.† Another useful arrangement consists in mounting a supplementary reading correction in a separate frame, to be hooked upon the front of the spectacles habitually worn in distant vision.

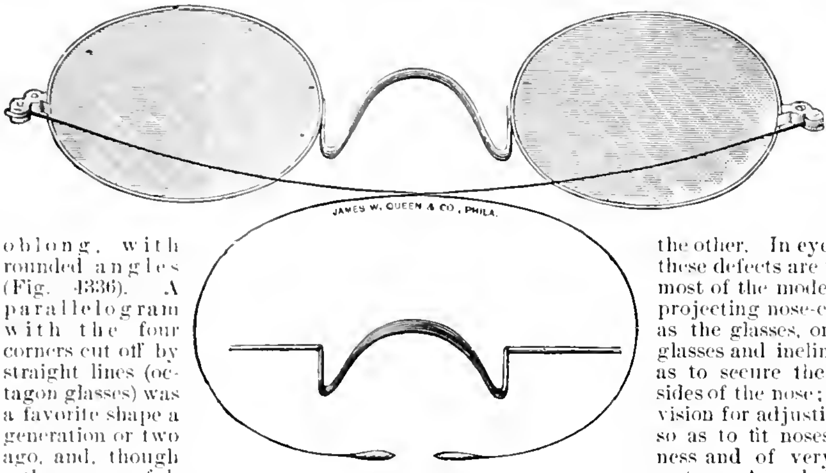


FIG. 4335.

Eyeglasses of the *pince-nez* ‡ pattern have been made since an early period in the history of spectacles, but their construction has been greatly improved within the past twenty years. In the older pattern (Fig. 4337) the centres of the glasses often fall much too near together, and the glasses themselves are apt to tip forward in a way that may be detrimental to their effect in distant vision. In many cases, also, they stand so near to the eyes as to allow insufficient room for the play of the eyelashes, and whenever the nose is unsymmetrical one glass is apt to stand noticeably higher or nearer to the eye than the other. In eyeglasses of improved construction these defects are to a great degree obviated. Thus most of the modern eyeglasses have some form of projecting nose-clips, set either in the same plane as the glasses, or in a plane behind that of the glasses and inclined to it at any required angle so as to secure the best possible bearing upon the sides of the nose; some eyeglasses have also a provision for adjusting the clips, upon the two sides, so as to fit noses of almost any shape and thickness and of very considerable degrees of asymmetry. A cork lining to the clips increases their adhesiveness, and so does away with the necessity of strong pressure in order to hold the glasses firmly in position. The tilting of the glasses, in cases of exceptional prominence of the forehead, is obviated by giving a forward slant to the connecting spring. For mounting cylindrical and prismatic glasses the *pince-nez* is generally unsuitable, by reason of the difficulty experienced in holding the glasses in proper position before the two eyes. In many cases of asthenopia, and especially in progressive myopia, the wearing of a *pince-nez* should be prohibited.

A convex lens, preferably of about four inches diameter and a focal length of about eight inches, with a handle by which it may be held at any desired distance from the book and from the eyes, is often used in reading by old persons with failing acuteness of vision. By reason of the greater distance of the glass from the eyes, its magnifying power is much greater than that of convex spectacles, and by varying the distance of the book the recti interni muscles are relieved of more or less of their load in convergence. A combination of two plano-convex

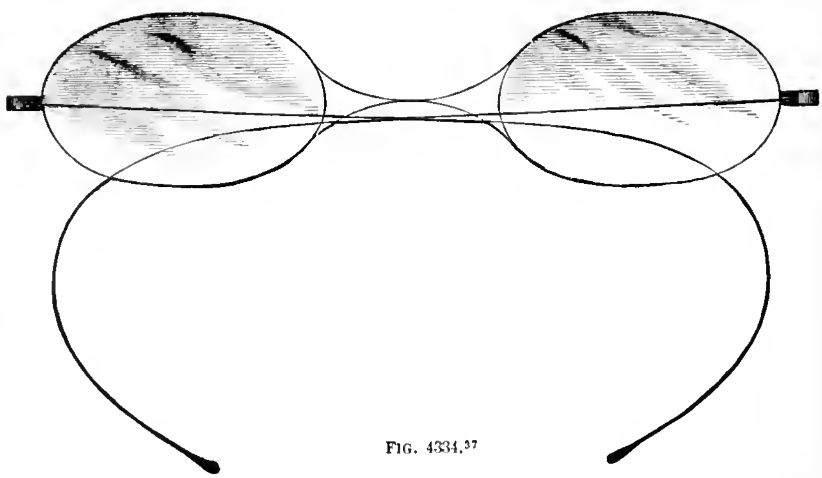


FIG. 4334.[37]

* Benjamin Franklin is said to have worn such glasses, and they are commonly called by his name.

† In this construction, and also in the more elaborate arrangement in which the correcting glass for distant vision is built up of two glasses cemented together (*cf.* Fig. 4324, *a d*), with the small reading lens enclosed in a cavity between them, there is an approach to an achromatic correction in the portion of the glass used in reading.

‡ In a fresco by Domº. Ghirlandajo (1449–94), in the Church of Sta. Trinita at Florence, an elderly bishop is represented as reading through a *pince-nez* set very low upon the nose; the rims of the glasses are circular, and the connecting arc is apparently rigid. This construction and manner of wearing the *pince-nez* recalls an objection formerly made to it, as compressing the nostrils and imparting a nasal quality to the voice. A fac-simile of the portion of the fresco containing this head has been reproduced, in color, in one of the publications of the Arundel Society, London, 1860.

lenses, mounted with their convex surfaces nearly but not quite in contact, is to be preferred to a double-convex lens, as giving a flatter field with less distortion of the virtual image.

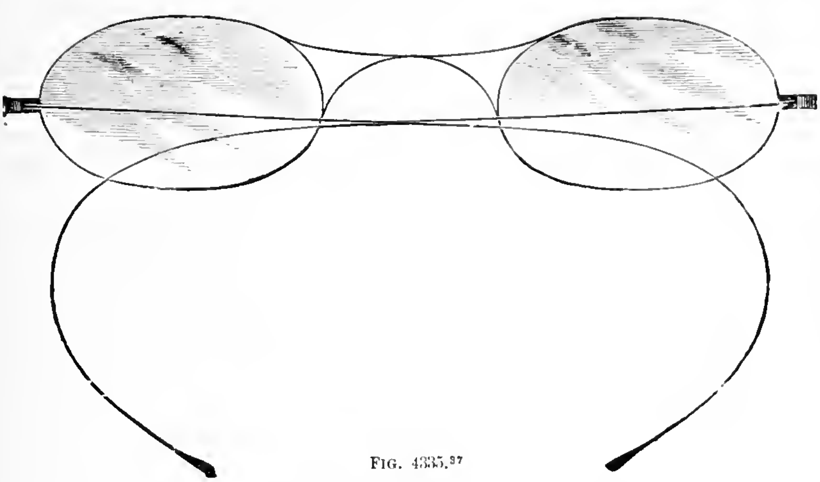


Fig. 4335.[97]

The different methods used in testing eyes for the correction of the several refractive and accommodative defects, whether simple or complicated, have been described in this Handbook under the titles *Astigmatism, Hypermetropia, Myopia, Presbyopia, Ophthalmometer, Ophthalmoscope, Optometry,* and *Shadow-Test.* The points to be particularly investigated are (1) the acuteness of vision, (2) the state of the refraction, (3) the state of the accommodation, and (4) the relation of the accommodation to the convergence. Only after these determinations have been made, with a close approximation to accuracy, can the selection of glasses for any particular kind of work be intelligently made. In the present state of diffusion of knowledge these tests can be safely intrusted only to the ophthalmic specialist — physicians and spectacle-dealers being alike incompetent, as a rule, to decide any but the simplest questions. A person who has arrived at the age of forty-five years without having experienced any trouble in the continuous use of his eyes, may fall into no very grave error in buying weak convex glasses when he becomes conscious that he is beginning to suffer from the disabilities of presbyopia; but even in such a case an examination of the eyes by a competent observer may bring to light some measure of astigmatism which it may be well worth while to correct, or possibly some pathological condition which it may be of vital importance to detect in its incipiency. The indiscriminate selling of concave spectacles and eye-glasses to young myopes, or to young persons hastily assumed to be myopic, is a most reprehensible, as it is, unfortunately, an almost universal practice.

The power of convex and concave spectacle lenses is expressed by numbers, with the plus (+) or the minus (−) sign prefixed. Two systems of numbering are in use, the older (inch) system, based on a unit-lens with two curved surfaces of equal radii of one Paris inch, and the newer (metric) system, in which a lens of a focal length of 1 metre (dioptric—D) is taken as the unit. In the older system it happens, through an accidental relation of the Paris to the English inch, that the focal length, in English inches, of a biconvex or biconcave lens is almost exactly the same as the radius of curvature of the two surfaces in Paris inches. The two systems may, therefore, be regarded as based upon unit lenses of one English inch and 1. metre focal length, respectively. The practical difference, in using the two systems, consists in the fact that in the case of the smaller unit, of 1. dioptric, the power of any lens of a power greater than this unit is expressed by a whole number or by a whole number and a decimal fraction, whereas in the case of the larger unit, of one English inch focal length, the power of any spectacle lens is expressed in the form of a vulgar fraction, with unity for its numerator, and the focal length of the lens, in English inches, for its denominator. The notation according to either system may, within a very small and practically negligible margin of error, be transformed into that of the other by taking the metre lens (dioptric) as equivalent to the lens numbered $\frac{1}{40}$ in the inch system.

Fig. 4336.[97]

Cylindrical lenses are numbered either according to their power (in dioptrics) or their focal length (in English inches) in the meridian at right angles to the axis.

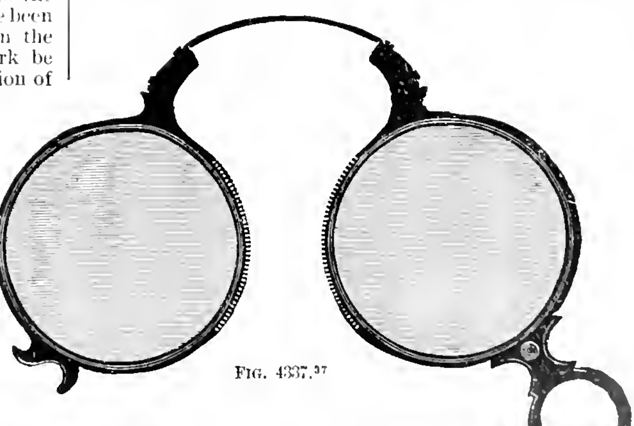


Fig. 4337.[97]

Lenses of unequal refraction in their two principal meridians are generally made by grinding a spherical and a cylindrical surface upon the two sides of the same glass, and the formula for such a lens is written, for each surface, as if the lens were made up of a plano spherical and a plano cylindrical lens with their plane surfaces in contact. The direction of the axis of a cylindrical lens or surface is defined by noting its inclination (in degrees of arc) to either the vertical or the horizontal meridian of the eye. If the two surfaces of any lens, at the points in which they are cut by the visual line, are not parallel, the deviation from parallelism is expressed by the magnitude of the angle which the two tangent planes make to each other, as if the two refracting surfaces were ground upon the two surfaces of a prism; the direction of the refracting angle of a prism is defined in the same manner as the direction of the axis of a cylindrical lens.

In prescribing spectacles it is convenient to lay off these angles on a printed diagram. Such diagrams have been in common use in this country since about 1876, and are furnished, in a variety of forms, by the opticians. In the diagram shown in Fig. 4338 the position is that in which the wearer is supposed to be looking through

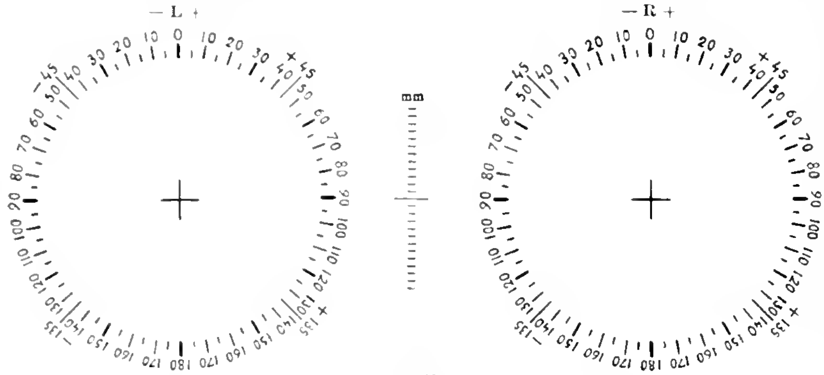


FIG. 4338.

his glasses, and the angles are marked, in degrees, with the plus (+) sign to the right, and the minus (—) sign to the left of zero, which is taken at the upper end of the vertical meridian. A widely used, but less natural, system of marking the angle of inclination is by beginning with zero on the horizontal line, at the left side, and numbering around the upper half of the circle to 180°. A half circle is sufficient to designate the direction of the axis of any cylindrical lens, but the whole circle of 360° is needed to indicate the different directions in which it may be required to turn the refracting edge of a prismatic glass.

The power of any (convex or concave) lens is measured by finding the equivalent (concave or convex) lens, and looking through the two lenses at a vertical line, such as a sash-bar of the window; the equivalence of the two lenses is shown by the absence of any enlargement or diminution of the virtual image, as indicated by the immobility of the image of the bar when the mutually neutralizing glasses are moved from side to side. In applying this test to a cylindrical lens the axis of the lens must be turned so as to coincide in direction with the line used as a test object; in the case of a sphericocylindrical lens the refraction is measured in the two principal meridians in succession, the algebraic difference of the two measurements representing the cylindrical refraction. The direction of the two principal meridians of a cylindrical or sphericocylindrical lens is found by holding the lens in a plane perpendicular to the visual axis, and looking through it at the sash-bar; the lens is then rotated, in its own plane, until the direction of the image coincides with that of the bar. This condition is fulfilled in two positions of the lens, at right angles to each other, in which positions the direction of one or the other principal meridian coincides with that of the bar. The middle point of any spherical or sphericocylindrical lens is found by noting the point at which the crossing of two sash-bars coincides in the image and in the object.

John Green.

[1] Scheler: Dictionnaire d'Etymologie Française, nouvelle édition, Bruxelles, 1873.

[2] Skeat: Etymological Dictionary of the English Language, Oxford, 1882.

[3] Encyclopedia Britannica, ninth edition, art. Beryl.

[4] Guy de Chauliac: Chirurgia Magna, Venetiis, 1546.

[5] Klein: Eulenburg's Real-Encyclopädie der gesammten Heilkunde, article Brillen.

[6] Paulus Ægineta: Lib. iii., sect. xxii.

[7] Pliny: Naturalis Historia, lib. xi., cap. liv.

[8] *Ibid.*, lib. xxxvii., cap. xvi.

[9] Seneca: Naturales Questiones, lib. i., cap. vi.

[10] Alhazen: Opticæ Thesaurus (Latin version), Basiliæ, 1572.

[11] Klein: Eulenburg's Real-Encyclopädie, article Brillen.

[12] *Ibid.*

[13] Salvino degli Armati—inscription on his tombstone formerly in the Church of Sta. Maria Maggiore at Florence.

[14] Bartisch: 'Οφθαλμουδουλεια, Dresden, 1583.

[15] Mackenzie: A Practical Treatise on the Diseases of the Eye, p. 914, fourth edition, London, 1854.

[16] De Sauvages: Nosologia Methodica, cl. vi., ord. i., iii., 3 and 4. Ed°. Ultima, Amstelodami, 1768.

[17] Rosas: Handbuch der theoretischen und practischen Augenheilkunde, Bd. i., § 648, Wien, 1830.

[18] Wollaston: Nicholson's Journal of Natural Philosophy, vol. vii., pp. 143, 192, 242, 291; vol. viii., p. 38, London, 1804. Cited from Mackenzie, *op. cit.*, p. 917, note.

[19] Rosas: *Op. cit.*, Bd. i., § 657.

[20] Airy: Transactions of the Cambridge Philosophical Society, vol. ii., p. 267, Cambridge, 1827. Cited from Mackenzie, *op. cit.*, p. 928, note.

[21] Donders: Astigmatisme en cylindrische Glazen, Utrecht, 1862. On the Anomalies of Accommodation and Refraction of the Eye, chap. viii., The New Sydenham Society, London, 1864.

[22] G. C. Harlan: Transactions of the American Ophthalmological Society, Twenty-first Annual Meeting, p. 96, 1885.

[23] J. Green: American Journal of Ophthalmology, March, 1886.

[24] Donders: On the Anomalies of Accommodation and Refraction of the Eye, chap. iv., pp. 132–135.

[25] *Ibid.*, chap. iv., pp. 166–168.

[26] Brücke: Archiv für Ophthalmologie, v., ii., S. 180, 1859.

[27] Brewster: Edinburgh Philosophical Transactions, xv., 1844.

[28] Donders: *Op. cit.*, chap. iv., pp. 128–132.

[29] *Vide* Desmarres: Traité théorique et pratique des Maladies des Yeux, tome iii., p. 706, 2ème edition, Paris, 1858.

[30] F. Ostwald: Archiv für Ophthalmologie, xlvi., ii., 1899; ix. congrès International d'Ophthalmologie, Utrecht, 1899.

[31] E. Jackson: Transactions of the American Ophthalmological Society, Twenty-second Annual Meeting, pp. 268–277.—G. Hay: *Ibid.*, pp. 384–390, 1886.

[32] Donders: *Op. cit.*, chap. iv., p. 130.

[33] Pierer's Universal-Lexicon, article Bernstein, neunte Auflage, Altenburg, 1867.

[34] J. Green: Transactions of the American Ophthalmological Society, Tenth Annual Meeting, p. 182, 1874.

[35] C. O. Curtman: American Journal of Ophthalmology, iii., 4, p. 106, April, 1886.

[36] Cohn: Berliner klinische Wochenschrift, No. 8, 1868; Klinische Monatsblätter für Augenheilkunde, vi., S. 293, 1868.

[37] From the trade catalogue of Meyrowitz Brothers, New York.

SPECTROSCOPY, MEDICAL.—The spectroscope is an instrument for examining the *spectrum*. A *spectrum* is, primarily, the series of colors produced when a ray of white light is transmitted through any transparent body, the surfaces of which are not parallel. The general form which this transparent body takes is that of an equilateral *prism* of glass, the sides forming an angle of sixty degrees. Hollow prisms with sides at the same angle are also used, being filled with transparent liquids.

Sir Isaac Newton first made the observation that when a ray of white light is transmitted through a prism the ray is not only bent out of its course, but is spread into an array of colors, the order of which is nearly invariable, no matter what the source of light or the material of which the prism is composed. Since the facility of differentiating colors varies in different persons, the exact tints of the spectrum so formed are not easy to express, but they are generally assumed to be seven in number, and arranged as follows: violet, indigo, blue, green, yellow, orange, red. If the ray of light be, as in Newton's original experiment, admitted through an opening of appreciable dimensions, the colors will be somewhat confused and will appear unbroken, but when the opening is very narrow a more distinct effect is produced, and, as will be seen below, the spectrum is crossed by numerous dark lines. It is a law of the propagation of light that when a ray passes from one transparent substance to another of different density it undergoes a deflection, known technically as *refraction*. The direction and extent of this refraction depend on the nature of the materials and on the difference of the densities. When the ray passes from a rarer to a denser subtance—for instance, from air to water, or from water to glass—the ray is bent (refracted) so as to be more nearly parallel to a line perpendicular to the surface of contact, while if the ray passes in the reverse direction—that is, from a denser to a rarer body, as from glass to water—the refraction is away from the perpendicular. It is upon this principle that the image-forming and magnifying properties of all lenses depend.

The accepted theories in regard to light refer it to very rapid vibration, and the difference between the various colors is supposed to be due to differences in the rate of vibration. White light is supposed to contain all the rates of vibration, and when such a ray undergoes refraction the different vibrations are refracted to different degrees, and hence are separated. If we view a ray through a plate of glass or other transparent body with parallel sides, the refraction produced in one direction on entering the glass is corrected by the refraction in the opposite direction on emerging, so that, with the exception of a slight displacement of the line of light, no striking optical change is manifest. If, however, the equilateral prism is used, the refraction on emergence is in the same direction as on entering, and the optical action is exaggerated. The separation of the different vibrations that compose a ray of white light is called *dispersion*, and is not coextensive with refraction; that is, bodies of equal refractive power do not necessarily separate the colors to the same extent. This law is a very important one in practical optics, for all lenses are forms with more or less prismatic outlines, and hence produce a dispersive effect. If it were only possible to prevent production of color by neutralizing the refraction, it would be impossible to construct any convenient optical apparatus free from colored images, but by combining different varieties of glass in such forms as to have equal and opposite dispersive powers with difference of refraction, large lenses entirely free from color defects (achromatic) may be constructed.

In the spectroscope the object is to secure as complete and extended a dispersion as possible; that is, to separate the colors thoroughly. For these purposes prisms of dense glass, or holl. w prisms filled with carbon disulphide, CS_2, are used.

The simplest method of examining the spectrum is to allow a ray of light to enter a dark room or dark box through a small opening and fall upon a prism. Upon the side of the room opposite the opening will be seen a more or less confused spectrum, in which all the colors will be found diverted from the path which the original ray would pursue if it did not enter the prism, the violet being most diverted and the red the least. Such a method of observation, however, is unsuitable for scientific purposes. The most serious defect in it is that if the ray has an appreciable thickness the vibrations on one part interfere and overlap those of the other, so that the series of colors obtained is really a combination of a number of spectra not coincident with each other. To obtain a pure spectrum the ray must be reduced to an exceedingly fine line of light, in which there will be but few sets of vibrations. This is accomplished by using a very narrow slit, and shutting off all light from the prism except that which passes through this slit. The observation is also much facilitated by viewing the spectrum through a telescope of low magnifying power.

About a century ago Dr. Wollaston, an English chemist, discovered, by using such a slit, that the spectrum of sunlight is not continuous, but is interrupted by numerous fine, dark lines. He did not develop this observation, and it was not until 1814 that Fraunhofer, a German optician, rediscovered these lines and mapped the positions of some of them. A few of the most prominent he distinguished by letters of the alphabet. They have in consequence generally been known as the Fraunhofer lines. They are all at right angles to the direction of the spectrum, and their distance from each other depends on the dispersive power of the prism. Since each particular line is always seen in the same color, and is more easy to define than the limits of the color itself, the lines are preferred for purposes of comparison.

Various improvements and advances in the construction of apparatus for observing spectra have been made from time to time, until the spectroscope in its usual form consists essentially as follows: A straight tube terminates at one end by a narrow, upright, adjustable slit, and at the other a convex lens, the focal length of which is the distance between it and the slit, so that the rays of light as they pass through the latter are rendered parallel by the lens. In the course of these rays is placed a dense glass prism, or series of prisms, greater dispersion being attained by a combination of prisms. A movable telescope of low magnifying power, arranged so that it can be brought in the course of the rays emerging from the prism, enables one to view conveniently the spectrum formed. Such an arrangement constitutes a *refraction spectroscope*. In the cut (Fig. 4339) there is shown a third tube, illuminated by a candle. This contains a graduated scale, an image of which is projected in the field of view above the spectrum, for the purpose of measurement, as given below.

Another form of the instrument depends on a somewhat different principle, and, as it is now in frequent use and possesses advantages over the older form, it will be necessary to describe it.

When the surface of a polished plate ruled with fine lines in close proximity is viewed obliquely, series of spectra are seen which are due to interferences in the different light waves as they are reflected from the angular surfaces produced by the ruling. This effect is called *diffraction*, and a plate so arranged is called a *diffraction grating*. The superiority of such an instrument rests principally on the fact that in all parts of the spectra the

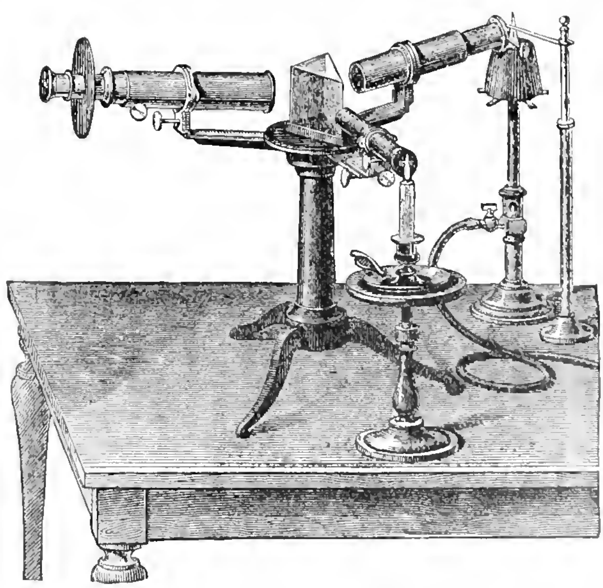


FIG. 4339.—Ordinary table spectroscope. In use the prism and abutting ends of the tube must be well covered to exclude light. This is usually attained by inserting them in the circumference of a brass box.

colors are proportionately distributed. In the ordinary spectrum, as seen by the prism, the dispersion is proportionately greater toward the violet end, and consequently this portion is abnormally spread out and the distances between the dark lines are exaggerated.

Spectra, by whatever method observed, may be divided into three groups:

1. Continuous spectra: those in which a more or less continuous sheet of color is seen, usually beginning with violet and ending with red. Such spectra are produced by the light which is emitted from solid objects in a highly heated state.

2. Interrupted or bright-line spectra: those in which the colors are seen in the form of narrow lines or bands, separated by proportionately wide, dark spaces. Such spectra are derived from light emitted by gaseous bodies in a highly heated condition.

3. Absorption spectra: those in which a nearly continuous series of colors is present, but interrupted by dark lines or bands. Such spectra are produced by various conditions, principally, however, by the transmission of white light, or light which would give a continuous spectrum, through substances which have the power of absorbing or annihilating special vibrations. In the applications of the spectroscope to medicine and organic chemistry these absorption spectra are the most important.

It is obvious from the above considerations that we have in the spectroscope, whether of the refraction or of the diffraction form, a very valuable means of studying structure. In the first place, we can determine with great exactness the character of the source of light, *i.e.*, whether it is composed of gaseous matter intensely heated or of solid particles. Further, taking a source of known character, we can, by interposing various substances in the path of the light, determine the effect which these substances produce upon the different forms of light vibrations present in the ray, and, as particular effects are often peculiar to particular bodies, we have here a means of identification. Thirdly, using a source of heat practically non-luminous, such as the flame of the Bunsen burner, we can detect different substances by the color which they impart to this flame, and when several such substances are present the eye alone is unable to separate and distinguish the colors, but by the spectroscope each tint is distinctly indicated.

As stated above, it is the absorption spectra that are most important in reference to the medical applications of the spectroscope. Except in the comparatively rare cases of the study of the character of light emitted by luminous organic bodies, living or dead, and in the detection of certain metals present in minute amount in the tissues and secretions, *e.g.* lithium, the direct study of normal spectra is not much resorted to in biological work.

The arrangement of the spectroscope for observation of absorption spectra is simple. An oil or gas flame is adjusted so as to throw a beam of light through the slit of the instrument, by which a continuous spectrum not broken at any point by dark lines is obtained. Sunlight does not answer so well for the purpose, because, owing to certain interfering conditions occurring at the surface of the sun, and also during the passage of the sunlight through our atmosphere, there are numerous absorption bands (Fraunhofer's lines) always present in its spectrum.

The material to be examined is placed in a cell with flat sides in the path of the light before it enters the slit. It is scarcely necessary to observe that to secure a satisfactory result the body must be sufficiently transparent to permit some light to pass through, otherwise no comparison as to the effect on different parts of the spectrum can be made. Such a condition is easily obtained by using solutions of the substance in the usual colorless solvents—water, alcohol, ether, glycerol, etc., and diluting until a satisfactory result is obtained. The character of the absorption spectra sometimes differs, according to the solvent used and the presence of free acid or alkali. Working spectroscopes are generally arranged so that two spectra can be compared, one being a standard obtained under known conditions, the other being that of the body to be tested.

To understand the functions of the spectroscope it is necessary to bear in mind that the colors seen are practically images of the slit through which the light passes, and that when the ray contains all the colors—that is, every vibration from violet to red—the prism, in setting out the vibrations according to dispersive power, gives, of course, a continuous series of images, that is to say, a continuous spectrum. When, however, in the ray of light that enters the slit any vibrations are missing, as in sunlight, or when by some interposed condition certain colors are struck out of the ray, the images which would otherwise be formed by those rays are missing, and hence the spectrum appears interrupted. When the interposed substance strikes out many rays, *e.g.*, deep-colored glasses, the great bulk of the spectrum is missing. The red glasses, for instance, used in photographic dark rooms strike out almost all rays but the red. The spectroscope as ordinarily constructed is, unfortunately, subject to serious defects, which can be avoided only by instruments of very expensive form. It has been found that all the forms of glass possess marked absorption powers for certain rays of light. If, instead of employing glass lenses and prisms, we use those made of quartz, and employ as a source of light the electric arc, or burning magnesium wire, a spectrum is obtained which is very much extended at the violet end. This portion of the spectrum exists to a greater or less extent in white light from any source, but is absorbed to such an extent by glass that it is not seen in the ordinary spectroscope. There are also color waves beyond the red, which are only demonstrable by special apparatus. In the usual applications of the spectroscope we cannot, therefore, utilize the so-called ultra-red and ultra-violet rays.

A very important advance has been made recently in practical spectroscopy in the application of photography. A sensitive plate is capable of responding to and recording conditions which the eye is unable to recognize, and we have, therefore, not only a method of extending our knowledge of spectra, but we may obtain permanent records of absolute accuracy, and independent of any general or special defects in vision. The photographic plate is especially capable of receiving impressions from the violet and ultra-violet portions of the spectrum, which are especially those which the eye appreciates with the greatest difficulty, while the yellow and red rays are practically inactive.

Many substances are known which have the power to retard the rate of vibration of light rays, so that they change the color of the light falling on them. Now the ultra-violet rays, which are inappreciable to the human eye, are caused by extremely rapid vibrations; any substance which will reduce this rate will bring the rays within the range of vision. This property is known as fluorescence. It does not come within the scope of this article to more than refer to it, but it may be mentioned that one of the best methods for the preparation of photographic plates is to incorporate into the sensitive material some fluorescent body by which the rays of light are modified and effects produced with colors that would otherwise be inactive.

The only way of acquiring familiarity with spectroscopic appearances is by actual use of the instrument. No drawing, colored or otherwise, can convey perfectly the appearances. Nevertheless, a method of indicating the character and position of the lines is useful, and several plans have been adopted. The use of colored plates is, of course, the most vivid, but too costly for most purposes. The usual methods are either by recording the position of any line, or the centre of a band, by its position on an arbitrary and fixed scale, or by angular position. A form of spectroscope made by Browning, of London, has this latter arrangement. The view telescope moves in a graduated arc, and cross-lines in the field enable it to be brought to exact position with any line. By such method or by the scale the lines may be mapped in their relative positions as seen in that particular instrument.

Another method is to indicate the positions of lines by their calculated wave lengths; that is, the length of one complete movement constituting the ray which produces a line at the given point. Such a method has the advantage of being an absolute indication, and not dependent on any particular instrument. Wave lengths are determined by mathematical calculation by means of the phenomena observed in diffraction, and the calculation may be easily applied to ordinary cases by plotting off on a chart certain lines of which the wave lengths are known, and interpolating those of which it is desired to determine the wave length. These lengths are very minute, and are usually expressed in millionths of a millimetre.

DESCRIPTION OF SPECIAL SPECTRA.—*Bright-line Spectra.*—Each of the known elements gives a special and distinct spectrum when heated sufficiently to become a luminous gas. It has been pointed out at the beginning of the article that solid substances give continuous spectra, and hence there is no appreciable difference between the spectroscopic appearances of the different elements as long as they remain solid bodies. When the temperature rises sufficiently to convert them into gases, and render them at the same time luminous, the characteristic bright-line spectra are obtained. This temperature can be attained with most elements only by the use of the electric spark. A few bodies, among which are potassium, sodium, lithium, barium, calcium, strontium, and boron compounds, yield, at the temperature of the non-luminous gas flame—Bunsen-burner flame—a limited number of rays which are early observed by the spectroscope as bright lines. Sodium imparts to flame a deep yellow color which consists of two tints, and is seen in the spectroscope as a narrow double line. Potassium gives red and violet lines. By increasing the temperature some of these spectra are modified. When the electric spark is employed the spectra obtained are usually more complex, the bright lines being numerous. The detection of the different elements by this means is not so widely applicable as might at first be supposed, for the method is extremely delicate, and it is difficult to distinguish between the minute traces which often have no significance and the presence of an appreciable amount. Nevertheless, the method has been of great usefulness in special cases in showing the occurrence of some elements in unexpected relations, and the wide distribution of others in minute quantities. Several elements, occurring in such minute quantities that ordinary chemical analysis would have failed to indicate them, have been discovered by the spectroscope.

There are a few substances which give a limited bright-line spectrum before reaching the temperature at which they became gaseous.

Absorption Spectra.—These are of several kinds. The absorption may affect a considerable part of one or both ends of the spectrum, by which a whole block of color may be cut out, or it may take place in broad bands or in fine lines. The spectrum of the sun and of many of the fixed stars is an example of the latter class. The lines of absorption are numerous, but they are narrow and represent but a small portion of the entire field, which appears to the unassisted eye to be a uniform sheet of color. Band absorption—that is, the cutting out of a considerable number of rays at some point on an otherwise continuous spectrum—is brought about very easily by means of many organic bodies.

Extended absorption, by which a considerable portion of the spectrum is absorbed, is seen in many substances possessing deep color, and the absorption may include all but a single color. Various colored glasses may be used. To test the effect of a graduated increase of color wedge-shaped glasses may be employed. Hollow wedge-shaped cells are often used for the examination of colored liquids.

The method of observing absorption spectra has been given above. It has been also already pointed out that no description, nor even drawing, can give an adequate idea of the actual appearances of spectra, but for the purpose of completing the article and indicating some of the practical applications of the methods a few absorption spectra will be described.

Line-absorption Spectra.—Some of the rarer elements possess the peculiar property, when in solution, of absorbing special rays of light. Among the best known of these are the metals formerly included under the term didymium. It consists of two elements, forming compounds that have distinct colors, but, even when so far diluted as to make the tint not perceptible, they give absorption bands. The vapors of bromine and of nitrogen dioxide, NO_2, which to the eye have much the same color, give each a peculiar series of numerous fine absorption lines in the central part of the spectrum. The absorption lines that normally occur in the spectra of the sun and stars are an important clue to the chemical composition and physical condition of those bodies, but a consideration of this topic does not belong here.

Band Absorption.—One of the most familiar and striking instances of this form of absorption is seen in *chlorophyl*, which is the general term under which the green coloring matter of plants is designated. A solution of this substance is easily obtained by macerating leaves with ether or alcohol. The filtered liquid being diluted so as to be fairly transparent, has a beautiful green color by transmitted light, and when viewed through the spectroscope transmits all the colors except a band in the extreme red, at which point there appears a well-marked broad dark band. The position of this band is highly characteristic of this substance, and can be detected by careful observation, even when the solution is too dilute to exhibit the color to the eye. In this way the adulteration of animal oils by vegetable oils—for instance, of lard oil by cotton-seed oil—may often be detected, for cotton-seed oil exhibits the absorption band of chlorophyl derived from the vegetable tissue.

Valuable use is made of absorption spectra in detecting the nature of various natural and artificial coloring matters. Fuchsin, for instance, not infrequently employed as an artificial coloring matter in wine, gives a broad but not very sharply marked band about the junction of the green and yellow of the spectrum.

It is, however, with reference to the absorption bands produced by the fluids of the animal body that the clinical applications of the spectroscope are seen. The most important of these are the appearances seen in blood under various conditions. These appearances are due to the hæmoglobin. As ordinarily seen by examining blood much diluted with water, the spectrum is that of oxidized hæmoglobin, *oxyhæmoglobin*. The dilution must be sufficient to allow considerable light to pass, and a modification of the absorption spectrum is obtained by continually adding water until no absorption at all occurs. The same effect may be produced by examining the solution through a wedge-shaped cell, gradually diminishing the thickness of the solution through which the light passes. The effects are briefly as follows: In rather strong solution, all the light is cut off except a portion of the orange and red; when the solution is diluted somewhat, green rays are transmitted, and the dark interval between these and the orange constitutes a broad absorption band; still further dilution produces a yellowish-green mass of light dividing the dark space into two nearly equal portions, developing, therefore, two well-marked absorption bands. On still further diluting, the absorption becomes reduced to a single band in the yellow. When to a solution of blood of sufficient density to give the two bands we add some reducing agent, *i.e.*, some body having an affinity for oxygen, the hæmoglobin is *reduced*, and a new spectrum is obtained. For this reduction ammonium sulphide is preferred. The spectrum of reduced hæmoglobin is a single band, broader than, and not exactly coincident with, either of the bands obtained from oxyhæmoglobin, the darkest portion corresponding to the mass of light dividing the two bands in that spectrum. The chemical condition of the blood in the vessels may in this way be tested. Another important result is in determining the effect of various gases and chemical substances in blood, either by direct action or by poisoning animals and quickly subjecting the blood to examination. If we examine blood charged with nitrous oxide (N_2O), we find the spectrum of reduced hæmoglobin, but agitating the blood with air will reproduce the oxyhæmoglobin. When, however, carbon monoxide (CO), carbonic oxide, is introduced into blood, we get a new condition which gives a spectrum resembling, but not identical with, that of oxyhæmoglobin, there being two bands, but their position being slightly nearer the violet.

Furthermore, we cannot so easily restore the original condition by agitating the blood with air, nor will the ordinary reducing agents produce the spectrum of reduced hæmoglobin. Carbon monoxide is known to be one of the most active of the gaseous narcotic poisons, and the above observations show, in part at least, the peculiar action it has on the essential breathing constituent of the blood. The carbon-monoxide-hæmoglobin spectrum is seen in the blood of persons poisoned by water-gas or fumes of burning charcoal, and an examination of the blood by the spectroscope in cases of this character may be an important medico legal point. Another important modification of the hæmoglobin is produced by the action of sulphides, especially by hydrogen sulphide (H_2S), sulphureted hydrogen. This gas is often present in sewer air, cesspool exhalations, and in other foul places, but not invariably, nor in so great quantity as is generally supposed. When its action upon blood is examined we find a spectrum which presents the broad single absorption band of reduced hæmoglobin (see above), but in addition a band in the red just at the junction with the orange. This band does not disappear on shaking the blood with air, although the two bands of oxyhæmoglobin appear. The body produced by the action of hydrogen sulphide on blood, and to which the properties above described are due, has been called *sulphæmoglobin*. It has been noticed that this substance cannot be formed by the action of hydrogen sulphide on reduced hæmoglobin, which is the form that exists in the veins; hence hydrogen sulphide may be introduced into the venous circulation without marked effect, but taken into the arterial system it is very dangerous. The difference between inhalations of this gas, by which it would get directly into arterialized blood, and its introduction into the system through the veins, has been shown strikingly in a method formerly in vogue of treating phthisis by injections of hydrogen sulphide and carbon dioxide. In this case the gas is taken up by the veins of the portal system and excreted before it comes in contact with the arterial blood.

If a solution of blood be exposed to the air for some time it undergoes various changes, accompanied by an alteration in the absorption spectrum. This alteration can be brought about by the action of weak acids, and also of potassium permanganate, on blood. A substance called *methæmoglobin* is formed. Its absorption bands are three, nearly coincident with those seen when sulphæmoglobin is shaken with air, but one band is more completely within the limits of the red. Methæmoglobin is believed to be a highly oxidized hæmoglobin, but its constitution is in some doubt.

Many other changes in the absorption spectra of blood are known, but while the investigation of them has much to do with physiological chemistry, the matter is too technical for discussion here. It is obvious, from what has been said, that very important medico-legal, toxicological, and even clinical questions can be determined by means of the spectroscopic appearances. The different effects produced on blood by different poisonous gases and vapors, the general symptomatology of which may be the same, offer a means of determining even post mortem the character of the gas.

Clinically, the spectroscopic appearances may be utilized for examining the fluids of the body either in their normal or in their abnormal condition. The spectrum of bile, for instance, may be utilized for the detection of it in the urine, for when the color reaction is too faint to be perceived by the unassisted eye, the spectroscope will show it. Normal urine contains a coloring matter believed to be derived from a constituent of bile, which gives a broad absorption band on the green. In certain febrile affections another band appears, also in the green, toward the border of the yellow. Blood in urine may also be detected by the spectroscopic tests. If it be in solution in the urine, the absorption spectrum is seen without difficulty. If the blood be present in the form of methæmoglobin, as is sometimes the case, it will give the three bands peculiar to that body, but it is necessary to distinguish these bands from those produced by a decomposition product of hæmoglobin known as *acid hæmatin*. This distinction can be made by the use of ammonium sulphide, when, if methæmoglobin is present, the band of reduced hæmoglobin, as described above, will appear. If the blood is in the insoluble form no absorption bands may be shown. In this case the blood is filtered and the filter paper treated with alcohol and ammonia, and then with ammonium sulphide; bands then appear which are due to *reduced hæmatin* formed by decomposition.

In the accompanying map (Fig. 4340) are shown some of the important absorption spectra as seen in a refraction

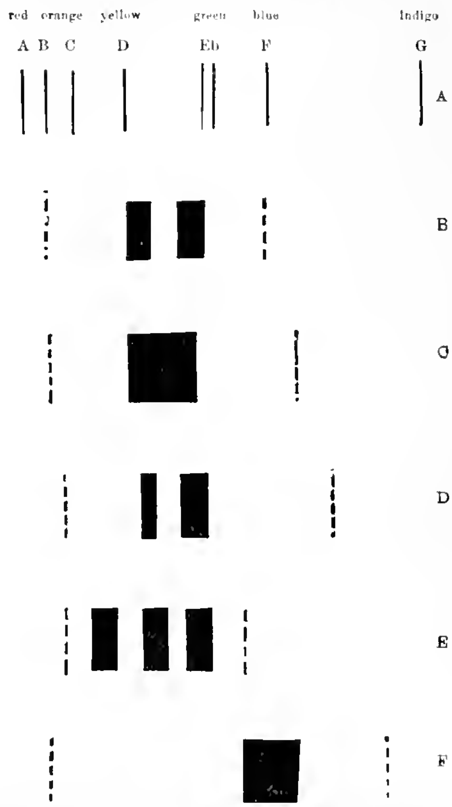


FIG. 4340.—A. Principal lines of solar spectrum as seen in a refraction spectroscope. B. Absorption bands of oxyhæmoglobin. C. Bands of reduced hæmoglobin. D. Bands of carbon monoxide hæmoglobin. E. Bands of methæmoglobin. F. Spectrum of normal urine.

spectroscope of moderate power. Over the plate has been placed indications of the limits of the various colors, but these must be regarded as a mere approximation, as it is not possible to determine precisely at what point one color ceases and another begins. The dotted lines at each end of the plates represent the limits of the visible spectrum in each case, and it will be noticed that there is considerable extinction of color, especially toward the violet end. *A* represents the spectrum of sunlight, with some of the principal absorption bands, and the letters which distinguish them. All these bands, as has been remarked above, are absent in the light of ordinary flames and electric lights. The observation of absorption spectra being made with artificial light does not therefore show any such bands. *B* shows the absorption bands of oxyhæmoglobin. The visible spectrum, it will be seen, extends only from green to a short distance on the red. *C* shows the spectrum of reduced hæmoglobin. The limits of the visible spectrum are extended slightly toward the violet. *D* is the spectrum of carbon monoxide hæmoglobin, that is, of blood impregnated with carbon monoxide. *E* is the spectrum of methæmoglobin. *F* is the spectrum seen commonly in normal urine. The broad band is at about the junction of the blue and green and is somewhat faint.

Limited practical clinical application is made of these spectroscopic appearances. The instruments required are expensive and involve delicate adjustment, and hence they are unsuited to the general uses of the practitioner. A combination of spectroscope and polariscope has been constructed for use in rapid approximate estimation of sugar in urine. The use of the spectroscope in the detection of various natural and artificial colors, and in the recognition of blood stains, belongs to special treatises.

Henry Leffmann.

SPEECH. See *Larynx, Physiology of the.*

SPERMACETI.—(*Cetaceum*, U. S. P., B. P.; Ger., *Blanc de Baleine ou Cétine*; Cod. Med., *Sperma-Ceti*). A solid paraffin-like substance obtained from cavities in the head of the sperm-whale, *Physeter macrocephalus* L. (order *Cetacea*). This whale is the largest living animal, gregarious in its habits and found in the oceans of both hemispheres, from the extreme north to the tropics. It is hunted for its oil, which is one of the most valuable of its class.

Crude spermaceti is a semisolid, yellow substance as it is scooped out from its reservoirs, but becomes hard and brittle upon exposure to cold; for purification, it is then pressed in bags, when the oil squeezes through, and the solid *cetaceum* is left behind. This can be further purified by melting in water, skimming, and recrystallization. Purified spermaceti is a pearly white, glistening, crystalline, translucent, odorless, and tasteless solid, insoluble in water; soluble in ether, chloroform, and boiling alcohol. Melting point 111° to 112° F. It is mostly composed of *palmitic* acid combined with *cetyl* (instead of glycerin); there are also small quantities of compounds of *stearic*, *myristic*, and *lauric acids*. It is fairly permanent in the atmosphere, in this respect excelling most fats.

Use.—Spermaceti has no active medicinal qualities. It is sometimes used in sore throats, etc., where its value is mostly as a protective. Its principal employment in medicine is as an ingredient of cerates and ointments, to which it gives consistence, blandness, and permanence.

There is an official cerate (*Ceratum Cetacei*) consisting of 35 parts of white wax, 10 of spermaceti, and 55 of olive oil, made by melting together the two former, adding the oil, previously heated, and stirring constantly until cold. Spermaceti is also an important constituent of ointment of rose water or cold cream (*Unguentum Aquæ Rosæ*, U. S. P.). *W. P. Bolles.*

SPERMATORRHŒA. See *Sexual Organs, Male, Diseases of.*

SPERMATOZOA.—(Greek, σπέρμα, seed, and ζῶον, an animal.) A *spermatozoon* is a free, usually motile cell that is capable of uniting with an ovum to form the germ of a multicellular organism. The penetration of the ovum by the spermatozoon and the union of the nuclei of the two cells constitute the chief processes in the act of fertilization, which is the essential feature in sexual reproduction; and the ability to produce spermatozoa or their equivalent is the essential distinction of organisms of the male sex (see *Sex*). The spermatozoon is distinguished from the ovum by being vastly smaller and generally by being capable of locomotion (see *Ovum*).

Historical.—Spermatozoa were observed for the first time by Ludwig Ham, a pupil of Leeuwenhoeck, who in turn communicated the discovery to the Royal Society of London in a letter dated November, 1677. The discovery of these minute living bodies in the semen of man and a number of animals aroused great interest, especially as Malpighi a few years before (1672) had published the results of his observations on the embryology of the chick, and had concluded, in contradiction to Harvey, that the embryo is preformed in the egg. Now the question arose as to whether the moving elements of the semen might be germs which enter the eggs and develop into embryos. Leeuwenhoeck took the affirmative position and had many followers, but a greater number of the preformationists took the opposite view and held those bodies to be merely internal parasites. The name "spermatozoa" was given to them by von Baer with this idea in mind. The position of the "ovists" was strengthened by Bonnet's discovery of parthenogenesis, published in 1762 (the experiments were begun in 1740), which showed that in some cases an embryo can be formed without a male parent.

The first successful step toward a real knowledge of spermatozoa by means of experiments in artificial fertilization of ova of animals was made by Jacobi, and communicated to the Berlin Academy by Gleditsch in 1764. Jacobi placed the ripe spawn of salmon and trout in water and added seminal fluid squeezed from a male. After five weeks the eggs showed signs of life. It was apparently not these experiments, however, but some unsuccessful attempts made by Malpighi much earlier that led to the truly remarkable series of experiments by Spallanzani (1786). He wisely chose the amphibia for his material. First, he showed that eggs taken from the oviduct could be caused to develop by the addition of sperm taken from the seminal vesicles, while similar eggs not so treated failed to develop.

Second, he disproved the idea current at that time that the fertilizing element was an *aura seminalis*, a seminal vapor. This was done by causing frog's eggs to adhere to a watch glass, which was then inverted over another containing some of the sperm, and both were put in a warm place. The eggs became wet by the condensation of the vapor that was distilled from the sperm, but no fertilization took place. After some of the material in the lower watch glass had been added to the eggs, however, they speedily developed.

Third, by filtering the sperm he showed that the *liquor seminalis* has no fertilizing effect, but that the residue washed from the filter paper has undiminished power. Spallanzani was prevented from reaching correct conclusions as to the nature of the spermatozoa, however, because he accepted Bonnet and Haller's theory of the preformation of the germ in the female, the truth of which he thought he had demonstrated in the amphibia. Spallanzani produced artificial fertilization also in the eggs of silk moths and in a dog.

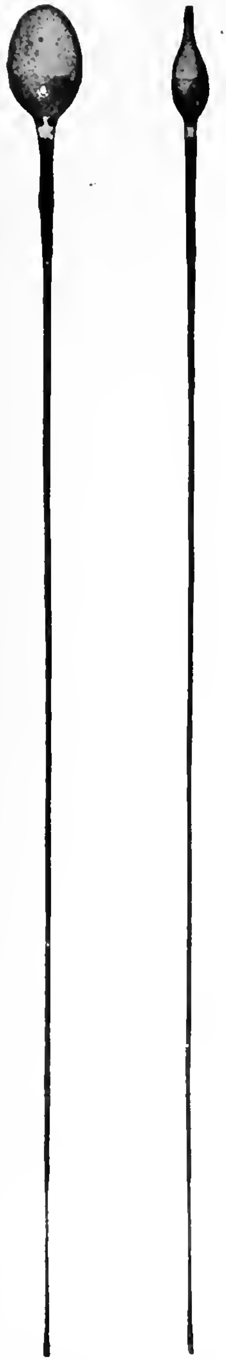
The next important contribution to the history of the spermatozoa is furnished by the brilliant observations and experiments of Prévost and Dumas (1824). They studied the anatomy and secretions of the reproductive organs of vertebrates of all classes above the fishes, and found that spermatozoa are produced in the testes only, and that these are the only organs essential to the fertility of the male; that spermatozoa exist in all fertile males and are absent from immature and senile individuals and from infertile hybrids; and that each species has its own peculiar form of spermatozoon. Having thus shown the close relation between the spermatozoon and its host and the correlation between the presence of spermatozoa and fertility of the male, these authors proceeded to repeat Spallanzani's experiments upon frog's eggs. They made improvements upon his methods, making the experiments more exact, and they demonstrated further that the spermatozoa are capable of penetrating the jelly surrounding the eggs. Spallanzani's results in regard to the aura seminalis and the liquor seminalis were confirmed and the important conclusion added that the spermatozoa are the essential fertilizing elements.

After all this it seems very strange to find the spermatozoa included in Owen's article on "Entozoa" in

"Todd's Cyclopædia" (vol. ii., 1836–39), and to read in Johannes Müller's "Physiology" (1840) that it is doubtful whether the spermatozoa are parasites or living parts of the animal in which they occur.

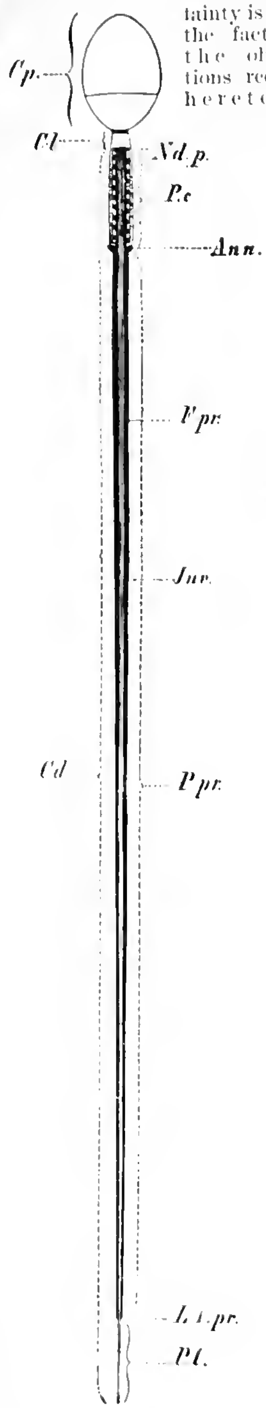
This uncertainty is due to the fact that the observations recorded heretofore lacked two essential points: they failed to show how the spermatozoa arise in the testis, and they failed to give any hint as to how the spermatozoa behave upon reaching the ovum. The first of these gaps was filled by a series of papers by Kölliker beginning in 1841, in which, besides describing the spermatozoa of a large number of species, largely invertebrate, he shows that they arise by the metamorphosis of cells in the tubules of the testis.

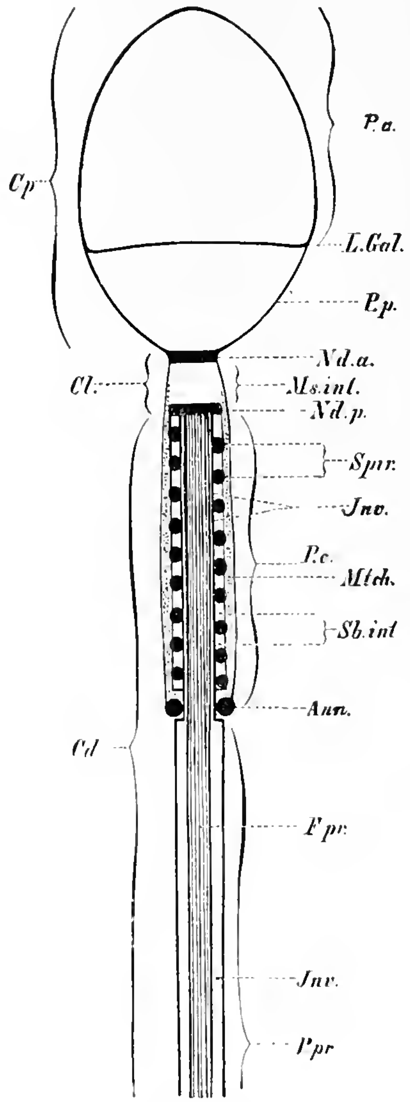
Although, according to J. A. Thomson, the union of spermatozoon and ovum was observed in the rabbit by Martin Barry, an Edinburgh medical student, in 1843, it really remained for



A B

FIG. 4341.—A Typical Human Spermatozoon. A, View of broad side; B, narrow side. Both show anterior and posterior part of head; neck with inner centrosome (in two parts); middle piece, main part of tail, and end piece. There is a dark spot in anterior part of head. Magnified about 3,000 diameters. (After Retzius.)





A B

FIG. 4342. Diagram of the Structure of the Human Spermatozoon. A, Whole; B, upper part more magnified. Cp, Head; Cl, neck; Cd, tail; P.c, middle piece; P.pr., main part of tail; P.t., end piece; P.a., and P.p., anterior and posterior parts of head; Nd.a., inner centrosome; Nd.p., anterior part of outer centrosome; Ann., annulus; Spir., spiral filament; Mtch., mitochondria; F.pr., axial filament; Jnv., involucrum. (After Meves, from Waldeyer.)

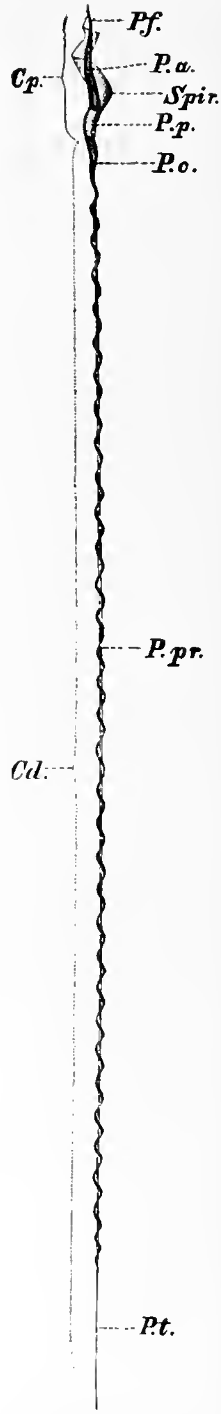


FIG. 4343.—Spermatozoon of a Bird, *Fringilla cœlebs*. Cp., Head; Pf., acrosome; P.a., anterior part; P.p., posterior part; Spir., spiral fold; Cd., tail; P.c., middle piece; P.pr., principal part; Pt., end piece. Highly magnified. (After Waldeyer.)

O. Hertwig to fill the second gap many years later (1875) from observations on starfish eggs. In this favorable material he was able to demonstrate that fertilization is effected by the entrance of one spermatozoon into the egg and the union of its nucleus with the egg nucleus. Thus two centuries, less two years, elapsed between the discovery of spermatozoa and the demonstration of the part played by them in the important function of reproduction. Even then the knowledge gained was very superficial. Much has been done during the past quarter-century toward gaining a deeper insight into the nature of the spermatozoon and the process of fertilization, but there is still an inner mystery into which our minds and our microscopes are equally unable to penetrate; and, while we may expect great progress in the future, it is probable that there will always be a limit beyond which the man of science must say, "I do not know" (see *Impregnation*).

Morphology.—There are as many forms of spermatozoa as there are species of animals. We may take as our type the spermatozoon of man, because of its intrinsic interest as well as on account of its relatively simple structure (Fig. 4341).

In the spermatozoa of vertebrates Waldeyer distinguishes three regions—the head, the neck, and the tail. The head of the human spermatozoon is flattened. The wider face is broadly oval or nearly elliptical (Fig. 4341, *A*). Viewed from the side, it is seen to be more flattened toward the apex, the proximal two-thirds being narrowly ovate (Fig. 4341, *B*). According to Meves, the head may be divided into two parts—anterior and posterior (*P.a.* and *P.p.*, Fig. 4342). The anterior part is covered with a thin protoplasmic cap extending to the line *L.Gal.*, Fig. 4342, *B*. From its staining reactions and its history the head, with the exception of the cap and a thin covering membrane, is known to be composed of the cell nucleus with its chromatin contents. The neck of the human spermatozoon is inconspicuous (*Cl.*, Fig. 4342). It is in all forms a short region joining the head and tail, and containing the anterior centrosome (*Nd.a.*, Fig. 4342, *B*) and the homogeneous material connecting it with the posterior centrosome (*Nd.p.*). The tail (*Cd.*, Fig. 4342) contains three parts—the middle piece, the principal part, and the end piece (*P.c.*, *P.pr.*, and *P.t.*, Fig. 4342, *A*). Throughout the length of the tail there extends an axial filament, which has been shown by maceration to be a bundle of extremely minute fibrils. The middle piece is about as long as the head and, according to Meves, has a rather remarkable structure. At its extremities are the two parts of the outer centrosome. The axial filament has its origin in the anterior part (*Nd.p.*, Fig. 4342) and passes through the posterior part, or annulus (*Ann.*, Fig. 4342). The axial filament is surrounded by an inner sheath. Outside of this is a spiral fibre lying in a clear substance. This is covered by a finely granular protoplasmic layer, the mitochondria. The principal part of the tail consists of the axial filament and a covering, the involucrum, which is probably continuous with the inner sheath of the middle piece. The end piece consists of axial filament alone.

Human spermatozoa are small compared to those of some other mammals, as will be seen by reference to the following table made from data given by Boston (1901):

SPERMATOZOA OF	Total length.*	Head.		Tail length.
		Length.	Width.	
Man	51–58	4–6	3–4	41–53
Dog (mastiff)	67–74	4–8	3–4	59–67
Rabbit	51–66	6–9	3–4	45–58
Horse	64–67	6–8	3–4	51–60
Bull	87–93	9	6	77–83
Sheep	83	9	6	74
Cat	58–74	6–7	3–5	53–66
Mouse	120–158	8–9	3–4	112–138
White rat	225–238	12–16	......	209–222
Guinea-pig	113–138	6–12	7–11	102–132

* All measurements are given in thousandths of a millimetre (μ).

Some of these figures differ considerably from those given by Waldeyer (1902, pp. 158, 159), and this is probably due to there being a large amount of individual variation among the spermatozoa from a single subject as well as variation in the types of spermatozoa produced by different males of the same species. Among the vertebrates the smallest spermatozoa are found in Amphioxus, 16 to 21 μ in length according to Sobotta, while the largest are produced by a European toad, *Discoglossus pictus*, the length, according to Spengel's measurements, being 2,000 μ = 2 mm.

The various forms of spermatozoa are classified by Waldeyer into two principal groups and several subdivisions as follows:

I. Spherospermia.
  1. Without appendages.
  2. With appendages.
II. Nematospermia.
  1. Without lateral membrane.
    (*a*) Head rounded.
    (*b*) Head elongated.
  2. With lateral membrane.
    (*a*) Head rounded.
    (*b*) Head elongated.

To the first group, spherospermia without appendages, belong the simple spermatozoa of the nematoda. For example, Ascaris has a simple conical spermatozoon without appendages of any kind.

Spherospermia with appendages are characteristic of the decapod crustacea—the lobsters, crabs, and their allies. They present a great variety of form. There is generally a more or less rounded body with several or many spine-like projections.

The human spermatozoa belong to the group of nematospermia without lateral membrane and with rounded head. These have been sufficiently described above. In the simple spermatozoa of a medusa, Aurelia, we find an elongated head tipped with a sharp point, or *acrosome*. In some of the more complicated spermatozoa the head is very much elongated and the long sharp acrosome is provided with a barb like a minute harpoon. The lateral membrane is a fin-like fold lying on one side of the tail and it usually shows undulating movements. At its margin it encloses a fibre made up of fibrillæ, like the axial fibre. This form of spermatozoa is especially characteristic of the tailed amphibia.

Besides the normal spermatozoa there have been found in many species abnormal forms—giant spermatozoa, worm-like, double ones, etc. Some of these forms are clearly pathological, but in other cases there may be a normal dimorphism.

Early Development.—The course of development of spermatozoa is identical with that of the ova up to the time of the differentiation of the gonads (see *Ovum* and *Reduction Division*).

Confining our attention for the present to the vertebrates—the rudiment of the testis, like that of the ovary, is a genital ridge lying upon the Wolffian body, and continuous with the peritoneum of the upper part of the body cavity. The seminiferous tubules are formed from strands of cells that grow into the stroma from the thickened epithelium of the genital ridge. According to B. M. Allen, these strands are homologous with the medullary cords of the ovary (see *Ovum*). They subsequently acquire a lumen, and become connected with the rete tubules, which in turn connect with the vas deferens.

The young seminiferous tubules contain two kinds of cells—large, clear, spherical germ-cells, or *archispermiocytes*, with large, round, darkly staining nucleus; and between them *epithelial cells*.

There is no further change until the advent of sexual maturity; then the process of spermatogenesis begins (Fig. 4344.) The archispermiocytes divide, one daughter cell of each pair remaining deep in the epithelium as a reserve germ cell (*spg. r.*, Fig. 4345), while the other changes somewhat in appearance and becomes a *spermatogonium*. The spermatogonia divide a number of times (*spgm.*, Fig. 4345) and finally produce a generation of *primary spermatocytes* (*spc.a*, Fig. 4345). These pass through the characteristic stages of synapsis and growth (*spc.g.* and *spc.i.*, Figs. 4346 and 4347). Finally, each

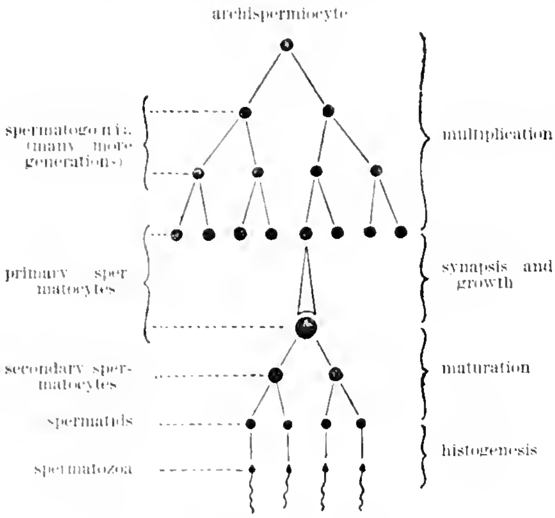


FIG. 4344.—Diagram showing the Genesis of the Spermatozoa. (Modified from Boveri.)

primary spermatocyte divides to form two secondary spermatocytes, and each of these in turn divides, giving rise to two spermatids (*spd*, Fig. 4345). During the divisions the process of maturation takes place (see *Reduction Division*).

In the mean time the epithelial cells have been undergoing a transformation into the peculiar "*cellule ramificate*" first observed by Sertoli in 1865. The cytoplasm of these cells is naked and extends in amœboid fashion among the germ-cells toward the lumen of the tubule. After the last maturation division the spermatids (*spd*, Fig. 4345) become united with the protoplasmic processes of the Sertoli cells (*symphoresis*, Waldeyer), and remain in this connection throughout the period of histogenesis. When the spermatozoa are fully developed they are released, and the Sertoli cell becomes connected with a new set of spermatids (Fig. 4345).

This peculiar condition in the vertebrate testis has caused much confusion in the past and has led to erroneous theories as to the nature of the spermatozoa. Although Sertoli regarded the cells which bear his name as nutritive cells, von Ebner in 1871 called them "spermatoblasts" and regarded them as directly concerned in the production of spermatozoa. In this view von Ebner had many followers. The correct theory was advanced by H. H. Brown in 1885 and by Benda in 1887, and in 1888 von Ebner corrected his error and added much to the knowledge of the Sertoli cells.

Another cause of confusion in the study of spermatogenesis in the vertebrates is that before one cycle of development is completed in any part of a seminiferous tubule another begins. In the bull the spermatogenesis is a continuous process and in sections of the testis of an adult individual four stages will be found in the wall of each tubule (Figs. 4345 to 4347), but in order to follow the consecutive stages a number of sections must be examined.

The nuclear changes leading to the formation of the spermatids have been described sufficiently in another article (*Reduction Division*), and we will pass directly to the consideration of the process by which the spermatid becomes a spermatozoon, confining our attention entirely to the vertebrates and making the description as general as possible.

Histogenesis.—After the division of the secondary spermatocyte the nucleus of the young spermatid acquires a nuclear membrane and passes into the resting condition with a chromatin reticulum. The centrosome moves from its original position and divides into two, either completely or incompletely, forming a minute dumb-bell-shaped structure. In its new position the outer part lies close against the cell wall, while the inner part is directed toward the nucleus. The "sphere" of denser protoplasm that collects around the centrosome after earlier cell divisions now forms independently of the centrosomes and is called the *idiosome* (*s*, Fig. 4348).

The fate of the various parts of the cell in the development of the spermatozoon is summarized by Waldeyer as follows: Out of the chromatin of the nucleus is developed the head of the spermatozoon; a part of the idiosome forms the acrosome; the centrosome takes part in the formation of the neck, the middle piece, and the axial filament; the cytoplasm gives rise chiefly to the axial filament, its mitochondria forms the spiral structures, and it takes part in the formation of the envelope of the tail.

The nucleus first moves from its originally central

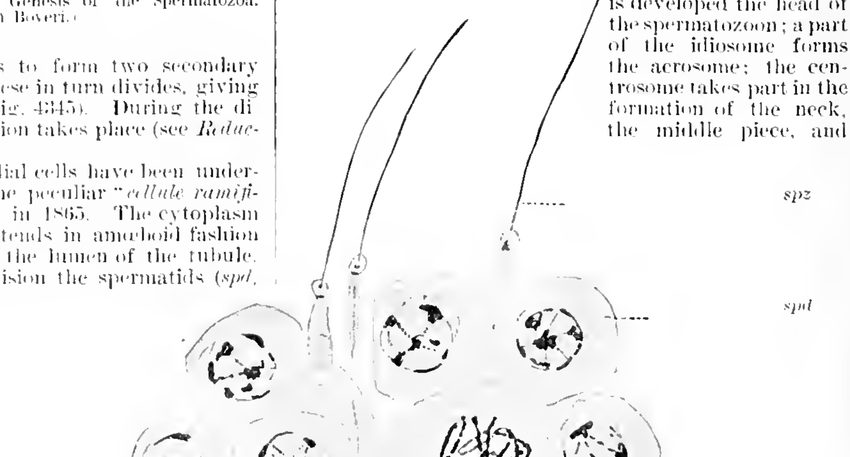


FIG. 4345. Part of Section of Testis of a Bull, showing Stages in Spermatogenesis. *c.s.*, Sertoli cell; *spg.r.*, reserve spermatogonium; *spg.m*, spermatogonia in mitosis; *spc.a.*, first stage in development of spermatocyte; *spc.i*, spermatocyte in later stage; *spd*, newly formed spermatid just after the last maturation division; *spz*, nearly ripe spermatozoon, separated from Sertoli cell. Highly magnified. (After Schoenfeld.)

position to the periphery of the cell opposite the centrosomes. Its chromatin network becomes gradually finer and more condensed until it forms an apparently homogeneous mass; at the same time the nucleus becomes smaller and gradually assumes its definitive shape.

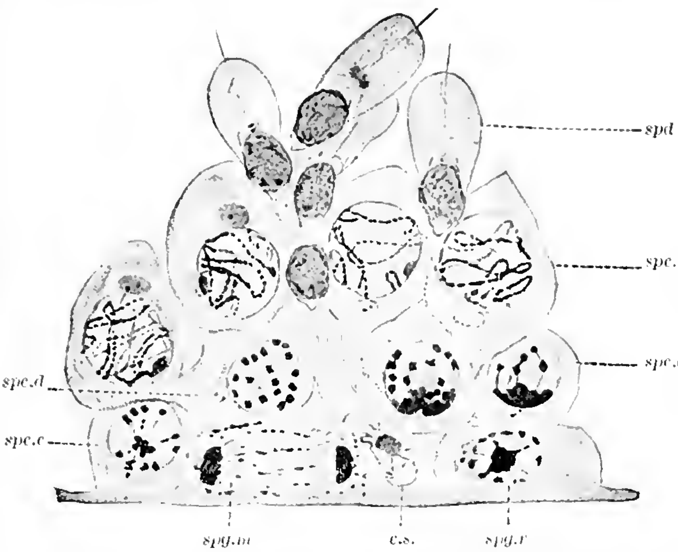


FIG. 4346.—Another Section of the Testis of a Bull. *spg.m*, Reserve spermatogonium in mitosis; *spc.c*, *d*, and *e*, spermatocytes in stages preliminary to synapsis; *spc. i*, advanced primary spermatocyte, growth nearly completed; *spd*, spermatid attached to Sertoli cell (*c.s.*) and undergoing histogenesis. Highly magnified. (After Schoenfeld.)

In the mean time a part of the idiosome, often containing a vacuole, becomes attached to the nuclear membrane and moves around the nucleus to take its position at the apex and becomes the acrosome (Figs. 4348 and 4350).

The outer centrosome becomes disc-shaped, and at a very early stage there grows out from the centre of the disc, or in close connection with it, a very fine filament, the rudiment of the axial filament of the tail (*ax*, Fig. 4348). The development of the tail, as remarked by von Ebner, is one of the most difficult problems of histogenesis. It is described variously by different authors for the same or closely related forms, and the course of development appears to differ considerably in the two groups of vertebrates in which it has been most carefully studied—the amphibia and the mammals. All agree, however, that very soon the periphery of the outer centrosome becomes separated from the axial filament and forms a ring surrounding it. In the amphibia (Fig. 4350) the axial filament appears to remain connected with the inner centrosome, while in the mammalia (Fig. 4348) the inner centrosome is free and the central part of the outer centrosome forms the end knob of the axial filament. In the mean time the whole apparatus has been moving toward the nucleus. The inner centrosome becomes attached to the nucleus and marks the position of the future neck. The central part of the outer centrosome with the axial filament follows, but in the mammals does not quite reach the same point, while the ring remains at or near the cell wall. The axial filament has been growing meanwhile and now consists of two parts, one within the cell and the other outside. The intracellular part will form the axis of the middle piece, and the outer part, the axis of the main part and the end piece of the tail. The material for the growth of the filament is probably furnished by the cytoplasm. The fate of the ring centrosome differs in the two groups. In the mammalia it remains intact and becomes the annulus at the distal end of the middle piece (Fig. 4349). In the amphibia part of it stretches out along the axial filament and gives rise in connection with the cytoplasm to the envelope of the main part of the tail. In the mammalia this part of the tail appears to be formed by differentiation of the surface of the axial filament.

As the spermatozoon begins to take shape the main part of the cytoplasm draws backward, leaving only a thin membrane on the head, and the mass of cytoplasm lies in the position of the middle piece (*cy*, Fig. 4349). Scattered thickly through the cytoplasm are fine granules with charcteristic staining qualities, the mitochondria, supposed to have been furnished by the Sertoli cell. The spiral filament is formed by the concentration and fusion of this material.

In the mammalia and some other forms there is more cytoplasm than can be used in the development of the spermatozoon. This part begins to undergo degenerative changes, and at the same time is gradually constricted off from the middle piece (*cy*, Fig. 4349 *F*). The cytoplasmic remnants may remain attached to the Sertoli cell for a time after the spermatozoa have moved away.

After leaving the testis the spermatozoa undergo a further "ripen-

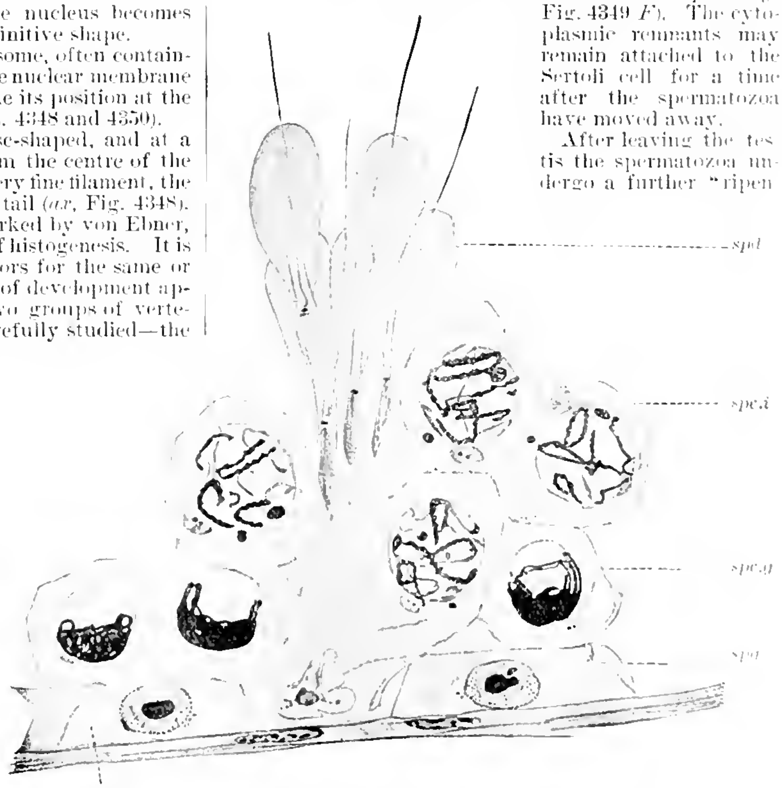


FIG. 4347. Later Stages in Spermatogenesis of the Bull. *spg.r*, Reserve spermatogonium; *spg*, spermatogonium; *spc.g*, spermatocyte in late synapsis stage; *spc.i*, spermatocyte in stage just preceding the maturation divisions; *spd*, spermatids in advanced stage of histogenesis, with heads deeply embedded in Sertoli cell. Highly magnified. (After Schoenfeld.)

ing" process, which consists chiefly in the completion of the outer envelope of the middle piece and the smoothing off of any projections or irregularities that may have remained after separation from the Sertoli cells.

It will be seen from this brief review of the development of spermatozoa that there can be no further question as to the character of these bodies. Each one contains all the essential elements of a cell.

Robert Payne Bigelow.

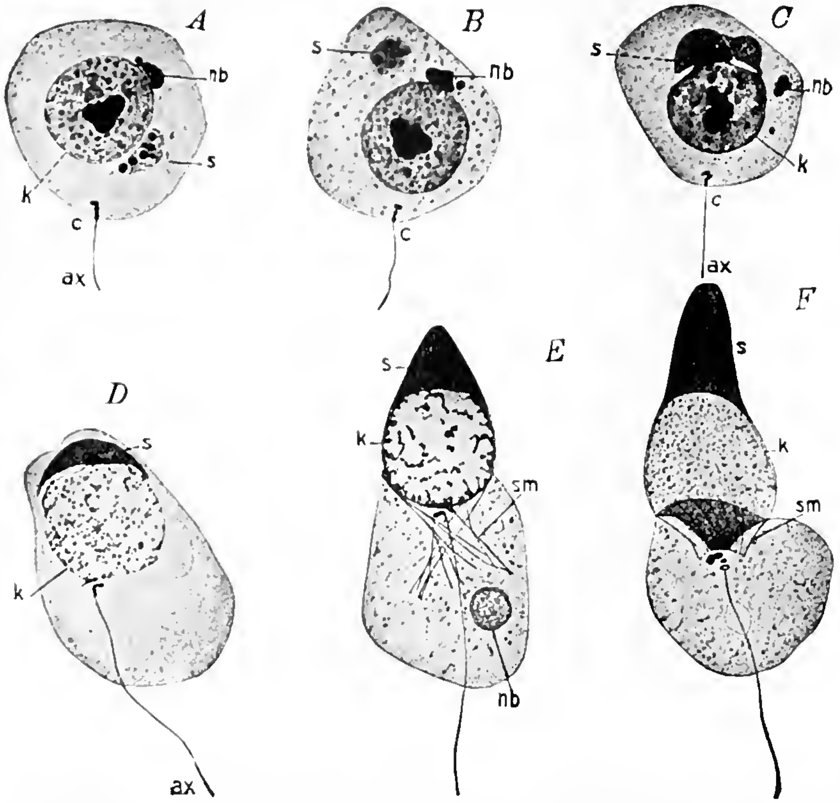


FIG. 4348. Spermatids of the Guinea-pig, *Cavia cobaya*, in Various Stages of Metamorphosis. *k*, Nucleus; *s*, sphere; *c*, centrosome; *ax*, axial filament. Highly magnified. (After Meves, from Korschelt and Heider.)

BIBLIOGRAPHICAL REFERENCES.

Allen, B. M.: The Embryonic Development of the Ovary and Testis of the Mammalia. Biol. Bulletin, vol. v., 1903, pp. 55-62.

Boston, L. N.: Spermatozoa of Man, Domestic Animals, and Rodents. Journ. Applied Micros., vol. iv., 1901, pp. 1360-1365.

Hensen: Physiologie der Zeugung. Hermann's Handbuch der Physiologie, vol. vi.

Kölliker, A.: Beiträge zur Kenntniss der Geschlechtsverhältnisse und die Samenflüssigkeit wirbellosen Thiere, Berlin, 1841. —Handbuch der Gewebelehre des Menschen, ed. 6 by V. von Ebner., vol. iii., 1902, pp. 402-455.

Korschelt, E., and Heider, K.: Lehrbuch der vergleichenden Entwickelungsgeschichte der wirbellosen Thiere, Allgemeiner Theil., 1902, pp. 397-538.

Löw, O.: Die Chemotaxis der Spermatozoen im weiblichen Genital-tract. Sitzber. d. k. Akad. d. Wiss., Wien, 1902.

McGregor, J. H.: Spermatogenesis of Amphiuma. Journ. Morph., vol. xv., suppl., 1899, pp. 57-104.

Meves, F.: Struktur und Histogenese der Spermien. Ergeb. d. Anat. u. Entw., vol. xi., 1902, pp. 437-508.

Prévost et Dumas: Nouvelle théorie de la generation. Observations relatives à l'appareil générateur des animaux mâles; Histoire et description des animalcules spermatique. Annales des Sciences Naturelles, vol. i., 1824, pp. 1-28, 167-186, and 274-292.—Deuxième mémoire sur la génération. Rapport de l'œuf avec la liqueur fécondante. *Loc. cit.*, vol. ii., 1824, pp. 100-120, 129-148.

Retzius, G.: Weitere Beiträge zur Kenntniss der Spermien des Menschen einige Saugethiere. Biol. Untersuch., N. F., vol. x., 1902, pp. 45-60.

Schoenfeld, H.: La spermatogénèse chez le taureau. Arch. de Biol., vol. xviii., 1901, pp. 1-72.

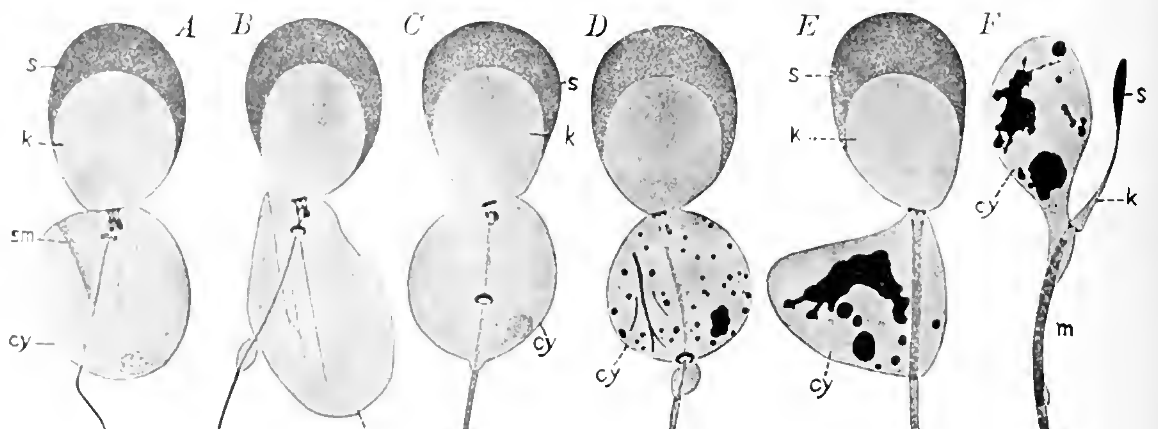


FIG. 4349. Later Stages in the Metamorphosis of the Spermatids of the Guinea-pig. *A–E*, views of broad side; *F*, narrow side. *cy*, Cytoplasm; *m*, middle piece. Other lettering same as in Fig. 4348. Highly magnified. (After Meves, from Korschelt and Heider.)

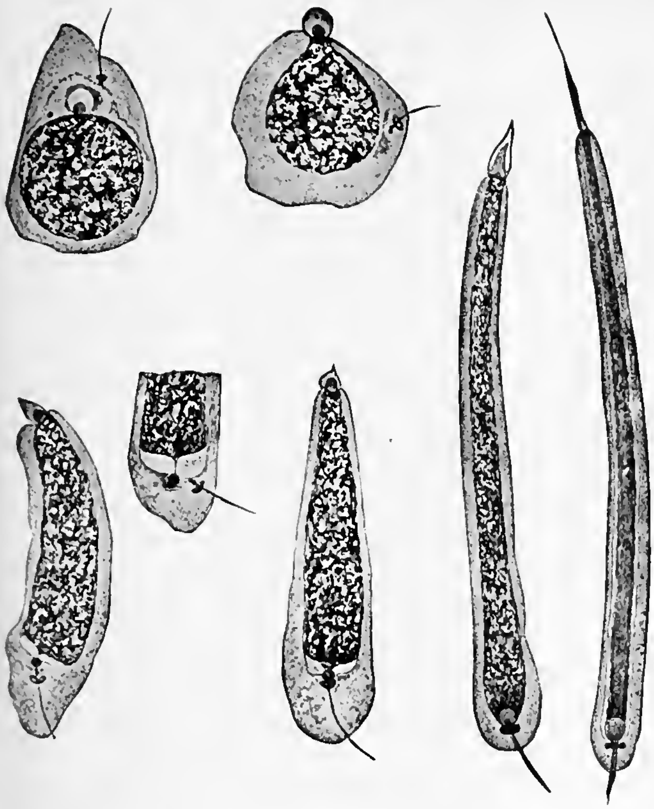


FIG. 4350.—Various Stages in the Metamorphosis of the Spermatids of Amphiuma. Highly magnified. (After McGregor.)

Spallanzani: Expériences pour servir à l'histoire de la génération des animaux et des plantes, Geneve, 1785.
Wagner, R., and Leuckart, R.: Semen. Todd's Cyclopædia, vol. iv., Pt. i., 1847–49, pp. 472–508.
Waldeyer, W.: Die Geschlechtszellen. Hertwig's Handbuch der Entwickelungslehre der Wirbeltiere, vol. i., 1901–3, pp. 86–220, 399–412, 429–447.

SPHACELUS. See *Gangrene*.

SPHYGMOGRAPHY.—Sphygmography (Gr., σφυγμός, the pulse; γράφειν, to write), strictly interpreted, is the art of taking pulse tracings. The present article will deal not only with the art of recording the arterial and the venous pulse, but also with the graphic method as

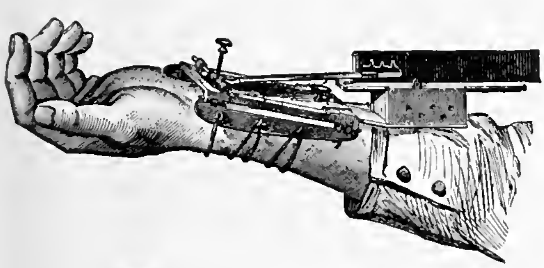


FIG. 4351.—Marey's Sphygmograph (new form).

applied to the heart (cardiography). The instruments employed for these purposes are of many types, but the principles involved can be made sufficiently clear by a few examples. Two essentials are common to all of them, a recording surface and a writing lever or pen. The recording surface is usually smoked paper set in motion by clock-work. The writing lever may be directly applied to the pulse or connected with it by a rigid or jointed support, in which case we speak of *direct sphygmography;* or the move-

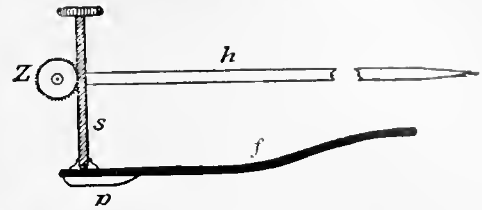


FIG. 4352.—Diagram of Connections in Marey's Sphygmograph.

ments to be recorded may be carried to the lever by air transmission, constituting *indirect sphygmography.*

DIRECT SPHYGMOGRAPHY.—Two examples of direct sphygmography will be given as represented in the instruments of Marey and of Dudgeon.

In *Marey's sphygmograph* (Figs. 4351 and 4352) the button *p* is pressed down upon the artery by the spring *f*. The screw *s* is connected with the button by a joint and rests against a cog-wheel *Z*, which is on the axis of the writing lever *h*. The thread of the screw catches in the teeth of the cog-wheel so that when the button is lifted by the pulse it raises the screw so as to turn the wheel and elevate the lever. At one end of the instrument there is a clock-work which moves a metal frame carrying a strip of smoked paper. The screw, which may be seen in Fig. 4351 under the centre of the writing lever, regulates the pressure of the button on the pulse.

In using the instrument, a strip of smooth paper is cut to fit the frame and smoked over a piece of burning camphor, a lamp burning without a chimney, or a tallow candle. The position of the

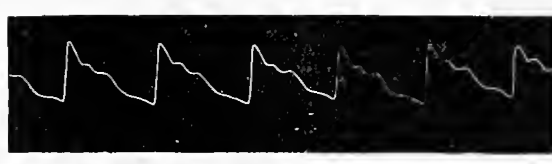


FIG. 4353.—Sphygmogram taken with Marey's Sphygmograph.

radial artery is determined and the point where the pulsation is best felt is noted. The instrument is then

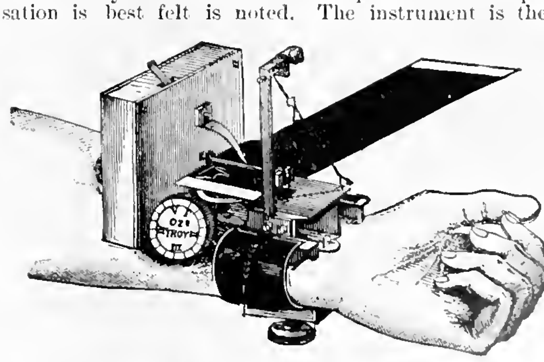


FIG. 4354.—Dudgeon's Sphygmograph.

bound to the arm, as shown in the figure, with the button on the point selected. The clock-work is wound up. The pressure of the button is regulated by the screw provided for the purpose, so that a suitable excursion of the lever is obtained with each pulse. It is usually wise to be satisfied with a moderate excursion of the lever, as with a maximum movement there is more inertia and the tracing may not represent the actual pulse so accurately. The lever can be brought to write at a proper level on the paper by turning the screw *s*. Care must be taken that the writing point of the lever is in contact with the paper but not pressing too heavily.

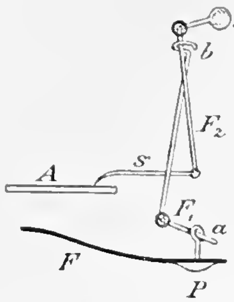


FIG. 4355.—Diagram of Connections in Dudgeon's Sphygmograph.

If the hand is steady and everything seems right, the clock-work may now be set in motion and the tracing taken. The tracing is removed from the frame and anything desired, such as the patient's name, the date, and the pulse rate, scratched upon it with a pin or other sharp instrument. Finally, it is to be fixed by dipping it in a suitable varnish. The writer uses a solution of shellac in methylated spirits with a little glycerin added to prevent the tracing being too brittle. Others use negative varnish, such as is employed by photographers, and yet others friars' balsam. A sample of the result obtained with Marey's sphygmograph is shown in Fig. 4353. For the interpretation, see the article on *Pulse*.

Dudgeon's sphygmograph (Fig. 4354) has the advantage over Marey's of being more compact and having a simpler arrangement for connecting the smoked paper with

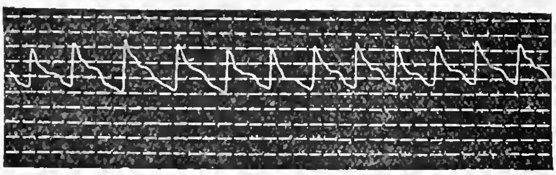


FIG. 4356. Sphygmogram taken with Richardson's Sphygmograph.

the clock-work. The arrangement of the levers is shown in Fig. 4355. This instrument is applied to the wrist in much the same way as Marey's. The pressure of the button on the pulse is regulated partly by the tightness of the band around the wrist, and partly by turning the wheel marked *oz troy*, which regulates the pressure of the spring.

Richardson's sphygmograph is a modification of Dudgeon's, which is preferred to it by some. In Richardson's modification the pressure is regulated by a movable weight, and the rollers which move the paper are supplied with teeth which mark broken horizontal lines upon the tracing. An example of a tracing taken with Richardson's sphygmograph is shown in Fig. 4356. Dudgeon's sphygmograph is the one to which the writer is most accustomed, and he finds it very satisfactory. It is compact, simple, and moderate-priced.

In the more elaborate sphygmographs of von Jacquet and of Frey there are arrangements for recording the time, and von Jacquet's permits of varying the rate at which the paper moves. There are often more disadvantages than advantages, however, in having too complicated an instrument.

INDIRECT SPHYGMOGRAPHY.—This is where the pulse is brought to bear upon a writing lever some distance away by transmission

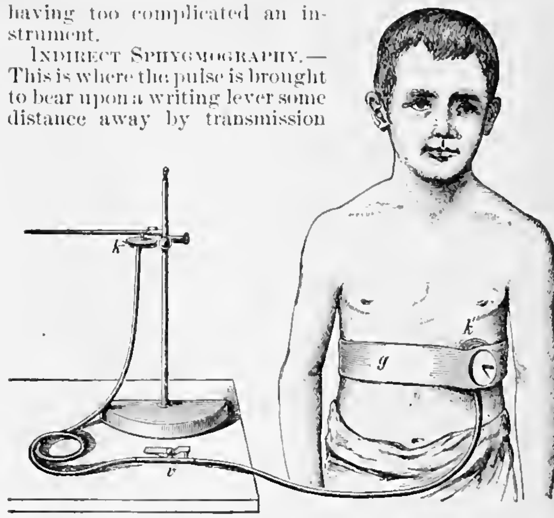


FIG. 4357.—The Cardiograph Applied.

of the changes in pressure through a rubber tube. By this method events occurring at different parts of the body may be made to record themselves one under the other on the same paper. It is well adapted for obtaining tracings of the cardiac impulse and of the carotid and jugular pulses.

For the recording surface a kymograph is required. This is the principal disadvantage of the method, for kymographs are usually large and not very portable. The arrangement of the apparatus for receiving and transmitting the cardiac impulse is shown in Fig. 4357. The essential parts of the apparatus are a receiving tambour, a connecting tube, and a recording tambour. A receiving tambour for the cardiac impulse is known as a *cardiograph*, and an example is shown in Fig. 4358. *k* is a shallow metal box or tambour covered with rubber membrane and bearing a button, *p*, to press

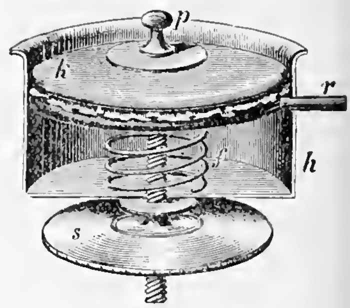


FIG. 4358.—Marey's Cardiograph.

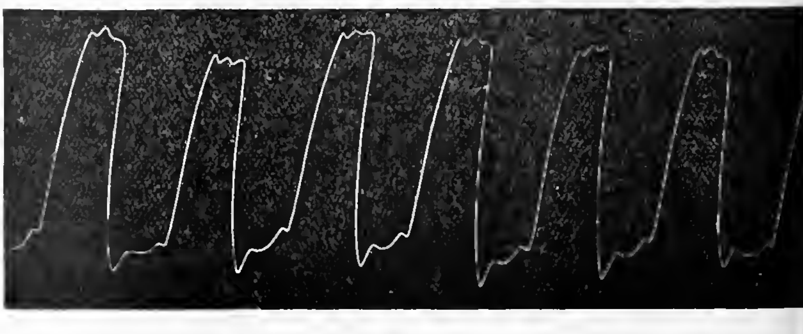


FIG. 4359.—Apex-beat Tracing from Man.

upon the point where the impulse is felt; *r* is a tube opening into the tambour and of a suitable size for the attachment of the connecting rubber tubing. The surrounding outer box, spring, and screw are for regulating the pressure exerted by the button on the skin. The recording tambour (k^2, Fig. 4357) is a similar metal box covered with rubber membrane. Resting upon the centre of the membrane is a support which raises the writing lever when air is driven over from the receiving tambour, k^1. In applying the cardiograph to the heart care must be taken to adjust the button exactly on the apex beat, as an inch or two nearer the middle line the chest wall may recede during the systole instead of being pressed outward, and the tracing obtained would be difficult to interpret. A tracing of the cardiac impulse is shown in Fig. 4359.

A modification of the cardiograph has been made for application to the carotid arteries (Fig. 4360), but for this purpose and also for the venous pulse an ordinary or cup-shaped funnel of suitable size usually suffices.

FIG. 4360.—Receiving Tambour for Carotid Pulse. (Hürthle.)

A small portable kymograph with recording apparatus for two simultaneous tracings is shown in Fig. 4361. The peculiarly shaped receiver *D* is for applying over the edge of the liver to obtain a tracing of the liver pulse.

COMBINED DIRECT AND INDIRECT SPHYGMOGRAPHY.—James Mackenzie has devised an arrangement which he calls "*the clinical polygraph*" (Fig. 4362). In this a recording tambour is attached to a Dudgeon's sphygmograph in such a way that while the radial pulse is being recorded in the ordinary way by direct sphygmography, a tracing of the carotid or jugular pulse or of the apex beat can be recorded over it on the same strip of paper by air transmission. This is a very portable apparatus and is quite delicate enough for obtaining venous pulse tracings. The writer uses an instrument improvised by

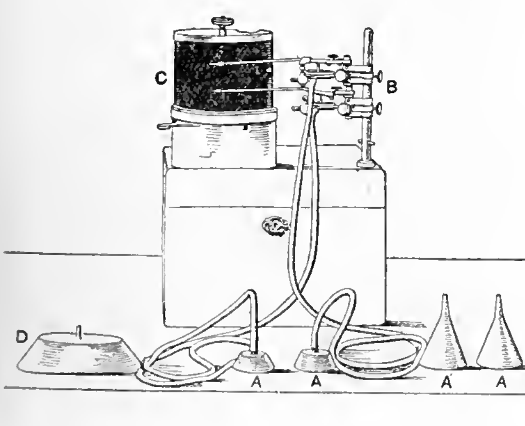


FIG. 4361.—Knoll's Polygraph with Receivers. (Mackenzie.)

himself and his laboratory assistant, but based on Mackenzie's model; with it he took most of the simultaneous tracings figured in the article on *Pulse*. Fig. 4363 shows an example of the radial and external jugular pulses taken simultaneously with this apparatus in a case of dilated heart without valvular lesion. In two of the curves simultaneous points are marked by vertical lines. These points are marked as follows: Before start-

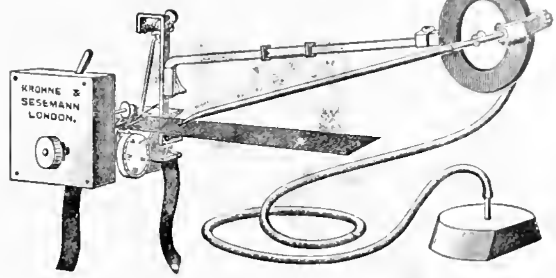


FIG. 4362. The Clinical Polygraph. (Mackenzie.)

ing the paper the two writing levers are allowed to mark vertical lines (× ×, Fig. 4363), to show the relative position of the writing levers. Points on the two tracings equidistant from these vertical lines correspond in time and may be measured off to any desired number. In taking venous tracings the writer usually selects the external jugular, but Mackenzie prefers the internal. The

FIG. 4363.—Simultaneous Tracing of Radial and Jugular Pulses taken by the Combined Method. Jugular above, radial below.

receiving funnel is held over the vein by hand, the amount of pressure required being learned by practice.

A figure illustrating the method of taking the volume pulse (plethsymography) is given in the article on *Circulation*. For further examples of pulse tracings and their interpretation, see article on *Pulse*.

References.—In preparing this article use has been made of the following books: O. Langendorff's "Physiologische Graphik," F. Shenk's "Physiologisches Practicum," James Mackenzie's "Study of the Pulse," T. G. Brodie's "Experimental Physiology," Hutchinson and Rainy's "Clinical Methods," and the catalogues of Baird and Tatlock, London, and Eugen Albrecht, Tübingen.

William S. Morrow.

SPINA BIFIDA.—PATHOLOGY.—Two congenital malformations of the spine, rachischisis and spina bifida are so closely related that they should be considered together. While both are characterized by a deficient formation of the arches of the vertebræ, they differ in the degree of development attained by the spinal cord. In rachischisis it is so rudimentary that even the central canal of the cord has not formed and the endothelium which should line it is exposed as a transparent membrane on the back, through which is seen a flat red area consisting of vascular nerve and connective tissues representing nature's abortive attempt to grow a spinal cord without any axis or "anlage." When the whole cord is involved it is spoken of as rachischisis totalis, amyelia, or absence of the cord; when only a part, partial rachischisis. In spina bifida the cord more nearly approaches its proper development. A hernia like sac of fluid protrudes through the cleft laminæ of the vertebræ; it may or may not contain the cord, spinal roots, and nerves

Rachischisis and spina bifida have their counterpart in the skull and brain: total rachischisis, or amyelia, in cranioschisis or anencephalus, partial rachischisis in derencephalus; the three varieties of spina bifida, me-

FIG. 4364.—Anencephalus with Total Rachischisis. Showing the short neck, upturned face, and dark area medullo-vasculosa in the centre of back; also the area epitheloidea on each side and the mane-like growth of fine hairs.

ningomyelocele, myelocystocele, and spinal meningocele in hydrencephalocele, encephalocele, and meningocele. Furthermore, they are frequently associated and are to be classed as defects of the central nervous system due to arrest of development or persistence of early embryonic conditions, combined with distention of certain cavities with cerebro-spinal fluid.

To better understand the condition spoken of as rachischisis, let us turn to the normal development of the central nervous system in the embryo. The earliest embryonic appearance of the central nervous system is a thickening of the ectoderm in front of the primitive furrow. This thickened area soon bears a longitudinal furrow of its own, which grows rapidly in length while the primitive furrow disappears, and the walls of the furrow grow together on the surface, forming a closed tube, which, however, retains for a long time a direct communication at its posterior end with the cavity of the intestine, while its anterior end expands to form the primitive cerebral vesicles of the rudimentary brain. This embryonic structure is not to be the future cord and brain, but represents the little central canal of the cord and the cerebral vesicles; the real elements of the spinal cord and brain grow around it as an axis. The walls of the neural furrow first coalesce to form a closed tube in what becomes the upper dorsal cord; hence that part is always a little in advance of the rest in its development, and malformations are rarer there than in any other part of the spine. The central canal forms very early. It exists as a closed tube in minute embryos less than one-eighth inch in total length, which, according to the tables of Mall represent about the twelfth day. The beginnings of the vertebral bodies appear later and the arches of the vertebræ still later, so that they project only a short distance from the sides of the vertebral bodies at the end of eight weeks, and it is four weeks more before they unite to enclose the dorsal section of the cord, which is also the first part of the spinal canal to close in.

Fig. 4364 is a photograph of the back of a rachischisic and anencephalic child at term. The cranial vault is wanting, and both the base of the skull and the middle of the back expose an irregular band of dark red, glistening, moist tissue looking like mucous membrane, the area medullo-vasculosa. External to this on each side is a glistening smooth membranous space, the area epitheloidea, merging in turn into normal skin. Outside of this again are a series of small elevations caused by the ends of the cleft arches protruding under the skin, and along this line a band of long, fine, silky hairs grow like a divided mane, extending from the forehead halfway down the back. The back and neck together are very short, the face is turned upward like a frog's, the ears rest on the shoulders, the eyes protrude. A median longitudinal section (Fig. 4365) shows the absence of both spinous processes and spinal cord and an abnormal curve of the cervical spine, which explains the frog-like position of the head on the shoulders. That this position is due to the condition of the spine rather than to deformity of the skull is shown by Fig. 4366, the skeleton of a rachischisic with abnormal cervical curve and a well-developed cranium, whereas Fig. 4367, a median

FIG. 4365. Longitudinal Section through Eight-months' Fœtus with Total Rachischisis. Showing abnormal curves of spine.

section through a fœtus with simple anencephalus, is without abnormal curves of the spine and the position of the head is normal. The study of twenty skeletons of rachischisics in the Warren Medical Museum, Boston, shows that both antero-posterior and lateral spinal curvatures are very common. The cleft in the spine is both wide and long. It is symmetrical, due to absence of the spinous process and of both laminæ; sometimes the transverse processes are unformed. Occasionally the bodies are cleft as well as the arches, so that there is both an anterior and a posterior split in the spine. The halves of the divided spine separate from each other, to unite below the cleft (Fig. 4368). Absence of a vertebra is not uncommon; also segmentation of one or more vertebral bodies, or absence of ribs; deformities of the thorax are common.

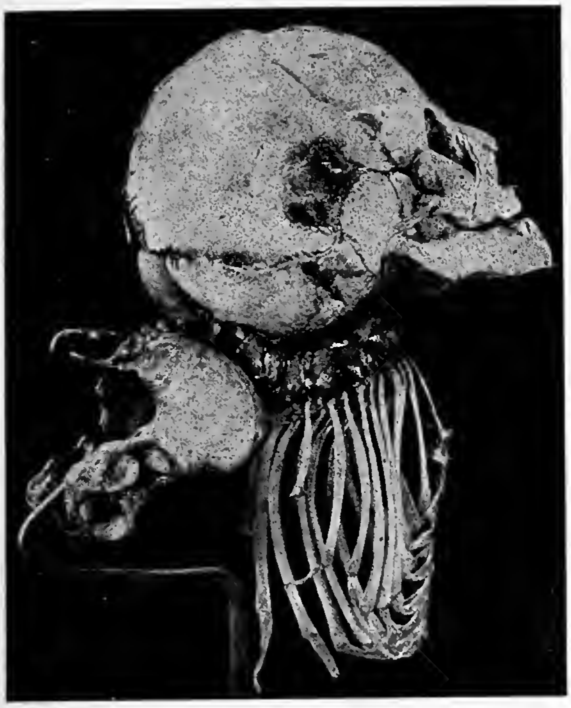


FIG. 4366.—Rachischisis with Great Shortening and Abnormal Antero-posterior Curvatures. Skull well developed. (Warren Museum.)

Partial or incomplete rachischisis may involve any number of vertebræ, from five up, in any part of the spine. Von Recklinghausen (in *Virchow's Archiv für Pathologie*, vol. cv.) describes the appearance of the back. There is absence of skin in a circular area in the median line of the back containing a central dark red area medullo-vasculosa, surrounded by thin glistening membrane which merges into true skin; two dimples, one at the upper and one at the lower part of the area medullo-vasculosa, called cephalic and caudal poles, mark the points where the central canal of the cord commences to be a tube above and below, and a bristle may often be passed into its lumen. Not infrequently a collection of fluid in the meshes of the pia raises this area on the top of a slightly projecting cyst. The appearance is then much like that of a spina bifida.

No surgical procedure has been performed for rachischisis. Most are still-born or die at birth, the rest a few hours after, although a recent case at the Infant's Hospital, Boston, lived eight days, and it is possible that some remain alive longer.

Spina bifida was first correctly described by Nicolai Tulpius, of Amsterdam, in 1685—a congenital malformation consisting of a cleft of the arches of the vertebræ and a sac containing fluid protruding on the back; very rarely there may be a cleft in the bodies of the vertebræ as well as in the arches. The Clinical Society of London in 1885 appointed a special committee to tabulate all the cases recorded in literature, all London hospital records and museum specimens, and incidentally to report on the best method of treatment. Their classification of the different forms of spina bifida is based upon the gross pathological appearances of museum specimens. It divides them into three varieties, according to the position of the fluid: first variety, fluid external to pia mater of cord; second variety, fluid contained in dilated cavities of pia-arachnoid; third variety, fluid within the cord itself in the dilated central canal. The first condition is named spinal meningocele, the second meningomyelocele, and the third myelocystocele. Then there are mixed forms in which a cyst of the cord is associated with one of the other varieties of spina bifida, called by Recklinghausen myelocystomeningocele. They constitute a fourth variety.

Spinal meningoceles represent a fairly large proportion of all cases of spina bifida, but different writers vary in their estimates. This is due to the scarcity of museum specimens, for unlike the other forms the death rate from operation is very low in this variety. The sac is usually large and always globular, either entirely covered with skin or with a relatively small membranous portion on top, while the pedicle is constricted and slender. Such sacs most frequently come in the lumbo-sacral or sacral region, are uncommon in the cervical and lumbar spine, and are rare in the dorsal region. The cleft is always small, involving only one or two vertebræ, is situated a little to one side of the median line, and the pedicle of the sac may even escape through a deficiency of the ligaments between well-formed arches of adjacent vertebræ. On opening it, a loop of cord or nerves may be found lying in the neck of the sac. Clinically the absence of subdivisions and of large nerves may be demonstrated by applying the hydroscope to the sac in the same manner as one would apply it in a case of hydrocele. The skin surrounding the base of the sac is usually covered with a growth of silky hairs.

FIG. 4367.—Longitudinal Section through Anencephalic Fœtus. Showing almost normal spinal curves.

Myelomeningoceles.—These are common in the lower segments of the spine, less common in the dorsal, and very rare in the cervical region. The cleft is large, involving the arches of four, five, six, or even seven vertebræ. The sac, therefore, has a wide base, and as it is usually subdivided by partitions into a number of chambers it has an irregular, more or less flattened contour. The external covering consists of both skin and membrane, but the summit and a considerable part of the walls are membranous. The skin about the base is hairy and often too thin and poor to make good flaps in operating. The sac contains cerebro-spinal fluid, spinal roots, spinal nerves, and the cord itself, except in a few cases in which the cauda equina alone enters. Sometimes the cord runs through without attaching itself to the sac; usually it is attached. The attachment shows externally as an umbilication of the summit, and was first described by Virchow in 1863. Internally the cord is greatly deformed and spreads itself out on the top of the sac, becoming indistinguishable from it save for the nerve roots that spring from it and traverse the cavity in long loops to reach their respective intervertebral foramina. This appearance is shown in Fig. 4371, where the sac has been opened by a vertical median incision. The nerve roots and nerves show plainly, unless there are numerous subdividing cross walls, as in Fig. 4372, which, however, is not uncommon. The nerves are seldom normal in appearance, at times they are very thin, and at other times very thick, translucent, red, and semitransparent from œdema; this swollen condition often corresponds to an absence of axis cylinders and explains paralysis. Clinically, myelomeningocele may be differentiated from simple meningocele by the shape of the tumor, the broad base, and irregular form, if umbilicated resembling a tomato, and the largely membranous covering; the presence of the cord, of nerves, and of septa may be inferred from shadows seen by examining the sac with the hydroscope, also by applying with a small electrode a mild faradic current to different points on the surface of the sac. On the summit, often close to the umbilication, one frequently finds superficial ulcers with a granulating base either round or irregular in contour, the appearance is suggestive of partial rachischisis, and it has been thought that the ulcer, which often corresponds to the attachment of the cord, is in reality an area medullo-vasculosa. The author has recently studied four such cases, but ... is unable to demonstrate on any of them the presence of the cephalic or caudal dimple of Recklinghausen.

FIG. 4368.—Cleft of Bodies of Cervical and Seven Upper Dorsal Vertebræ with Separation; Great Shortening and Deformity of the Thorax and Neck. Anterior aspect. (Warren Museum.)

Myelocystocele and Myelocystomeningocele.—Myelocystoceles, where the fluid lies wholly in the distended central canal of the cord, are very rare. The committee of the Clinical Society found but two uncomplicated cases. They were in the cervical and lumbar regions. Recklinghausen speaks of eleven cases and noted the occurrence of a large hernia of the abdominal contents, *bauch-darm-blase-spalte*, in ten of them. These cases were, however, not pure myelocystoceles, for they were associated with fluid in the meshes of the pia-arachnoid and were classified by him as belonging to the fourth variety of spina bifida, called myelocystomeningocele. These are of four kinds:

1. A cystic cord with a spinal meningocele lying on its dorsal side.

2. A cystic cord squeezed up out of the spinal canal by a meningeal cyst beneath it.

3. A rupture of the cystic cord into a meningeal cyst, the cord where it is split open exposing the lining of its central canal like the area medullo-vasculosa, only it is exposed in the interior of the spina bifida sac instead of externally to the air.

4. A distended cord lifted upon a meningeal cyst bursts externally, leaving on top of a spina bifida sac a small sinus opening into the central canal.

In pure myelocystoceles the vertical split involves only one or two arches, while in the myelocystomeningoceles four to six may be deficient. The covering consists of skin, fat, subcutaneous and deep fascia, aponeurosis, and tissue of the spinal cord; in other words, it is thick enough to be opaque when viewed by transmitted light. The cavity is glistening, smooth, and regular, without any nerves or bands traversing it. The spinal roots arise from the outside of the sac anteriorly. Simple spinal meningocele differs from it clinically chiefly in the thinness and translucency of the sac wall. Myelocystocele, however, is accompanied by conspicuous curvatures of the spine, absence or deformity of ribs, the great congenital hernia already alluded to, also club foot, paraplegia, and paralysis of the sphincters. The presence of a number of other deformities or of extensive paralysis involving the sphincters may raise the presumption, in a doubtful case,

FIG. 4369.—Rachischisis with Lateral Curvature. The arches of the cervical spine are closed. (Warren Museum.)

that we are dealing with a myelocystocele or a myelocystomeningocele.

Differential Diagnosis.—There are distinct differences in the physical characteristics of the varieties of spina bifida—differences great enough to enable the surgeon to guess shrewdly before operating what he will find in the sac and to guide him in selecting a method of procedure adapted to the conditions confronting him. His opinion is to be based on an examination of the tumor, of the presence and extent of paralysis, and on the presence of other congenital deformities. The form, size, and location of the tumor, the character and thickness of its covering, its translucency, the presence of shadows indicating partitions or nerves in the sac, when examined with the hydroscope by transmitted light, the size of the pedicle or base, and the number of deficient vertebral arches—all these together afford valuable evidence of the variety of spina bifida one is dealing with, while the presence of extensive grave malformations and paralysis confirm and correct the diagnosis. The table given below may be of use.

Fig. 4370.—Spina Bifida in Child of Five Years. Deficiency of sacral arches. Probably a myelomeningocele. (Warren Museum.)

Natural History.—What is the natural life of spinæ bifidæ if they are unoperated and receive home care? How much does the deformity interfere with the enjoyment of life, and what proportion live to be adults? It may be stated without hesitation that only a small proportion live to adult life. The mortality in the first year is very great; in London the mortality returns for a single year show that out of 89 deaths from spina bifida 86 were under a year old, and the death rate is much higher during the first three months than for the rest of the year. The chief causes of death are rupture of the sac, meningitis, convulsions, marasmus, hydrocephalus; intercurrent affections play a subordinate rôle. Of 32 untreated cases followed by Demme, of Berne, all of whom died under two years old, 15 children died from rupture of the sac, 10 from marasmus, and 7 from intercurrent diseases. Out of 60 unoperated cases collected by Marsh, Gould, Clutton, and Parker, there were 3 deaths in adults (most of the cases were children), 1 from spontaneous rupture and meningitis, 1 from stone in the bladder, 1 from unknown cause. Rupture and meningitis are undoubtedly the largest factors in the death rate both of children and of adults.

Fig. 4371.—Section through a Myelomeningocele. The lumbar enlargement is attached to the posterior wall of the sac, and has been divided. The nerve roots are seen running from this part of the posterior sac wall toward the foramina. (Warren Museum.)

When a child survives the first few years, the tumor either persists or undergoes spontaneous cure by shrink-

Aids in Differentiating Varieties of Spina Bifida.

	Spinal Meningocele.	Meningomyelocele.	Myelocystocele Pure.	Myelocystomeningocele.
Form	Globular or nearly so	Irregular, slightly lobulated, often with umbilication.	Globular	Irregular, often higher than broad.
Size	Plum to child's head	Small plum to orange	Plum to ?	Plum to orange.
Location	Lower lumbar and sacral, uncommon cervical and rarely dorsal.	Lumbar and sacral, rare in cervical and dorsal.	Lumbar, sacral, cervical	Cervical, lumbar, sacral
Thickness of sac	Thin	Thin	Thick	Thick.
Character of covering	Skin sometimes with a small part membranous.	Usually more membrane than skin. Rarely skin covered, frequently ulcerated.	Skin	Skin or part membrane.
Translucency	Translucent	Translucent	Fairly opaque	Fairly opaque, may be transparent in part.
Shadows of bands, etc.	Not seen	Present	Not seen	Not seen.
Size of pedicle	Small	Broad base	Small	Large.
Number of defective arches.	One, two or three sometimes not in median line.	More than three	One or two	Often four to six.
Paralysis	Uncommon	Not infrequent, partial paraplegia common.	Often considerable	Generally present.
Sphincter paralysis	Absent	Very rare	Generally present	Present frequently.
Other malformations	Usually absent	Usually present	Usually some, not very grave.	Usually present, grave; abdominal hernia common.

age. However, out of eight adults and three children in whom the tumor persisted untreated there was only one who could say that he had no ill effects from it. Spontaneous cure I have observed to take place after superficial ulcers on the surface of the sac had cicatrized; scar contraction seemed to be the chief factor in shrinking the tumor. Spontaneous cure has also followed rupture of the sac, but it is a surprising result, for this is usually a fatal accident. Spina bifida is very often associated with other malformations and deformities from paralysis, conditions not benefited by spontaneous cure.

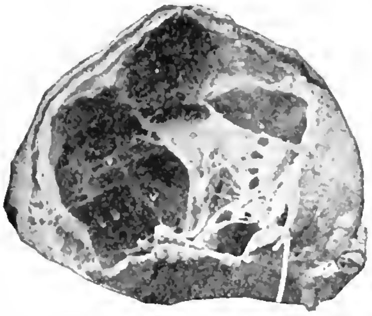


FIG. 4372.—Myelomeningocele: Sac much Subdivided. (Warren Museum.)

TREATMENT.—Without surgical intervention the chance of life for a young baby with spina bifida is small. His chance improves as he grows older, but his chance of living a useful, industrious life is slim; he will be an invalid nine times out of ten if he lives. Does surgery offer any better outlook? What is the mortality in cases which undergo operation? The recently compiled statistics of Swedish surgeons show that out of 229 cases which underwent operation 82 were fatal, a mortality of 35.8 per cent. Out of 21 cases over five years old but 1 was lost, while 43.3 per cent. of the cases under a week old ended in death. It is impossible to fix a mortality rate for the different forms of spina bifida, because clinical records have been made without reference to its division into varieties; for this reason some writers assert that about all children with spina bifida die before they are a year old; other surgeons whose experience is limited to a few successful operations believe that it is a simple thing to cure them all. In a measure both are right.

Simple meningoceles if protected against rupture not infrequently get well by gradual obliteration of the pedicle with fibrous tissue and subsequent shrinkage from absorption of fluid. If the meningocele is ruptured, whether during birth or afterward, convulsions and death from septic meningitis follow as a rule, unless the sac be ligatured and excised promptly to prevent the infection of the spinal canal. At least four cases, however, of rupture have been known to have healed without infection with a spontaneous cure. The fear of rupture often leads to excision of the sac, and the great majority of these cases make a perfectly good recovery. Nicoll, of Glasgow (*Lancet*, 1901, vol. i., p. 615), reports a good result in three cases, all in the cervical region, operated in the outpatient department and sent to their homes where a trained nurse attended them. The children were treated in this way rather than in the hospital ward because they were nursing and their mothers could not be admitted with them. A recent Italian writer reports a cure following repeated aspirations of a lumbar case. Hydrocephalus sometimes makes its appearance in a few weeks after operation and is a very unfavorable prognostic sign, just as it is in the other forms of spina bifida. The surgical technique for excision of a simple spinal meningocele presents no difficulties. The skin, subcutaneous fat, and fascia are divided on the tumor about an inch above the true pedicle, and the dissection is carried down to where the pedicle emerges and a ligature of silk or catgut loosely placed around it; the sac is then opened by a median incision and part of the fluid in it emptied in order to see if the cord or nerves are looped into the sac where the ligature might constrict them; if so, they should be gently tucked back into the canal with a probe or the ligature raised upon the pedicle sufficiently to avoid them before tying and excising the sac. If more than one vertebral arch is deficient, flaps from the aponeurosis covering the muscles of the back should be turned up and stitched over the pedicle, then the skin is sutured and a sterilized gauze dressing applied. If the patient is a young baby, loss of heat is to be guarded against during the operation by laying the infant face downward on a couple of hot-water bottles at about 110° F., and extra care should be taken to guard against shock. Anæsthesia should not be pushed too far with young babies, as it is easy to produce profound narcosis.

In England twenty years ago the injection of Morton's iodoglycerin solution was extensively employed. Dr. James Morton, the inventor, claimed to have obtained well-marked shrinkage and obliteration of the sac in forty out of fifty consecutive cases. The solution is made by dissolving ten grains of iodine and a drachm of iodide of potassium in an ounce of glycerin. One drachm of this is slowly injected with a hypodermic syringe into the sac; the child is held with the back down during operation and for several hours after, a precaution to prevent the fluid diffusing by gravity into the spinal canal. Sudden death followed occasionally; large clefts of the lumbosacral region were considered dangerous. The application of an elastic ligature has been abandoned in favor of cleaner and more modern methods.

Meningomyelocele is a much graver malformation, because with very few exceptions the cord is deformed where it is attached to the sac; the deformed region frequently involves the origins of six or more pairs of spinal roots; where the cord itself is not attached the nerve roots are adherent and are drawn out into long loops. Partial paraplegia and paralytic club-foot are commonly associated with it, as might be expected, and not infrequently congenital dislocation of the hip. No improvement of the paralytic condition has been obtained from operations upon the sac in this class of cases. Is it not wiser to refrain from operating? This question would certainly receive an affirmative answer were no other point of view obtainable. Most patients with meningomyelocele die during the first year of life; the chief causes are septic meningitis from rupture or ulceration, and hydrocephalus. Operation is justifiable if either of these causes of death can be eliminated. Hydrocephalus can neither be eliminated nor improved by operation, but a tight covering of healthy skin can be substituted for a thin ulcerating membrane in many cases and the danger of infection and rupture removed. Operations are often undertaken with only this end in view, and two methods have been successfully used—the injection of the sac with iodine and the cutting operation miscalled excision. The former method has just been described. The latter operation is performed somewhat differently from that employed for spinal meningocele. It consists in laying out as large skin flaps as possible from the base of the tumor and removing if possible the thin outer layer of membrane covering the vault of the tumor without opening the sac. The latter is then opened by a small incision somewhere on the side to avoid injuring the nerve roots and cord; the flaps are prepared from the muscle aponeurosis and tightly stitched over the collapsed sac; the skin is sutured over it with a layer of superficial stitches. In children of the age of puberty flaps of bone are often turned in to prevent the subsequent bulging which is bound to come on account of the large size of the cleft; foreign bodies have also been employed—pieces of gold or celluloid. The main object of the operation, however, must be to unite the divided sac and the skin flaps in such a way as to avoid leakage of cerebro-spinal fluid and not to injure the cord and nerves in replacing them in the canal. On account of these real difficulties the prognosis before operation must be much less favorable than in a case of simple meningocele. The after-care should also embrace every precaution to prevent leakage until union may take place. Little babies are best kept face down on the nurse's lap for six to ten hours, and then kept in bed still on the face with the hips raised for six days. Feeding in this position is difficult, but may be accomplished by using the old-fashioned nursing-bottle with long flexible tube.

Myelocystocele pure and simple is fortunately a very rare deformity. Dr. Morton greatly improved one case by iodine injections. Aspiration alone or the evacuation of fluid by simple incision would inflict very little injury on the cord; but operators are wary of doing anything which might produce an increase of the paralysis, especially as a tough healthy skin covering, affording good protection against rupture, is usually found. After a small incision had been made, aponeurotic flaps could be turned back and closely sutured to prevent leakage of cerebrospinal fluid, as is done for meningomyelocele; the thickness of the skin flaps also would aid in preventing leakage. The myelocystomeningocele of Recklinghausen or myelocystocele complicated by meningomyelocele or by spinal meningocele is less common than either of those varieties. As the anatomical conditions vary widely treatment must be varied to suit the individual case. It was Mr. Clutton's intention, if he should find the sac becoming smaller, in a case in which a meningeal cyst was lying on the dorsal side of a myelocystocele, to inject Morton's solution. Excision of the meningocele could be performed in such a case, but the dilated cord would be too big to be replaced in the spinal canal.

In case the position is reversed and the hydromyelocele is on the dorsal side of a meningeal cyst, the same difficulty renders replacement of the cord into the canal impossible, although if impending rupture or danger of septic meningitis make operation imperative, an operation similar to that described for meningomyeloceles may be performed, the surgeon taking large enough flaps from the muscle aponeurosis to cover in the collapsed cysts which would probably be too voluminous to re-enter the canal. Unless these dangers threaten, however, cases are better unoperated, especially if the healthy skin covers the sac. A shield of metal, hard rubber, or stiffened leather should be worn to protect the sac from pressure. In case we have to deal with a myelocystocele which has ruptured on its ventral side into a subjacent meningeal cyst, the condition cannot be differentiated clinically from meningomyelocele and the treatment should be the same. In case the rupture has come on the dorsal side, leaving the sinus connecting the central canal of the cord with the external surface of the sac, it would seem rational first to explore, lay open, and obliterate the sinus, provided it is not too long, before attempting to deal with the sac itself. Curiously enough, several cases have been reported of adults who have borne these sinuses all their lives; it is probable that in these cases the sinus is limited by a closure of the central canal not far from the orifice.

In deciding on the treatment for a case it is well for the surgeon to ask himself three questions: Is this a case in which no operation should be done, or is it one in which a successful operation is possible, or one in which operation has to be done as a life-saving measure? No operation should be performed if the tumor is decreasing in size without leaking, unless meningitis is feared from the presence of deep ulcers; because a natural spontaneous cure offers just as good a result to the patient as does an operation. No operation should be performed if hydrocephalus be present, except with the distinct understanding that it is undertaken to avert for a short time death from rupture or meningitis. No operation should be performed on a myelocystocele which has a thick covering of healthy skin unless it is rapidly enlarging. Operation may be successful in any other case, whether spinal meningocele, myelomeningocele, myelocystocele, or myelocystomeningocele. Simple spinal meningoceles are almost always much benefited by excision. Excision should be done as a life-saving measure in all cases of rupture, and it should be done as soon as possible after the rupture; it should be done as a life-saving measure whenever rupture seems imminent or the proximity of septic ulcers awakens just fears of septic infection spreading to the meninges.

Temporary relief from impending rupture may be obtained by aspiration if the child's condition renders operation unjustifiable.

Spina Bifida Occulta.—In the so-called spina bifida occulta there is no projecting sac; an abnormal hairy patch in the median line is usually the only external sign on the back. Some paralysis, or paresis, a paralytic club-foot, muscular atrophy of the limb, anæsthetic areas, or sphincter paralysis which cannot be logically accounted for in other ways, may lead to its recognition; in some cases peculiar ulcers of the foot of nervous origin are observed. The affection is frequently obscure unless the bare back is seen. Sometimes a soft mass like a diffused lipoma may be felt beneath the hairy patch.

Recklinghausen says, in explanation of this condition, that in fœtal life there was present a spina bifida which collapsed and shrivelled, leaving only a minute scar and the hypertrichosis to mark where it had once been. On dissection one, two, or three cleft vertebræ are found closed in with a thick, dense, fibrous membrane, like a drum head. This is perforated by a fibrous or fibromuscular band uniting the superficial part of the tumor with that lying within the spinal canal; for a tumor, usually a fibro-lipoma, has been found at autopsy in these cases, and not infrequently considerable softening or compression of the cord as a result of its growth. The removal of this tumor and of fibrous tissue bands has in a few instances been followed by a complete disappearance of paralysis. One case was reported by Robert Jones in 1889. The lumbar cord in spina bifida occulta extends in the spinal canal often to the lower part of the sacrum instead of ending opposite the first or second lumbar vertebra. No explanation has been offered for the cause of the hypertrichosis. The tumor is regarded by Recklinghausen as the growth of some embryonic cells which had been drawn into the spinal canal along with the collapsed spina bifida sac. These cells may at times belong to another embryo and give rise to cases of fœtal inclusion like that reported by Jones, who removed a third arm from between the scapulæ and in so doing opened the spinal canal. *Augustus Thorndike.*

SPINAL COCAINIZATION AND LUMBAR PUNCTURE.—Analgesia by the subarachnoid injection of cocaine was first demonstrated by Dr. J. Leonard Corning, of New York, in 1885, and since that date this method of inducing anæsthesia has been carefully elaborated and has been practised in several thousand recorded cases by numerous observers in various parts of the world.

The knowledge so far accumulated does not justify a strict comparison of this procedure with general anæsthesia by ether or chloroform inhalation, and its relative safety is not yet definitely determined, but the meagre and fragmentary statistical data at present available indicate a mortality considerably in excess of that attendant upon the use of chloroform, and it is more than probable that the vast majority of practical surgeons do not, for various reasons, indorse the procedure as a trustworthy expedient. The more conservative advocates of this measure, being mindful of the hazard, regard it, not as a substitute for other methods of producing anæsthesia, but rather as appropriate to cases in which local anæsthesia cannot be applied, or when general anæsthetic agents are clearly contraindicated in consequence of pulmonary, cardiac, or renal disease, in aged persons, in alcoholics, in operations of a class rendered extra-hazardous by the administration of a general anæsthetic, and in operations in which the concurrence or the consciousness of the patient is desirable or necessary.

In the hands of prudent men, immediately disastrous results have been few, although alarming symptoms and sudden death, inexplicable on any other hypothesis than that of shock or intoxication, have followed lumbar puncture, both without and after the cocaine injection, thus clearly establishing the fact that the procedure is by no means free from danger.

It is worthy of remark that a number of failures have been reported, but how far the negative or the unfavorable results have been influenced by faulty technique, by impure cocaine, or by idiosyncrasy is not known, and the possibility of provoking by puncture remote pathological changes in the cord or in its membranes remains to be ascertained.

Spinal cocainization is commonly resorted to for the purpose of producing analgesia in those parts of the body which are below the diaphragm, but it is claimed that the effect may be extended to the upper part of the trunk, to the head, neck, and upper extremities, and that it is available for operations upon these parts as well as for major and minor abdominal and pelvic operations, and for other operations on the lower portions of the body.

Various substances possessing more or less analgesic power have been used in like manner for the same purpose. Among them, eucaine, antipyrin, nirvanin, and morphine; but cocaine is employed far more than all the others combined, and is decidedly to be preferred for this purpose to any known agent.

A drug introduced into the subarachnoid space should be absolutely sterile, as the risk of infection ranks among the prominent dangers of the practice. It should also be of pure quality and of definite strength. Several methods of rendering cocaine aseptic have been proposed and have proven satisfactory. Most operators who undertake to sterilize the drug depend upon heat applied to an aqueous solution, using a temperature of 180° to 212° F., for from one minute, which does not sterilize, to fifteen minutes, which is said to destroy much of the cocaine and seriously to impair the analgesic property of the solution thus treated. The method of fractional sterilization of a two-per-cent. solution by subjecting it, in glass capsules, to a heat of 176° F. for four hours, on four successive days, is efficient, but very troublesome, as the solution does not keep well and is generally regarded unfit for use after about two weeks, so that a fresh preparation of the drug becomes necessary. The dry method appears to be the most feasible. This consists in subjecting a chemically pure specimen of cocaine to a dry heat of 300° F. for ten minutes or longer. The powder is not decomposed or injuriously affected by this temperature, and if properly protected it will keep indefinitely and is always ready for use.

The usual dose for a robust adult is from one-quarter to one-half of a grain, dissolved either in sterile water or in the spinal fluid itself. Smaller doses are recommended for young, very old, or feeble subjects. A two-per-cent. solution is ordinarily employed—the smaller dose of a stronger solution being generally preferred to a corresponding dose of a weaker solution.

The use of cocaine by spinal injection is not restricted, exclusively, to surgical procedures. It has been successfully employed in obstetric practice for the purpose of lessening the pains of parturition. The injection is made during the second stage, and it is claimed that the pains are relieved, while at the same time the force of the uterine contractions is not diminished, but that voluntary effort, on the other hand, is increased—the suffering being absent—so that the duration of the labor is thereby actually decreased.

Some of the ardent supporters of medullary narcosis attribute to it, if promptly invoked, the power to limit or to arrest shock from violent injuries.

The anaesthetic effect of an average injection of cocaine is felt in the lower portions of the body after three or five to ten minutes. The upper portions of the body are affected in from twenty to thirty minutes, and the maximum dose is usually required to accomplish this result. Complete insensibility to pain may continue for from one hour to one hour and a half or two hours, and sometimes for three, four, or even five hours. In prolonged operations or in tedious labor, the injection may be repeated, in a slightly decreased dose, if necessary to maintain the anaesthesia.

A glass syringe which can be boiled and rendered thoroughly aseptic fulfils the requirements of a satisfactory instrument. The needle should not be less than three inches long, of small diameter, with a sharp point and a short bevel. It may be constructed of steel or of a composition of iridium and platinum, which is strong, not brittle, and is less likely to rust than steel.

Subarachnoid injection, whether with cocaine or with any other substance, is liable to be attended by more or less serious symptoms—by untoward phenomena associated either with the simple puncture or with the effect of the injected material. Among the most important manifestations are cardio-respiratory disturbances, asphyxia, panting, shock, headache, restlessness, delirium, rapid pulse, nausea, vomiting, sweating, cyanosis, collapse, cramps, rigors, transient paraplegia, sensations of heat, general depression, elevated temperature, subnormal temperature, fibrillary muscular contractions, relaxation of the sphincters with involuntary discharges, retention of urine, etc.

In very nervous and apprehensive patients, the eyes and ears should be closed during the operation, and a dose of morphine and strychnine, given as a preliminary safeguard, is sometimes advantageous. The instruments, the hands of the operator, and the skin over the entire back and loins of the patient should be prepared as carefully as for an abdominal section. Any of the lumbar interspaces may be selected for the puncture, though the third or fourth is usually chosen. It has been done as high as the sixth cervical vertebra, but it is generally conceded that under ordinary circumstances puncture in the lumbar region is safest and best, even when high analgesia is desired. The spinous process of the fourth lumbar vertebra can be located by drawing a transverse line to connect the two iliac crests. It may then be accurately defined by deep palpation. The seat of puncture should be frozen by ethyl chloride, and the skin—the only sensitive tissue—penetrated with the point of a bistoury. The patient should lie on either side, with the body well curved forward and a pillow under the hip. The needle may be entered just beneath the spine in the median line and pressed firmly a little upward and forward, or it may be entered a half-inch to the right or to the left of the median line and passed obliquely toward the spinal canal. When the point of the needle enters the space, which in a well-developed adult is about two and a half inches below the surface, a sense of diminished resistance will be noticed, and the spinal fluid, always clear and limpid, will flow from the outer end, drop by drop or in a steady stream. If the lumen of the needle should be obstructed or if from any cause the fluid does not appear after the point is supposed to have entered the space, a stylet may be passed, the patient may cough or make a slight straining effort, or gentle aspiration by means of a syringe will overcome the obstacle. When the fluid begins to flow, the finger should be placed over the end of the needle, and the syringe containing the warm solution or the sterilized crystals of cocaine should be attached. Operators of experience disagree as to the advisability of allowing a few drops of the fluid to escape before throwing in the cocaine solution, some alleging that the normal quantity of the fluid in the cavity should not be disturbed, but that the amount withdrawn should equal or slightly exceed the amount introduced, while others assert that severe headaches and other bad effects are infrequent if the spinal fluid is not wasted. If the solution is used, the piston should be slowly depressed, but if the powder is to be dissolved in the spinal fluid the piston, already closed, should first be withdrawn until the barrel is about half filled with the fluid, which readily dissolves the cocaine, and then the solution should be gradually returned into the space, the needle removed, and the puncture closed with collodion.

Emphasis is laid upon the importance of very deliberate introduction of the solution, and a little delay in withdrawing the needle is advised; if, however, analgesia of the upper parts of the body is desired, the very rapid and forcible depression of the piston is considered essential.

Lumbar puncture, as an independent procedure for the purpose of withdrawing cerebro-spinal fluid, was introduced to the profession by Quincke in 1890, and since then it has been frequently practised as a diagnostic means and to lessen pressure in acute or chronic hydrocephalus.

It should be remembered that the spinal cord proper terminates at the first lumbar vertebra, and that the subarachnoid space is continuous with the ventricles of the brain through the foramina of Magendie, Key and Retzius. It is not certain, however, that these foramina are always sufficiently patent to allow the free passage of the fluid. The normal quantity of the cerebro-spinal fluid varies in different individuals. It has been estimated at from half an ounce to two ounces. It is more abundant in old than in young persons, and is quickly reproduced.

The operation of lumbar puncture is simple and easy of performance, but it is attended with considerable danger. The withdrawal of a very small amount of cerebro-spinal fluid has caused extremely grave symptoms, and has been followed in repeated instances by immediately fatal results. The puncture is usually made, with strict antiseptic precautions, at the third or fourth lumbar interspace as above described for spinal anesthesia. *James B. Baird.*

SPINAL CORD.—*General Description of the Macroscopic Appearances.*—The spinal cord (*medulla spinalis*) (Figs. 4373, 4374, and 4375) is that portion of the central cerebro-spinal nervous system which is situated within the vertebral canal. In human beings it is a slightly flattened cylindrical strand, varying in calibre somewhat at different levels. It is markedly curved in its course, corresponding to the curvature of the vertebral column. The spinal cord measures from 43 to 45 cm. in length, being on the average somewhat longer in the male than in the female. It is continuous above, at the lower edge of the foramen magnum, with the medulla oblongata, and extends below into the lumbar part of the vertebral canal, where it is suddenly drawn out into a terminal filament (*filum terminale*). The lower limit of the cord is variable in position in human beings. Usually the junction with the terminal filament is met with opposite the lower third of the first lumbar vertebra, or opposite the upper third of the second lumbar vertebra, but it may be found even higher or lower than these levels. In the adult, therefore, the spinal cord does not extend throughout the whole length of the vertebral canal; the condition is very different from that found in the embryo (*vide infra*). Nor does the spinal cord come anywhere near filling up the lumen of the vertebral canal. A cross section through the vertebral canal with the cord *in situ* reveals a large space between the surface of the cord and the inner surface of the bony vertebral canal (Fig. 4374). This space is subdivided by the coverings of the cord into several spaces. One of these, between the arachnoid membrane and the pia mater, the so-called subarachnoid cavity (*cavum subarachnoidale*), is filled with the cerebro-spinal fluid (*liquor cerebrospinalis*). This disproportion between the size of the cord and that of the cavity of the vertebral canal is of great significance for the protection of the cord from injury during the various movements which the vertebral column undergoes.

The spinal cord, though in general of a cylindrical shape, is everywhere somewhat flattened from before backward; the sagittal diameter is always less than the frontal diameter. In the smallest portions of the cord the difference between the sagittal and frontal diameters may not exceed 1 or 2 mm., but in the two enlargements of the cord the difference may be much greater. The upper principal enlargement is situated at the junction of the neck and thorax, and is known as the cervical enlargement (*intumescentia cervicalis*); at the point of its maximal enlargement the frontal diameter exceeds the sagittal by 4–5 mm. The other principal enlargement, at the junction of the thoracic with the lumbar spine, is known as the lumbar enlargement (*intumescentia lumbalis*); the maximum of this enlargement is reached at the level of the twelfth thoracic vertebra, where the frontal diameter exceeds the sagittal by 2.5–4.5 mm. These two principal enlargements correspond to the places where the spinal cord gives off nerves to, and receives nerves from, the upper and lower extremities respectively.

Just below the intumescentia lumbalis the spinal cord diminishes very rapidly in calibre, giving rise to the so-

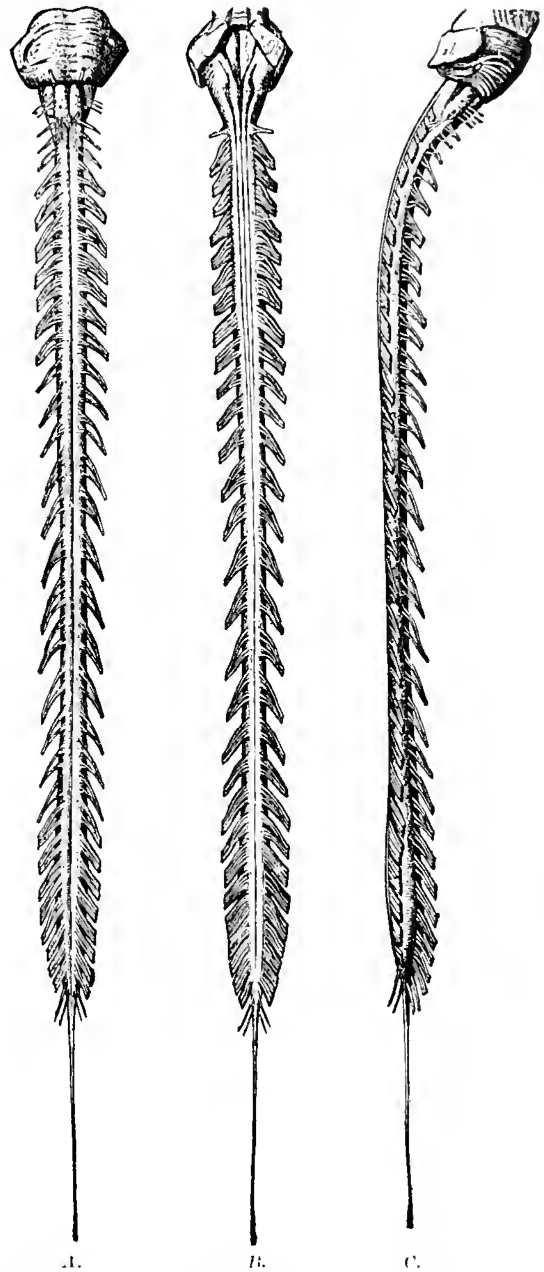


FIG. 4373.—Views of the Spinal Cord (Medulla spinalis). *A*, From in front; *B*, from behind; *C*, from the right side. (From Toldt.)

called medullary cone (*conus medullaris*). From the lower end of the conus medullaris the terminal thread (*filum terminale*) extends downward as a delicate strand for a distance of from 20 to 25 cm., to terminate upon the posterior surface of the os coccygis (Fig. 4375).

The spinal cord weighs on the average from 27 to 28 gm., but in individual cases the weight may be considerably above or below the average.

The external surface of the cord is not perfectly smooth. On examination, a deep longitudinal groove is seen in the median line upon the anterior surface. This is

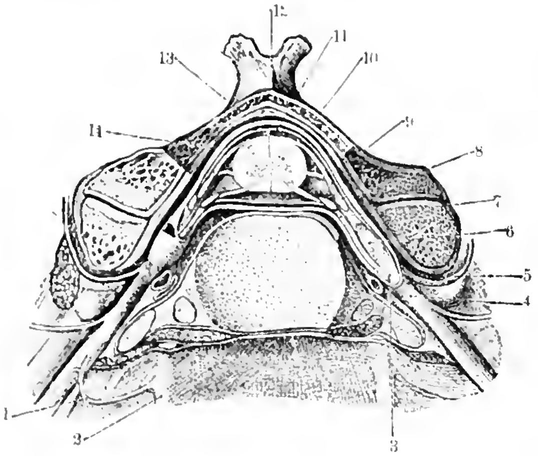


FIG. 4374.—Transverse Section Through the Intervertebral Fibro-Cartilage Between the Third and Fourth Cervical Vertebræ. The spinal meninges are shown in cross-section and their relations to the spinal nerves are indicated. (After C. Toldt, "Anatomischer Atlas," Wien, 1900.) 1, Ramus communicans; 2, trunk of the sympathetic; 3, fourth spinal nerve; 4, ramus anterior; 5, ramus posterior; 6, ganglion spinale; 7, radix anterior; 8, radix posterior; 9, spinal dura mater; 10, subarachnoid space; 11, spinal arachnoid; 12, spinous process of the third cervical vertebra; 13, subdural space; 14, epidural space.

known as the anterior median fissure (*fissura mediana anterior*). In the median line, on the posterior surface of the cord, there is no such deep groove, but only a shallow sulcus called the posterior median sulcus (*sulcus medianus posterior*). These anterior and posterior median sulci indicate the line of subdivision between the two symmetrical halves of the cord—the right and left halves of the spinal cord.

Attached to the surface of the cord are the radicular threads (*fila radicularia*) of the roots (*radices*) of the spinal nerves (*Nn. spinales*). These are arranged in four rows, two ventral or anterior and two dorsal or posterior. These rows of the fila radicularia unite to form roots which are spoken of respectively as the anterior or ventral roots (*radices anteriores seu ventrales*) and the posterior or dorsal roots (*radices posteriores seu dorsales*). Lateralward each ventral root unites with a dorsal root of the same side and level to form a single trunk, the spinal nerve (*N. spinalis*). On each dorsal root, just before its union with a ventral root, is a distinct swelling, the so-called spinal ganglion (*ganglion spinale*). The fila radicularia of the anterior or ventral roots of the spinal nerves leave the spinal cord along a longitudinal area situated a little lateralward from the anterior median fissure; though there is, in reality, very little if any depression of the surface at the points of exit of the anterior or ventral roots, a shallow groove has been described here and designated the anterior lateral sulcus (*sulcus lateralis anterior*). Behind, however, a few millimetres laterad from the sulcus medianus posterior on each side and corresponding to the line of the fila radicularia of the posterior or dorsal roots, there is a distinct groove, called the posterior lateral sulcus (*sulcus lateralis posterior*).

These longitudinal sulci, running the whole length of the cord, subdivide its surface into strands which are known as funiculi (*funiculi medullæ spinalis*). Of these funiculi there are three for each half of the cord. Thus between the fissura mediana anterior and the sulcus lateralis anterior is situated the anterior funiculus (*funiculus anterior*); between the sulcus lateralis anterior and the sulcus lateralis posterior of the same half of the cord is situated the lateral funiculus (*funiculus lateralis*); and, finally, between the sulcus lateralis posterior and the sulcus medianus posterior is situated the posterior funiculus (*funiculus posterior*). In the upper part of the spinal cord the funiculus posterior on each side is further subdivided by an additional sulcus known as the posterior intermediary sulcus (*sulcus intermedius posterior*). The lateral portion of the funiculus posterior included between the sulcus lateralis posterior and the sulcus intermedius posterior is known as the wedge-shaped funiculus (*funiculus cuneatus*). The medial portion, situated between the sulcus intermedius posterior and the sulcus medianus posterior, is known as the delicate funiculus (*funiculus gracilis*).*

Besides the fila radicularia of the anterior and posterior roots of the spinal nerves, there can be made out in the uppermost part of the spinal cord a few fila radicularia coming off from the lateral surface between the anterior and posterior lateral sulci; these unite to form on each side a nerve trunk which passes upward in the vertebral canal to enter the cranial cavity through the foramen magnum. These fila radicularia belong to the so-called accessory nerve (*N. accessorius*) or eleventh cerebral nerve.

Since the time of Sir Charles Bell, it has been customary to speak of the anterior or ventral roots as *motor roots*, of the posterior or dorsal roots as *sensory roots*, and of the spinal nerves resulting from the fusion of anterior and posterior roots as the *mixed nerve trunks*.

The mixed nerve trunk leaves the vertebral canal through the corresponding intervertebral foramen (*foramen intervertebrale*). In some parts of the cord the corresponding intervertebral foramen lies in a horizontal direction from the fila radicularia of the nerve, but in other parts of the cord, owing to greater rapidity of growth at certain periods of development of the bony vertebral canal than of the spinal cord itself, the intervertebral foramina are situated at much lower levels than are the fila radicularia of the corresponding spinal nerves. The result is that certain of the spinal nerves follow a more or less markedly oblique course between the cord and the intervertebral foramina. When this course is very oblique a considerable extent of the spinal nerve may be included within the cavity of the vertebral canal. Particularly striking is the obliquity of course and long intravertebral extent of the lumbar and sacral nerves. Indeed, some of the latter follow almost a vertical course, enveloping the conus medullaris and the filum terminale as a great bundle of nerves known as the horse's tail (*cauda equina*).

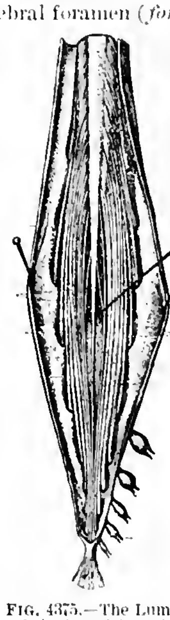


FIG. 4375.—The Lumbar Spinal Cord (pars lumbalis medullæ spinalis) with the terminal cone (conus medullaris), terminal thread (filum terminale), and the horse's tail (cauda equina). Viewed from behind. (After C. Toldt, "Anatomischer Atlas," Wien, 1900.)

There are thirty-one pairs of spinal nerves, connected with the spinal cord. The spinal nerves are named according to their exit from the vertebral canal. The uppermost spinal nerve leaves the vertebral canal between the atlas and the os occipitale. All other spinal nerves come out through the intervertebral foramina between adjacent vertebræ, the lowermost one making its exit through the opening between the first and second por-

* It is customary to find the funiculi of the spinal cord referred to in English text-books as the "columns of white matter" of the cord. It is preferable to retain the term column for the longitudinal strands of *gray* matter, and to use the terms funiculi and fasciculi for the strands of white matter.

tions of the os coccygis. It is customary then to divide the spinal nerves into cervical nerves (*Nn. cervicales*), thoracic nerves (*Nn. thoracales*), lumbar nerves (*Nn. lumbales*), sacral nerves (*Nn. sacrales*), and coccygeal nerve (*N. coccygeus*). There are eight cervical nerves, twelve thoracic nerves, five lumbar nerves, five sacral nerves, and one coccygeal nerve The portion of the spinal cord connected with the cervical nerves is known as the cervical part (*pars cervicalis*). The portion of the cord connected with the thoracic nerves is known as the thoracic part (*pars thoracalis*). The portion of the cord connected with the lumbar and upper sacral nerves is known as the lumbar part (*pars lumbalis*). That portion of the cord which is below the pars lumbalis is called the conus medullaris. The pars cervicalis includes the intumescentia cervicalis; the pars lumbalis includes the intumescentia lumbalis.

Each spinal nerve belongs to one segment of the body (*metamere*). The motor part of each spinal nerve innervates the muscle derived from the muscular part (*myotome*) of a given metamere. The sensory part innervates all of the derivatives of a given metamere supplied with sensory nerves. One spinal nerve, together with its fibres of distribution, its ramus communicans and corresponding portion of the sympathetic, its roots, and the portion of spinal cord belonging to it, makes up the nervous part (*neurotome*) of a given metamere.

If the spinal cord be cut through at different levels (*sectiones medullæ spinalis*), it will be seen to contain a central canal (*canalis centralis*) and to be made up of gray matter (*substantia grisea*) and white matter (*substantia alba*). In general, the white matter is outside and the gray matter inside, and the latter in a transverse section assumes more or less the shape of the letter **H**; but the relations which exist between the white matter and the gray matter vary somewhat at different levels of the spinal cord. It will be convenient, therefore, to study first the topographical appearances of a transverse section through the *middle of the cervical portion of the spinal cord* (Fig. 4376), and afterward to compare with it the topographical appearances met with at other transverse levels.

On each side of the middle line of the cord the structures are almost identical. The anterior median fissure in front and the posterior median sulcus, together with the septum medianum posterius behind, divide the cord almost completely into two symmetrical halves.

The sulcus medianus anterior is broad and deep; as seen in cross-section it extends through about one-third of the depth of the cord. In it is lodged a fold of the pia mater carrying blood-vessels. The shallow sulcus medianus posterior is situated in the middle line behind. Extending from the floor of this sulcus through the white matter as far as the transverse bar of the **H** of gray matter, the septum medianum posterius can be seen. It consists of a condensed mass of certain supporting structures of the cord (ependyma cells).

While the cord is nearly cut in two by the fissura mediana anterior in front and the septum medianum posterius behind, the two halves are really connected by a transverse bar of nerve substance called the commissure. This commissure consists partly of white matter, partly of gray matter. The anterior third is white matter and is called the white anterior commissure (*commissura anterior alba*). The posterior two-thirds consists of gray matter called the gray commissure (*commissura grisea*). In the middle of the commissure is seen the cross-section of the central canal (*canalis centralis*) of the spinal cord, lined by ependymal epithelium, a canal which is continuous above with the ventricles of the brain. The gray matter surrounding it differs from the rest of the gray matter, being somewhat more transparent and reacting in a different way to staining reagents. This special gray matter is called the central gray substance of the spinal cord (*substantia grisea centralis*). It will be noticed that the central canal divides the commissure into an anterior part (*commissura anterior*) and a posterior part (*commissura posterior*). The anterior commissure consists of white matter in front, the anterior white commissure (*commissura anterior alba*), and gray matter behind, the anterior gray commissure (*commissura anterior grisea*). The posterior commissure (*commissura posterior*) consists chiefly of gray matter, though some white fibres run through it. The posterior median septum abuts upon the commissura posterior. The fissura mediana anterior extends in the depth as far as the commissura anterior alba.

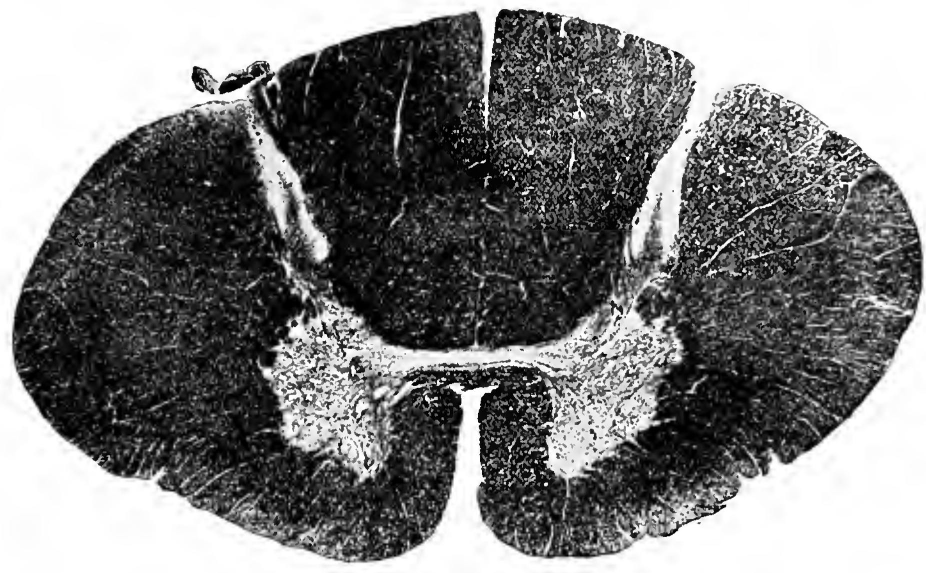


FIG. 4376.—Transverse Section Through the Fourth Cervical Segment of the Human Spinal Cord. (After A. Bruce, "Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

An examination of the distribution of the **H**-shaped mass of gray matter shows that the long lateral limbs of the **H** are directed, generally speaking, from before backward, though they are inclined a little lateralward behind. The gray commissures form the cross bar of the **H**; the lateral limbs of the **H** are not, however, even in thickness, the gray mass being more expanded in its anterior part and more elongated and narrow in its posterior part. On the lateral surface of the gray matter there is a distinct projection of gray matter lateralward into the white matter, to be seen in the cross section. The expanded anterior part of the gray matter is known as the anterior or ventral horn, and since, when the third dimension is considered, it represents a mass extending the whole length of the cord in its anterior part, it is called the anterior column of gray matter of the cord (*columna anterior*). The posterior narrower portion of gray matter is called the posterior or dorsal horn of the gray matter, or posterior column (*columna posterior*). The lateral projection of gray matter is known as the lateral horn, or lateral column (*columna lateralis*) These seen emerging from the area corresponding to the sulcus lateralis anterior. In the cross-section, fibres running out from the anterior horn or anterior column of gray matter can be traced horizontally, or somewhat obliquely,

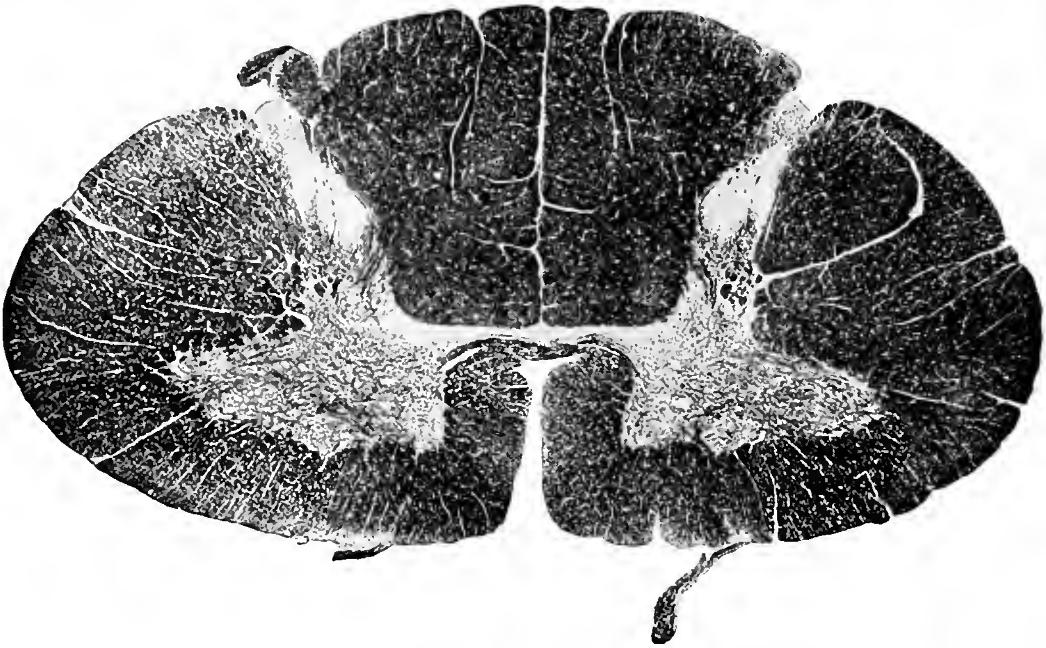


FIG. 4377.—Transverse Section Through the Sixth Cervical Segment of the Human Spinal Cord. Weigert myelin-sheath stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

three gray columns (*columnæ griseæ*) on each side, together with the gray commissures, make up the whole extent of the gray matter of the cord, with the exception of a few strands of gray matter which mix in with the white matter in the form of a network at the angle between the lateral column and posterior column of gray matter. This network of gray matter is the so-called reticular formation (*formatio reticularis*). Elsewhere the gray matter is sharply marked off on all sides from the white matter which surrounds it.

The anterior horn, or anterior column of gray matter, is separated from the periphery of the cord by a thick layer of white matter. The posterior horn, or posterior column of gray matter, arrives much nearer to the surface in the region of the sulcus lateralis posterior. It does not, however, reach the surface of the cord, being separated from it by a narrow zone of white matter, known as the fasciculus of Lissauer.

On looking more closely at the posterior horn or posterior column of gray matter, it will be seen to be somewhat constricted in the cross-section, a little behind the gray commissure. This constriction is known as the neck of the posterior column (*cervix columnæ posterioris*). The tip of the posterior column behind is called the apex (*apex columnæ posterioris*). It is sometimes capped, more often crossed, by a somewhat expanded mass of unusually transparent gray matter known as the gelatinous substance of Rolando (*substantia gelatinosa* [*Rolandi*]).

On the surface of the cord the fila radicularia of the radix anterior of the spinal nerve on each side have been through the white matter between the anterior column and the sulcus lateralis anterior. Reaching the surface of the cord they form the fila radicularia of the anterior root.

On the surface of the cord behind, along the sulcus lateralis posterior, the fila radicularia of the posterior root have already been seen. An examination of the sections shows that, on entrance into the cord, the fibres of these fila do not penetrate into the gray matter of the posterior horn, but enter directly the white matter of the funiculus posterior.

FIG. 4378.—Transverse Section Through the Third Thoracic Segment of the Human Spinal Cord. Weigert's myelin stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

The subdivision of the white matter in each half of the cord into three funiculi is well shown in the cross-section. The position of the fila radicularia of the anterior roots of the spinal nerves serves to separate the *funiculus*

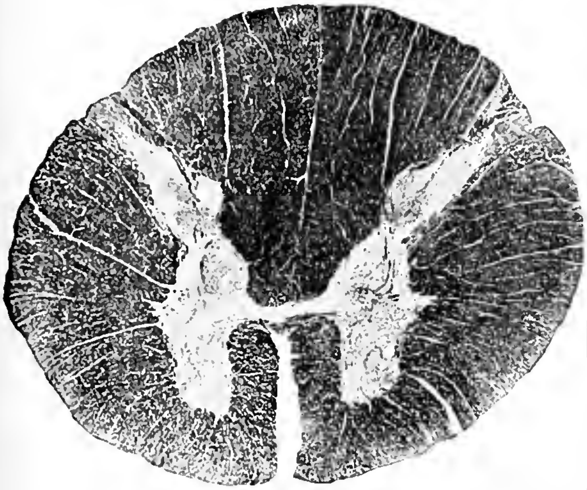


FIG. 4379.—Transverse Section Through the Twelfth Thoracic Segment of the Human Spinal Cord. Weigert's myelin-sheath stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

anterior from the *funiculus lateralis* much better than does the shallow sulcus lateralis anterior. Indeed some will have it that no sulcus lateralis anterior exists; it is therefore common to hear the anterior and lateral funiculi grouped together as a single mass of white matter, called the *fasciculus anterolateralis*. The *funiculus posterior* is sharply separated, however, from the funiculus lateralis in the section, by the sulcus lateralis posterior, and in the depth the white masses of the two funiculi are separated from one another by the columna posterior grisea.

The large posterior funiculus, situated between the sulcus lateralis posterior and the sulcus medianus posterior, is subdivided at this level by the sulcus intermedius posterior. Extending into the white substance from this sulcus is a septum of supporting substance known as the *dorsal paramedian septum*. The portion of white matter of the posterior funiculus medial from this septum is called the delicate fasciculus or bundle of Goll (*fasciculus gracilis* [*Golli*]), while the portion laterad from it is known as the wedge-shaped fasciculus or bundle of Burdach (*fasciculus cuneatus* [*Burdachi*]).

The relative distribution of gray and white matter may next be studied in a transverse section, taken at the *level of the sixth cervical nerve*, that is, through the cervical enlargement (*intumescentia cervicalis*) (Fig. 4377). The cord is here seen to be much larger than in the previous section, and the shape of the gray matter is considerably altered. The anterior horn or columna anterior is much larger, and has fused with the lateral horn or columna lateralis so that the latter does not exist at this level as an independent column. The posterior horn or columna posterior of gray matter is a little larger than at the higher level. The formatio reticularis is less pronounced. The frontal diameter of the cord is increased much more than the sagittal. The subdivision of the funiculus posterior into the fasciculus gracilis (Golli) and the fasciculus cuneatus (Burdachi) is still well marked.

At the *level of the third thoracic nerve* (Fig. 4378) the size of the cord has become much reduced, and the sagittal diameter is now much more nearly equal to that of the frontal diameter. The gray matter is present in much smaller amount, the anterior horn or columna anterior has been greatly reduced in size, the lateral horn or columna lateralis is small, and the posterior horn or columna posterior, slender and long. On the medial side of the columna posterior, just in front of its neck in the angle formed by it with the gray commissure, there is an expansion of the gray matter which was not visible in the two sections previously examined. This mass of gray matter contains large cells and is known as the dorsal nucleus of Clarke (*nucleus dorsalis* [*Clarkii*]). It is sometimes known as the column of Clarke or of Stilling. It is present on each side for a long distance in the cord; thus it extends throughout the whole thoracic part of the spinal cord and into the pars cervicalis as far as the level of the eighth or seventh cervical ne. 'e; below, it extends into the pars lumbalis as far as the first or second lumbar nerve. The beginner will find in it a useful landmark for the recognition of sections derived from the pars thoracalis.

The dorsal paramedian septum, separating the fasciculus gracilis from the fasciculus cuneatus, is still present at this level, but it is less distinct than at higher levels, and is placed much nearer the middle line. The fasciculus gracilis is seen to be, accordingly, much smaller in volume than at higher levels. The septum grows less and less distinct as the pars thoracalis is descended, until at about the level of the eighth thoracic nerve it has entirely disappeared and the posterior funiculus is no longer subdivided into two fasciculi.

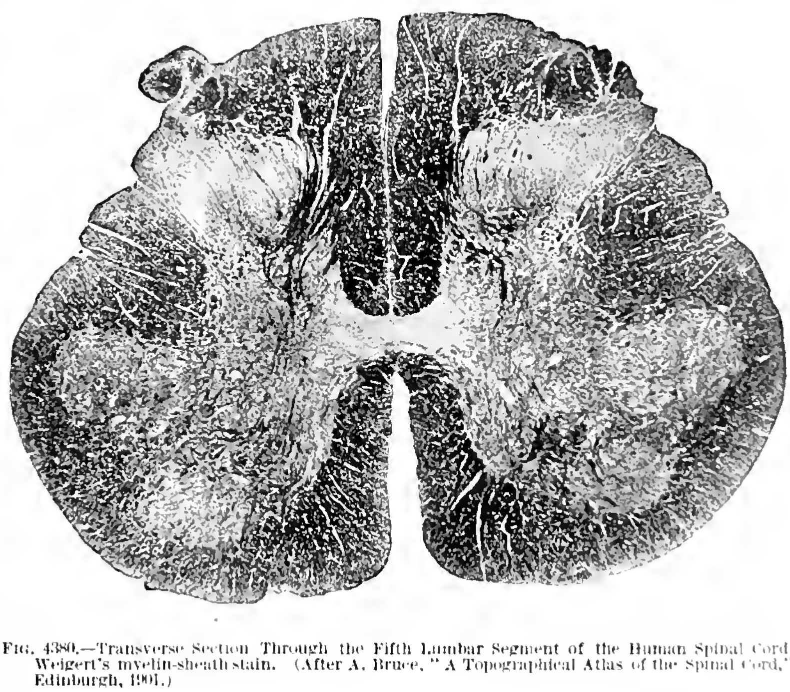


FIG. 4380.—Transverse Section Through the Fifth Lumbar Segment of the Human Spinal Cord. Weigert's myelin-sheath stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

Sections of the thoracic cord below the eighth thoracic nerve show no marked alterations in the disposition of the white and gray matter until the lumbar enlargement (*intumescentia lumbalis*) is approached. Then the whole cord grows larger, both the gray matter and the white matter increasing in amount, the gray matter, however, to a greater extent than the white matter.

At the *level of the twelfth thoracic nerve* (Fig. 4379) a transverse section of the cord shows the beginning expansion of the gray matter. The nucleus dorsalis

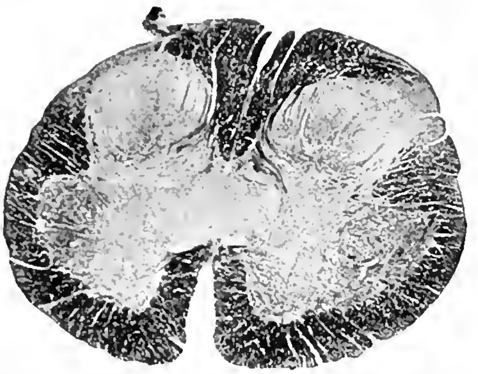


FIG. 4381.—Transverse Section Through the Third Sacral Segment of the Human Spinal Cord. Weigert's myelin-sheath stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

(Clarkii) is here very distinct. From this level on, the gray matter increases very rapidly in amount, until the maximum expansion is reached in the largest part of the intumescentia lumbalis.

The relations at the *level of the fifth lumbar nerve* are well shown in Fig. 4380. The anterior and lateral columns of gray matter are again fused and form a much expanded mass in the anterior part of the cord. The posterior column or horn is enlarged to a greater extent here than in any other part of the cord. The enlargement involves especially its medial surface, with the result that the volume of the funiculus posterior of the white matter is relatively small. Indeed, a striking feature of cross sections through the lumbar enlargement is the thinness of the white envelope and the marked expansion of the gray matter. In the latter the substantia gelatinosa (Rolandi) is especially prominent.

In the parts of the cord below the lumbar enlargement this disproportion between the volume of the gray matter and that of the white matter increases. A transverse section at the *level of the third sacral nerve* (Fig. 4381) shows this distinctly, and it is even more marked in a transverse section through the lower part of the conus medullaris at the *level of origin of the N. coccygeus* (Fig. 4382). Here the terminal mass of gray matter is surrounded only by a thin film of white matter. The filum terminale is so atrophic that sections of it reveal only the central canal, lined by ependymal epithelium and surrounded by a thin layer of gray substance, and outside of all the filum duræ matris spinalis.

To the naked eye the white matter of the different funiculi looks very much alike, and cannot be differentiated into the fasciculi, of which, from embryological and pathological studies, we know it to be composed. It will be seen later, however, that the funiculus anterior of the white matter contains the anterior cerebro-spinal fasciculus, or anterior pyramidal tract (*fasciculus cerebrospinalis anterior*) and the so-called ground bundle of the anterior funiculus (*fasciculus anterior proprius*). The funiculus lateralis of the white matter contains the lateral cerebro-spinal fasciculus or lateral pyramidal tract (*fasciculus cerebrospinalis lateralis*), the direct cerebellar tract (*fasciculus cerebellospinalis*), Gowers' tract (*fasciculus anterolateralis superficialis*), and the lateral ground bundle (*fasciculus lateralis proprius*). The funiculus posterior of the white matter contains the tracts of Goll and Burdach (*fasciculus gracilis Golli et fasciculus cuneatus [Burdachi]*). The exact location of these various fasciculi and the mode of determining their location will be described farther on in this article.

The Coverings of the Cord (*Meninges*).—The spinal cord is surrounded in the vertebral canal by three membranes known as the spinal meninges; they are continuous above with the cerebral meninges. These three membranes are known as the *dura mater spinalis*, the *arachnoidea spinalis*, and the *pia mater spinalis*.

The dura mater is the strongest of the three and most external. The pia mater is the most delicate and the most internal, being applied everywhere closely to the cord. Between the two is the delicate non-vascular arachnoid. Between the dura mater and the inner surface of the bony vertebral canal is a cavity known as the epidural cavity (*cavum epidurale*). Between the dura mater and the arachnoid is a space called the subdural cavity (*cavum subdurale*). More important, however, is the space between the arachnoid and the pia mater. This is the subarachnoid cavity (*cavum subarachnoideale*); it contains the cerebro-spinal fluid (*liquor cerebrospinalis*).

The spinal dura mater (*dura mater spinalis*) extends from the foramen magnum to the level of the second or third sacral vertebra. It differs from the dura mater of the brain in that it splits into two layers, the outer one becoming continuous with the periosteum and ligaments of the vertebral canal, and the inner one forming the dura mater spinalis proper. The latter layer is the one usually referred to when the spinal dura mater is spoken of, but it must be remembered that the outer layer must be added to it to make it homologous with the dura mater encephali. In the space between the outer layer and the dura mater spinalis proper, that is in the cavum epidurale, there are besides fatty tissue and some plexuses of veins and lymph channels. The thickness of the dura mater spinalis in the adult averages 0.5–0.6 mm.

Some fibrous filaments from the anterior middle line of the dura run obliquely downward and ventralward to be inserted into the posterior longitudinal ligament of the spine. These are especially developed from the fourth lumbar vertebra downward, where they fuse to form a membrane, the so-called anterior sacrodural ligament (*ligamentum sacrodurale anterius*).

The spinal dura mater forms a separate sheath for each of the two roots, the anterior root and the posterior root, of each spinal nerve. These sheaths are continued upon the roots as far as the spinal ganglia, where they become lost in the connective tissue of the peripheral nerves and in the periosteum of the bones.

At its lower extremity the dura mater spinalis forms a sac which envelops the nerve roots of the cauda equina. This sac terminates at the level of the second or third sacral vertebra, but the dura mater is continued as a sheath closely applied to the filum terminale. This portion of it, a long, tough thread, called the filum duræ matris spinalis, is finally inserted upon the posterior surface of the os coccygis.

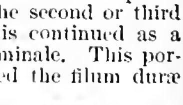


FIG. 4382.—Transverse Section Through the Coccygeal Segment of the Human Spinal Cord. Weigert's myelin-sheath stain. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.)

The dura mater spinalis is connected with the arachnoidea by means of the so-called subdural threads and with the pia mater by the denticulate ligament (*ligamentum denticulatum*). The subdural threads are very fine and short, are connected with the outer surface of the arachnoidea, and usually carry blood-vessels. The ligamentum denticulatum is a membrane stretched out in a frontal or coronal plane between the dura mater and the pia mater, just midway between the anterior and posterior surfaces of the cord; it passes between the anterior and posterior roots of the spinal nerves. Its medial border is firmly attached to the pia mater. Its lateral border is toothed, the teeth being inserted at their summits into the dura mater midway between the exits of adjacent spinal nerves. Intermediate between the teeth the lateral edge of the membrane forms free arcades. The number of teeth varies from eighteen to twenty-three. In the cervical region the N. accessorius runs behind the ligament.

The spinal arachnoid (*arachnoidea spinalis*) bounds the subdural cavity internally. It is to be noted that this is what is called by many anatomists the "visceral layer of the arachnoid"; below, it is reflected at the tip of the conus terminalis upon the dura mater to form the "parietal layer of the arachnoid" of various authors. This is why some writers call the cavum subdurale, situated between the parietal layer and the visceral layer of the arachnoid, the "arachnoid cavity." It is a serous cavity, like the pleura.

The arachnoid contains no blood-vessels; occasionally calcified plates are found in the membrane. The arachnoid is prolonged over the nerve roots, and over the summits of the teeth of the ligamentum denticulatum.

As a rule, it is very difficult to separate the arachnoid from the pia mater macroscopically. Key and Retzius describe the two together as the "meninx tenuis." These soft membranes, together, are also designated, the "leptomeninges," to distinguish them from the hard or tough membrane, the dura mater or "pachymeninx." If the visceral layer of the arachnoid be lifted carefully in the region of the cauda equina and cut through with fine scissors and then split longitudinally upward a little to one side of the median line, the space between the arachnoid and the pia mater, the subarachnoid cavity (*cavum subarachnoideale*), will be exposed. This space is not a free cavity, but really a communicating network of cavities, the walls of which are formed by delicate processes which extend between the arachnoidea and the pia mater. The meshes are filled with cerebro-spinal fluid. It is this cavum subarachnoideale which is tapped in Quincke's lumbar puncture when the needle is introduced opposite the interspace between the third and fourth lumbar vertebræ.

The spinal pia mater (*pia mater spinalis*), a very delicate membrane, closely envelops the spinal cord. It sends a fold into the depth of the fissura mediana anterior and elsewhere is intimately adherent to the external surface of the cord. It is extremely rich in blood-vessels, for it is in this membrane that the arteries which supply the cord undergo multiple subdivision before penetrating into the substance of the cord. When the pia mater is pulled off the cord, a number of minute arteries and capillaries are always torn out of the white substance; many of these are so small, however, that they cannot be made out with the naked eye.

The Blood-Vessels of the Spinal Cord (Fig. 4383).—The arterial supply of the spinal cord is derived from the vertebral arteries (*rami spinales Aa. vertebrales*), the ascending cervical arteries (*rami spinales Aa. cervicales ascendentes*), the posterior rami of the intercostal arteries (*rami spinales Rr. post. Aa. intercostales*), the posterior rami of the lumbar arteries (*rami spinales Rr. post. Aa. lumbales*), the ilio-lumbar arteries (*rami spinales Aa. iliolumbales*), and the lateral sacral arteries (*rami spinales Aa. sacrales laterales*).

Besides the rami spinales given off from the cervical portion of the A. vertebralis which pass through the foramina intervertebralia, each vertebral artery gives off an anterior spinal artery (*arteria spinalis anterior*) (O. T. A. vertebrospinalis anterior), and a posterior spinal artery (*A. spinalis posterior*) (O. T. A. vertebrospinalis posterior). The anterior spinal arteries of the two sides run medialward and caudalward and unite near the fissura mediana anterior somewhere between the foramen magnum and the level of the third cervical nerve. The trunk resulting from the fusion of the two, sometimes called the median anterior vertebro-spinal artery (*A. vertebrospinalis anterior mediana*), runs downward, unpaired on the anterior surface of the cord (not in the anterior median fissure), as far as the level of the fourth or fifth cervical nerve, where it ends by fusing with the *tractus arteriosus*

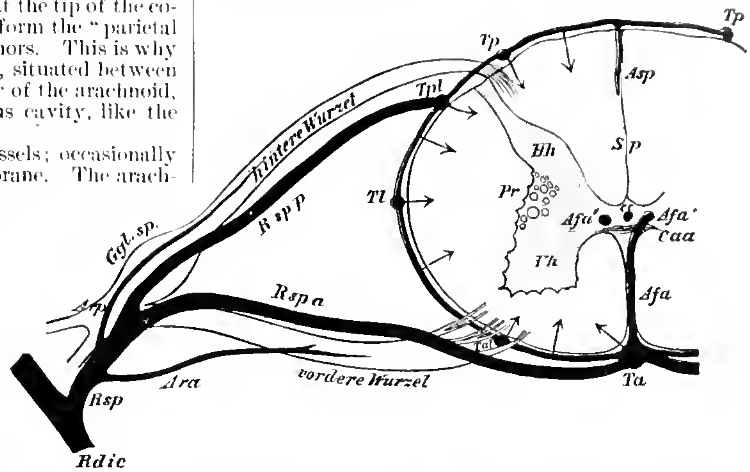


FIG. 4383.—Schematic Representation of the Arterial Vessels of a Segment of the Spinal Cord. For the sake of clearness the relative size relations of the vessels have been incorrectly drawn. *Afa*, Arteria fissuræ anterioris; *Afa'*, longitudinal central branch (ascending or descending) of *Afa*; *Afa"*, longitudinal central branch of the *Afa* next above or next below; *Ara*, arteria radicina anterior; *Arp*, arteria radicina posterior; *Asp*, arteria septi mediana posterior; *Caa*, commissura anterior alba; *Ce*, canalis centralis; *Ggl.sp.*, ganglion spinale; *Hh*, posterior horn of columna grisea posterior; *Vh*, anterior horn or columna grisea anterior; *Pr*, processus reticularis; *Rdic*, rhombus dorsalis seu posterior arteriæ intercostales; *Rsp*, ramus spinalis; *Rspa*, *Rspp*, ramus spinalis anterior, posterior; *Sp*, septum medianum posterius; *Ta*, *Tal*, *Tp*, *Tpl*, tractus arteriosus anterior, anterolateralis, lateralis, posterior, posterolateralis; *hintere Wurzel*, posterior root; *vordere Wurzel*, anterior root. (After T. Ziehen, in Bardeleben's "Handbuch der Anatomie des Menschen," Jena, 1899.)

spinalis anterior, the unpaired anterior median trunk resulting from anastomoses between the various spinal rami which come to the cord at the levels of the nerve roots all the way down as far as the filum terminale.

The posterior spinal artery given off by the vertebral artery is delicate, bends around the lateral margin of the medulla oblongata and runs downward near the nervus accessorius on each side. Having reached the level of the fourth or fifth cervical nerve, it fuses with the longitudinal trunk, known as the *tractus arteriosus posterolateralis*. The latter is made up of ascending and descending branches of the spinal rami of the A. vertebralis, Aa. intercostales, lumbales, iliolumbales, and sacrales laterales.

Besides this tractus arteriosus posterolateralis the posterior spinal artery from the vertebral gives off segmental branches, the so-called penetrating arteries (*Aa. penetrantes*), which, passing medialward and joining with branches of the Aa. intercostales, give rise to another longitudinal trunk called the *tractus arteriosus spinalis posterior*. The latter does not run in the middle line, but runs lengthwise of the cord just behind the line of entrance of the posterior roots. The tractus arteriosus posterolateralis, on the other hand, runs anterior to and lateralward from the sulcus lateralis posterior or line of entrance of the posterior roots.

The rami spinales of the rami posteriores of the Aa. intercostales, the rami spinales of the Aa. lumbales, the A. iliolumbalis, the A. sacralis lateralis, as well as of the A. cervicis ascendens all run through the intervertebral foramina. On passing through the foramen, each ramus spinalis gives off two delicate branches, one to the anterior root (*A. radicina anterior*), the other to the posterior root (*A. radicina posterior*), and then, near the spinal ganglion, usually divides into two branches, one going to the front of the cord (*ramus spinalis anterior*), the other going to the postero-lateral surface of the cord (*ramus spinalis posterior*). It is to be noted that there is not a ramus spinalis for every nerve-root level; and further, that sometimes when a ramus spinalis is present, it does not divide into two branches but becomes entirely an anterior ramus or a posterior ramus, more often the latter. Thus, according to Kadyi, there are, as a rule, eight large rami spinales anteriores and as many as sixteen or seventeen rami spinales posteriores. Among the rami spinales anteriores there is usually one which is much larger than the others; this is sometimes called the *A. magna spinalis*, or *A. radicalis magna*. It may be either on the left side or on the right side, and is most often found in the lower thoracic region at the level of the ninth, tenth, or eleventh thoracic nerve. These anterior spinal rami run medialward as far as the fissura mediana anterior, and there divide into an ascending and a descending ramus. These ascending and descending rami fuse with those of adjacent levels, thus helping to form the general *tractus arteriosus spinalis anterior* of Kadyi, which lies in the epipial areolar tissue in the cavum subarachnoideale.

The posterior spinal rami run also medialward to the surface of the cord, just in front of the line of entrance of the posterior roots, and like the anterior spinal rami also divide into ascending and descending limbs, which, anastomosing with corresponding limbs of rami of adjacent levels, give rise to the longitudinal trunk known as the *tractus arteriosus posterolateralis*. Other rami spinales posteriores run farther backward and medialward, pass between the posterior roots of different levels, or among the fila radicularia of the posterior roots to reach a position just medial from the sulcus lateralis posterior, where they divide into ascending and descending limbs, which contribute to another longitudinal anastomosis known as the *tractus arteriosus posterior*, to which the Aa. penetrantes from the A. spinalis posterior of the A. vertebralis has above been seen to contribute.

The tractus arteriosus posterolateralis lies lateral from the posterior root and outside the pia mater. The tractus arteriosus posterior lies medial from the posterior root, but inside the pia mater. Between the tractus arteriosus posterior of one side and its fellow on the opposite side pass transverse anastomoses like the rungs of a rope ladder. These transverse rami are particularly noticeable opposite the cervical and lumbar enlargements.

About one-half a centimetre above the tip of the conus medullaris a large transverse anastomosing branch can be seen, connecting the tractus arteriosus posterolateralis with the tractus arteriosus anterior. The presence of this large branch, sometimes called the *ramus cruciens*, explains why it is that fluid injected through the arteria spinalis magna may be distributed through the blood vascular network of the whole lower half of the cord on its posterior surface.

The anterior spinal artery and the tractus arteriosus spinalis anterior with which it is continuous give off two sets of branches. One set is central (*Aa. fissurales anteriores seu centrales*); the other set is lateral and peripheral (*rami laterales*).

The anterior fissural arteries (*Aa. fissurales anteriores seu centrales*), two hundred to two hundred and sixty in number, pass into the depth of the anterior median fissure and divide into two branches, one of the latter passing to the right, the other to the left. These branches go through the commissura anterior alba to the gray substance. They are known as the sulco-commissural arteries (*Aa. sulcocommissurales*). They often divide into ascending and descending branches which supply the whole of the gray matter of both the anterior and posterior horns, with the exception of the most peripheral part of the gray substance next to the white matter. The special branches going to the nucleus dorsalis are called the *arteriolæ columnarum Clarkii*.

The rami laterales go to the anterior roots and anastomose with the Aa. radicinæ anteriores; sometimes they form a longitudinal anastomotic chain called the *tractus arteriosus anterolateralis*. Other branches run backward to meet branches running forward from the tractus arteriosus posterolateralis and to form a lateral longitudinal anastomosis known as the *tractus arteriosus lateralis*.

The whole of the white matter and the most peripheral part of the gray matter get their blood supply from branches penetrating the cord from the tractus arteriosus anterolateralis, tractus lateralis, tractus posterolateralis, tractus posterior, and the Aa. radicinæ anteriores et posteriores. All these vessels have been grouped together by Adamkiewicz, under the name vasocorona.

From the transverse anastomoses between the tractus arteriosi posteriores of the two sides, certain unpaired posterior sulcal arteries (Aa. sulcales posteriores) penetrate into the cord in the region of the sulcus medianus posterior. These are much branched and supply the white substance, but scarcely go so deep as the posterior commissure. Branches from them may, however, reach the posterior horn or the nucleus dorsalis, and help to contribute to the blood supply of those parts. Minute vessels, entering the white substance between the fasciculus gracilis (Golli) and the fasciculus cuneatus (Burdachi), tolerably constant in the upper portions of the cord, have been called the interfunicular arteries (*Aa. interfuniculares*). The branches of the Aa. radicinæ posteriores et anteriores which reach the interior of the cord are small, but they play some part in the vascularization of the anterior and posterior horns of gray matter.

The arteries supplying the spinal cord are *end arteries* in the sense of Cohnheim. This is true of all the branches going in from the vasocorona as well as of the branches of the Aa. sulcales anteriores et posteriores. This explains the possibility of minute infarctions in the spinal cord. Despite the manifold longitudinal anastomoses throughout the whole length of the cord between the arteries of all levels, the cutting off of the blood supply through the lumbar and sacral vessels leads irrevocably to the death of the gray matter of the lower part of the cord, as has been over and again demonstrated by the experiment in which the abdominal aorta is compressed for half an hour.

The capillaries of the cord empty into the veins which form a network in the pia. Out of this network several large veins become differentiated, and these have been given special names. Thus, on the anterior surface of the cord are found: (1) *V. spinalis mediana anterior*; (2) *V. spinalis lateralis anterior dextra*; (3) *V. spinalis lateralis anterior sinistra*. On the posterior surface of the cord a median and two lateral veins can also be made out: (1) *V. spinalis mediana posterior*; (2) *V. spinalis lateralis posterior dextra*; and (3) *V. spinalis lateralis posterior sinistra*.

All these veins are devoid of valves. They empty through the *Vv. spinales anteriores et posteriores* largely into the *plexus venosi vertebrales interni*, and partly through the *Vv. intercostales* into the *V. azygos*. Some of the veins pass by way of the *Vv. lumbales* into the V. cava inferior. Other veins go by way of the *V. iliolumbalis* and the *Vv. sacrales laterales* into the V. hypogastrica, and so through the V. iliaca communis into the V. cava inferior.

The veins from the gray matter empty largely through the *Vv. fissurales anteriores* into the V. spinalis mediana anterior.

On Some Macroscopic Details

Upper and Lower Limits of Cord.—The upper limit of the spinal cord in man and mammals corresponds to the lateral exit of the uppermost fila radicularia of the first cervical nerve. This point corresponds ventralward to the lowermost bundles of the decussatio pyramidum. The lower level of the cord, that is its junction with the filum terminale, nearly always lies on a level corresponding to the lower third of the first lumbar vertebra or the upper third of the second lumbar vertebra, though in forty per cent. of the cases it may lie opposite the upper two thirds of the first lumbar or the lower two-thirds of the second lumbar vertebra. In one case it ended 5 mm. above the lower border of the twelfth thoracic vertebra, and it has been found as far down as the lower margin of the second lumbar vertebra. (See report of Committee of Collective Investigation of Anatomical Society of Great Britain and Ireland for the year 1893–94, *Jour. Anat. and Physiol.*, vol. xxix., 1895, pp. 35–60.)

Length of Spinal Cord.—The extreme variations in the male are 44–50.6 cm.; in the female, between 39 and 47 cm. As to the relation of the length of the cord and the length of the vertebral column, measured from the foramen magnum to the basis ossis sacri, it may be stated that when the average length of the spinal column is designated 100, the length of the male spinal cord will be 64, that of the female spinal cord about the same. The average length of the vertebral column in the male is 70 cm.; in the female, 68 cm. (Ziehen).

Frontal and Sagittal Diameters.—The minimum measurements are met with in the middle of the thoracic cord, where the sagittal diameter measures about 8 mm., the frontal diameter about 10 mm. The maximum measurements in the intumescentia cervicalis are met with opposite the fifth or sixth cervical vertebra, where the sagittal diameter is 9 mm., the frontal diameter 13–14 mm. The maximum measurements in the lumbar enlargement are met with opposite the twelfth thoracic vertebra, where the sagittal diameter is about 8.5 mm., the frontal diameter 11–13 mm.

Upper Level of Conus Medullaris.—Charpy designates as the arbitrary upper limit of the conus medullaris a plane lying between the exit of the fifth sacral nerve and the nervus coccygeus. According to this the conus medullaris would measure about 10 mm. in length. Raymond states that clinicians usually regard the conus medullaris as extending farther up, usually to the plane between the third and fourth sacral nerve roots. This would make the conus medullaris considerably longer.

Swellings Other Than the Cervical and Lumbar Enlargements.—The segmental swellings observable in animals and corresponding to the origins of the nerve roots, despite the assertions of some authors, are not observable in the human spinal cord. Two slight enlargements, however, are to be made out in the human conus medullaris and filum terminale. One is situated at the region of transition of the conus medullaris into the filum terminale and corresponds to the ventriculus terminalis; the other enlargement is situated about 1 cm. farther caudalward.

Weight of Spinal Cord.—The average weight has been given above. The weighings of Meckel are of interest. For the three-months' fœtus, 0.12 gm. (= $\frac{1}{8}$ of brain weight); for the five-months' fœtus, 0.36 gm. (= $\frac{1}{63}$ of brain weight); for the nine-months' fœtus, 2.7 gm. (= $\frac{1}{107}$ of brain weight); for a five-months' child, 5.4 gm.

The relative weight of the human spinal cord compared with the body weight is as 1:1849.5 in the adult; in the new-born as 1:851.4. The relation of the human spinal-cord weight to body weight in a whole series of animals is given in Ziehen (*loc. cit.*). Keith has made many such measurements. Ziehen also gives a long table in which the relative weight of the spinal cord to the brain weight in animals is given. It is smallest in man and increases in the animal series steadily downward until fish are reached. In the adult human being the relation has been variously estimated from as 1:19 to as 1:51.13. The latest figures are those of Mies, who gives the relative weight of the cord to the brain as 1:49.80 in the female and 1:51.13 in the male.

Relation of Individual Spinal-Cord Segments (*Root Levels*) *to Spinous Processes.*—A number of researches dealing with the problem are available. In general it may be said that in the cervical region of the vertebral column the ordinal numeral of the spinous process is to be increased by one in order to give the ordinal numeral of the cervical nerve root arising at the level of that spinous process. In the region of the thoracic vertebræ two is to be added to the number of the spinous process in the upper half, while from the sixth to the eleventh thoracic vertebræ one must add three. The lower part of the spinous process of the eleventh thoracic vertebra and the interspace between this spine and the next lower corresponds to the origin of the third to the fifth lumbar roots; the spinous process of the twelfth thoracic vertebra and the interspace between it and the spinous process of the first lumbar vertebra correspond to the origin of the sacral roots. It is to be remembered that when the trunk is strongly flexed, the spinal cord with attached nerve roots is displaced a few millimetres upward.

The levels of the nerve roots differ somewhat in the child from those in the adult, as Chipault has pointed out. Thus in children under seven years of age we add three to the ordinal numeral for the spinous process in the region of the first four thoracic vertebræ to get the number of the nerve root of corresponding level; and in the region of the fifth to ninth thoracic vertebræ four must be added.

The lower level of the dural sac in the adult corresponds about to the level of the spinous process of the first sacral vertebra.

The topographical relations between the spinous processes and the roots of the spinal nerves are well shown in the accompanying figure copied from Reid (Fig. 4384).

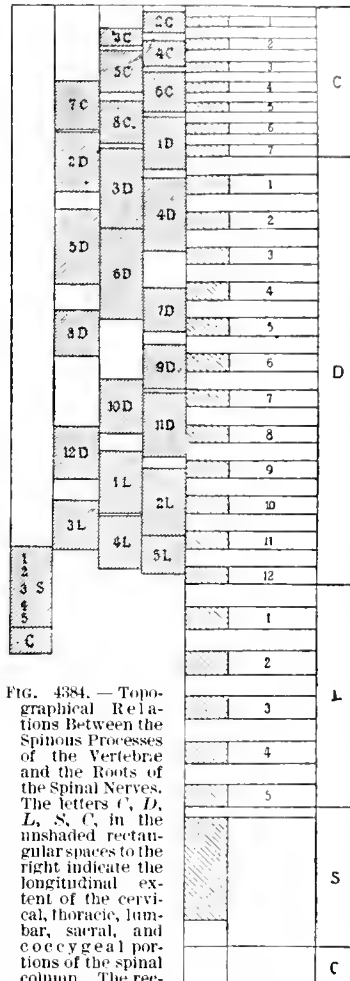


FIG. 4384. — Topographical Relations Between the Spinous Processes of the Vertebræ and the Roots of the Spinal Nerves. The letters *C, D, L, S, C*, in the unshaded rectangular spaces to the right indicate the longitudinal extent of the cervical, thoracic, lumbar, sacral, and coccygeal portions of the spinal column. The rectangular spaces shaded obliquely from the left and above downward and to the right indicate the longitudinal extent of the spinous processes of the individual vertebræ, while the rectangular spaces shaded obliquely from the right and above downward and to the left, indicate the region within which the origin of the individual roots of the spinal nerves is to be sought. The horizontal extent of the rectangular space has no significance. (After Reid, *Journ. Anat. and Physiol.*, Lond., 1889, p. 341.)

Cauda Equina.—Exact measurements have been made in an eighteen-year old individual of the distances between the root origins of the lumbar and sacral nerves and their foramina intervertebralia of exit by Testut. The distances measured are as follows:

N. lumbalis I........	114 mm.	N. lumbalis V.......	181 mm.
N. lumbalis II.......	138 "	N. sacralis I.........	188 "
N. lumbalis III......	151 "	N. sacralis V..	280 "
N. lumbalis IV......	163 "		

The filum terminale measures 16 cm. in length and extends from the third lumbar vertebra to the second coccygeal vertebra.

Length of Different Portions of the Cord.—Ravenel (*loc. cit.*) gives the following measurements:

	In the male.	In the female.
Pars cervicalis	9.9 cm.	9.6 cm.
Pars thoracalis	26.2 "	22.9 "
Pars abdominalis	5.1 "	5.7 "
Pars pelvina	3.6 "	3.1 "

The thirty-one segments corresponding to the thirty-one pairs of nerve roots have been carefully measured in six individuals by Lüderitz (for the figures his original article is referred to). The longest segment is found about the middle of the pars thoracalis and corresponds to the fifth, sixth, seventh, or eighth N. thoracalis. The shortest segment usually pertains to one of the lowermost Nn. sacrales. The difference in length of segments is dependent upon growth relations. The length of the segments increases steadily from the lower part of the sacral cord up to the middle of the pars thoracalis, the increase being at first slight, between the individual segments, but higher up it is greater. The length of the segments then diminishes until the lowermost portion of the pars cervicalis is reached. In the latter the segments measure about alike, though there are slight variations.

Number of Spinal Nerves.—Thirty one pairs of spinal nerves are usually described for human beings, though Rauber has demonstrated traces of a second and third coccygeal nerve lying close upon the filum terminale. Occasionally a sixth pair of sacral nerves is present when there are more sacral vertebræ than normal. Single thoracic nerves may be absent (Adamkiewicz).

Topographical Relations of Gray Matter and White Matter.—A most valuable contribution to our knowledge of the details of these relations is to be found in Bruce's "Atlas of the Human Spinal Cord." It includes photographs of transverse sections through every segment of the cord. It is of the greatest convenience in helping to localize the origin of transverse sections of the human cord of unknown level.

Exact measurements of the surface amounts of the white and gray substances at different levels of the cord have been made by Stilling, who even went so far as to measure the surface areas of the individual funiculi at nearly all levels of the cord. Stilling's book on the spinal cord is a mine of valuable statistics.

In Stilling's book (1859) there are data concerning the areas of white and gray substance in cross-sections of the spinal cord of a child of five years, and these data were later used by Woroschiloff (1874) for the construction of curves. His curves are those at present employed in most text-books, too often without any accompanying statement to show that they are based on the measurement from an immature cord. Another point to be borne in mind in dealing with curves representing the true relations between the gray and the white matter is this, that the segments of the cord should be represented in their true length. The curves worked out by Krause and Aguerre would have been more valuable had they paid attention to the lengths of the segments.

Donaldson and Davis, of the University of Chicago, have recently constructed curves in which not only the area of the entire section, but also those of the white matter and the gray matter separately are represented, and in which the age of the individual and the true lengths of the individual segments of the spinal cord have been regarded. The accompanying charts make clear at a glance the results obtained (Fig. 4385). Donaldson and Davis find that the form of the cord from one to five years is nearly like that of maturity, the difference being that in the mature cord the relative enlargement of the areas of the cross-sections has become greater in the thoracic region, but less in the sacral and coccygeal. At maturity the relative enlargement of the two intumescentiæ is practically the same as at the fifth year. From the fifth year to maturity both the length and the weight of the entire cord, as well as the area of the cross-sections at the level of the several segments, are increased. The sum of the areas of the white substance at maturity is ninety-eight per cent. greater than at five years, and that of the gray substance twenty-three per cent. greater. This absolute increase must represent either enlargement of elements

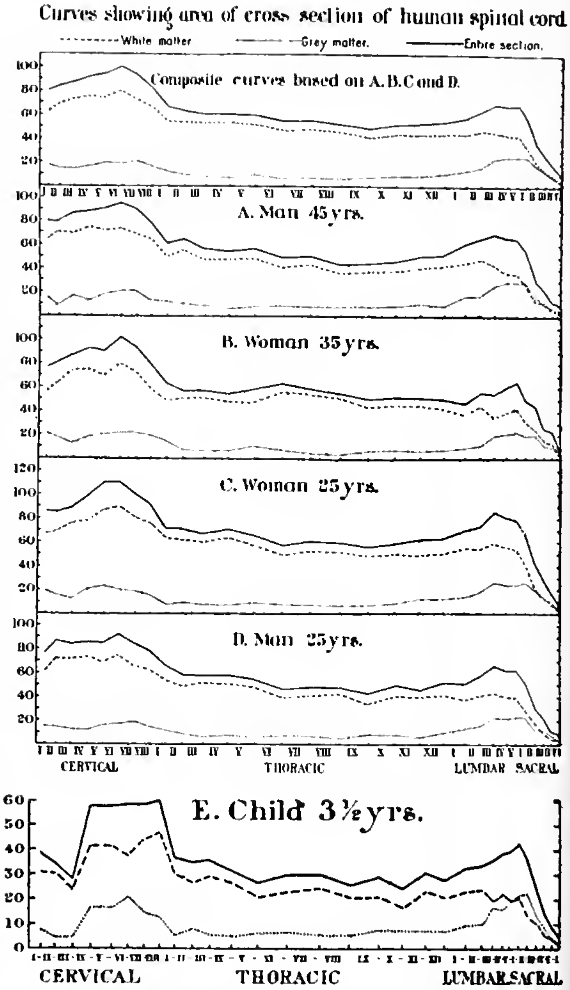


FIG. 4385.—This chart represents, by curves, the areas of the cross-sections of several human spinal cords, as well as the areas of the gray and white substances as they appear in each section. The base line in all the charts is just one-third the length of the spinal cord for which it stands, and is divided into lengths proportional to those of the spinal-cord segments of which it is composed. For the adult cord, the lengths of the segments given in the first table of the series were used in making the original drawings. On the ordinates one linear millimetre corresponds to one square millimetre of area. In all cases the measurement of the area was made up at the caudal end of the segment. In the order from above downward, the curves are as follows:

Composite Curve. Based on *A*, *B*, *C*, and *D*, to give the average of the several areas in the curves named. The curves are generalized and apply to a cord of medium length—44.6 cm. long. The influence of sex is neglected. The average age of the four cases would be thirty-three years. *Curve A*, Man of forty-five years; data for areas from Stilling. *Curve B*, Woman of thirty-five years; data for areas from Stilling. *Curve C*, Woman of twenty-five years; data for areas from Stilling. *Curve D*, Man of twenty-five years; data for areas from Stilling. *Curve E*, Child—data for areas from Stilling's observations on the cord of the two-year-old child. Length of segments from Lüderitz's observations on the cord of a three-and-a-half-year-old girl. Cord rather short. (After Donaldson and Davis.)

already completely developed or the development of elements still immature at the earlier age, or some combination of both of these processes. Yet the failure of the intumescentiæ to increase in their relative area in the mature cord or in their proportional length would seem to indicate that during this period there was no increase in their relative complexity, a result which, to say the least, was unexpected.

Central Canal.—This is very often invisible in the adult. Its lumen may vanish for considerable distances. It is stated that the central canal may remain open in perhaps ten per cent. of the cases throughout its whole length. Headward it is continuous with the central canal of the medulla oblongata (fourth ventricle), while caudalward it can be followed as far as the middle of the filum terminale, where it ends blindly.

The form of the canal is usually circular or elliptical; in the latter case the longer diameter is most often sagittal. In the intumescentia cervicalis it is a transverse ellipse, and in the intumescentia lumbalis a dorso-ventral ellipse.

The gray matter about it has a gelatinous appearance (substantia gelatinosa centralis) and is rich in neuroglia and derivatives of ependymal cells.

The expansion of the central canal, known as the ventriculus terminalis, lies so near the posterior surface of the cord that some authors have assumed that it opens into the sulcus medianus posterior. No such communication, however, exists.

Heterotopias of the Gray Matter.—Most of the so-called heterotopias or displacements of the gray matter, like many of the so-called doublings of the gray matter and of the cord, have doubtless been due to artefacts produced by violence on removal of the cord. The subject has been thoroughly discussed by van Gieson, who gives credence to a true heterotopia in only a very few of the published cases.

Glial Sheath and Glial Septa.—The thin layer of glia just outside the substantia alba, much thicker in some parts of the periphery than in others, is known as the glial sheath (*Gliahülle* of the Germans). Running in from this glial sheath through the white matter to the gray matter can be seen various glial septa. An excellent description of the distribution of these glial septa is to be found in Ziehen's article on the "Nervous System," in Bardeleben's "Handbook," pp. 57–62.

REFERENCES.

On General Macroscopic Appearances.

Edinger, L.: Vorlesungen über den Bau der nervösen Centralorgane des Menschen u. der Thiere, fifth edition, Leipzig, 1896.
Gehuchten, A. van: Anatomie du système nerveux de l'homme, third edition, Louvain, 1900.
Obersteiner, H.: Anleitung beim Studium des Baues der nervösen Centralorgane im gesunden und kranken Zustande, second edition, Leipzig u. Wien, 1892.
Spalteholz, W.: Hand Atlas of Human Anatomy (Eng. trans. by Barker), vol. iii., pp. 617–623.
Zieheo, T.: Makroskopische und mikroskopische Anatomie des Rückensmarks in Handbuch der Anatomie des Menschen. Herausg. von Prof. Dr. Karl von Bardeleben, Bd. iv., Abt. 1, Jena, 1899, pp. 1–76.

On the Coverings of the Cord or Meninges.

Bichat, Marie-Francois-Xavier; Traité des membranes en général et de diverses membranes en particulier, Paris, 1799.
Key, E. A. H., and Retzius, G.: Studien in der Anatomie des Nervensystems und des Bindegewebes, 1. Hälfte, Stockholm, 1875.
Trolard: Recherches sur l'anatomie des méninges spinales, des nerfs sacrés et du filum terminale dans le canal sacré. Arch. de Physiol. norm. et path., Paris, 1888, t. ii., 4 s., pp. 191–199.

On the Blood-Vessels of the Spinal Cord.

Adamkiewicz, A.: Die Blutgefässe des menschlichen Rückenmarks. Sitzungb. d. k. Akad. d. Wissensch., Math.-Natur. Cl., 3 Abt., Wien, Bd. lxxxiv., 1882, SS. 469–502.
Duret, H.: Sur la distribution des artères nourricières du bulbe rachidien. Arch. de Physiol. norm. et path., vol. v., pp. 97–114, 1873.
Kadyl, I.: Ueber die Blutgefässe des menschlichen Rückenmarks, Lemberg, 1889. The Polish original appeared in 1886.

On Some Macroscopic Details.

(a) *Upper and Lower Limits of Cord.*

Hirschfeld, Ludovicus: Névralogie et esthésiologie: traité et iconographie du système nerveux, et des organes des sens de l'homme, avec leur mode de préparation, Paris, 1853, p. 21.
Ziehen, T.: *Loc. cit.*

(b) *Length of Spinal Cord.*

Report of Committee of Collective Investigations of Anatomical Society of Great Britain and Ireland, *loc. cit.*
Fehst, C.: Ueber das Verhältniss der Länge des Rückenmarks zur Länge der Wirbelsäule. Inaug.-Diss., St. Petersburg, 1874. Chir. Centralbl., Bd. i., 18, 1874, p. 283.
Pfitzner, W.: Zur morphologischen Bedeutung des Zellkerns. Morph. Jahrb., Leipz., vol. xi., 1885–86, pp. 54–77.
Ravenel, M.: Die Massverhältnisse der Wirbelsäule und des Rückenmarks beim Menschen. Ztschr. f. Anat. u. Entwickelungsgesch., Leipz., Bd. ii., 1877, pp. 334–356.

(c) *Frontal and Sagittal Diameters.*

Ravenel, M.: *Loc. cit.*

(d) *On Upper Level of Conus Medullaris.*

Charpy, A.: Traité d'anatomie, by Poirier et Charpy, second edition, t. iii., 1901, pp. 169–170.
Raymond, F.: Hématomyélie du cone terminal. Nouvelle Iconographie de la Salpêtrière, Paris, 1895, vol. vii., pp. 149–157.

(e) *On Swellings Other than Cervical Enlargements.*

Bräutigam, H.: Vergleichende anatomische Untersuchungen über den Conus medullare. Jahrb. f. Psychiat., Bd. xi., Hft. i. u. 2, S. 111.
Collins, Samuel: A System of Anatomy Treating of the Body of Man, Beasts, Birds, Fishes, Insects, and Plants, London, 1685.
Foville, Achille-Louis: Traité complet de l'anatomie, de la physiologie et de la pathologie du système cérébrospinal, Paris, 1844.
Gall et Spurzheim: Anatomie et physiologie du système nerveux en général et du cerveau en particulier, avec observations sur la possibilité de reconnoitre plusieurs dispositions intellectuelles et morales de l'homme et des animaux par la configuration de leur têtes, Paris and Strasbourg, 1810–19.
Krause, W.: Der Ventriculus terminalis des Rückenmarks. Arch. f. mikr. Anat., Bonn, vol. xi., 1875, pp. 216–230.

(f) *Weight of Spinal Cord.*

Keith, A.: The Growth of Brain in Men and Monkeys, with a Short Criticism of the Usual Method of Stating Brain Ratios. Journ. of Anat. and Physiol., vol. xxix., 1895, p. 297
Meckel, J. F.: Handbuch der menschlichen Anatomie, Halle u. Berl., 1815–20, Bd. iii., S. 567.
Mies, J.: Ueber das Gewicht des Rückenmarks. Centralb. f. Nervenheilk. u. Psychiat., Bd. xvi., 1893, p. 547.—Einwirkung der von einem Homöopathen bei Facialislähmung angewandten Röntgenstrahlen auf Haut und Haar. Deutsch. med. Wochenschr., Bd. xxiii., 1897, Leipz. u. Berl., S. 417.
Vierordt, H.: Daten und Tabellen, Jena, 1893.
Ziehen, T.: *Loc. cit.*

(g) *On Relation of Root Levels to Spinous Processes.*

Chipault, A.: Rapports des apophyses épineuses avec la moëlle, les racines médullaires et les méninges, Paris, 1894, p. 36 *ff.*
Pfitzner, W.: Ueber Wachstumsbeziehungen zwischen Rückenmarks- u. Wirbelkanal. Morph. Jahrb., Leipz., Bd. ix., 1883, S. 161.
Reid, R. W.: Relations Between the Superficial Origins of the Spinal Nerves from the Spinal Cord and the Spinous Processes of the Vertebræ. Journ. Anat. and Physiol., London, vol. xxiii., 1888–89, pp. 341–353.

(h) *On Number of Spinal Nerves.*

Adamkiewicz, A.: Ueber den häufigen Mangel dorsaler Rückenmarks beim Menschen. Virchow's Archiv, Bd. 88, 1882, S. 388.
Rauber, A.: Die letzten spinalen Nerven und Ganglien. Morph. Jahrb., Bd. 3, 1877, S. 603.

(i) *On Length of Different Portions of Cord.*

Lüderitz, Carl: Ueber das Rückenmarkssegment. Arch. f. Anat u. Physiol., 1881, Anat. Abt., S. 423–494.
Ravenel, M.: *Loc. cit.*

(j) *On Topographical Relations of Gray and White Matter.*

Bruce, A.: An Atlas of the Human Spinal Cord, Edinburgh, 1901.
Donaldson, H. H., and Davis, D. J.: A Description of Chart Showing the Areas of the Cross-sections of the Human Spinal Cord at the Level of Each Spinal Nerve. Journ. Comp. Neurol., Granville, vol. xiii., 1903, pp. 18–39.
Krause, B., and Aguerre, J.: Untersuchungen über den Bau des menschlichen Rückenmarkes mit besonderer Berücksichtigung der Neuroglia. Anat. Anz., Jena, Bd. 18, 1900, pp. 239–252.
Stilling, B.: Neue Untersuchungen über den Bau des Rückenmarks, Cassel, 1859.
Woroschiloff: Der Verlauf der motorischen und sensiblen Bahnen durch das Lendenmark des Kaninchens. Berichte über d. Verhandl. d. Königl. Sächs. Gesellsch. d. Wissensch. zu Leipz., Bd. 26, 1874, pp. 248–304.

(k) *On the Central Canal.*

Stilling, B., and Wallach, J.: Untersuchungen über die Textur des Rückenmarks, Leipzig, 1842.
Ziehen, T.: *Loc. cit.*

(l) *On Heterotopias.*

Van Gieson, I.: A Study of the Artefacts of the Nervous System; the Topographical Alterations of the Gray and White Matters of the Spinal Cord caused by Autopsy Bruises and a Consideration of the Heterotopia of the Spinal Cord. New York Med. Journ., vol. lvi., 1892, pp. 337, 365, 421.
Cramer, A.: Faserschwund nach Insolation. Centralbl. f. allg. Path. u. path. Anat., Jena, Bd. i., 1890, SS. 185–194.
Kronthal, P.: Ueber Heterotopie grauer Substanz im Rückenmark. Neurol. Centralbl., Leipz., vol. vii., 1888, SS. 97–105.
Pick: Beiträge zur Pathologie und pathologische Anatomie des Centralnervensystems, Berlin, 1898, S. 310.
Kronthal, P.: Zwei pathologisch-anatomisch merkwürdige Befunde am Rückenmark. Neurol. Centralbl., Leipz., Bd. ix., 1890, pp. 393–395.

(m) *On Glial Sheath and Glial Septa.*

Arnold, F.: Bemerkungen über den Bau des Hirns und Rückenmarks nebst Beiträgen zur Physiologie des zehnten und eilften Hirnnerven, mehreren kritischen Mittheilungen, sowie verschiedenen pathologischen und anatomischen Beobachtungen, Zürich, 1838.
Frommann, C.: Untersuchungen über die normale und pathologische Anatomie des Rückenmarks, Jena, 1864, vol. i., S. 24.
Ziehen, T.: *Loc. cit.*

Microscopic Anatomy of the Spinal Cord.

We have now completed the description of the grosser anatomy of the cord, and shall next pass on to an account of the microscopic appearances. The anterior and posterior roots will first be described, then the white matter of the cord, and lastly, the gray matter. A description of the appearances as met with in ordinary sections will be given first, and afterward the special facts brought to light by special methods will be detailed. In what follows, the reader is expected to have some familiarity with the histology of nerve cells and nerve fibres, to know what is meant by a neurone, to understand the terms dendrites, axone, collaterals, telodendrion, perikaryon, etc. A brief account of all these features will be found in this Handbook under *Brain, Histology of*, Vol. II., pp. 331–344. A reader approaching the microscopic anatomy of the spinal cord for the first time would do well to read this section before going further.

The Anterior Roots.—The exit of the fila radicularia at the sulcus lateralis anterior has already been described. A cross-section of an anterior nerve root shows that it consists almost entirely of medullated nerve fibres, all of which represent axones of lower motor neurones, the cell bodies or perikaryons of which are situated in the columna anterior grisea or anterior horn, of the same side of the spinal cord. Generally speaking, the calibre of the nerve fibre of the anterior root exceeds that of the nerve fibre of the posterior roots. This is especially true of the anterior roots of the Nn. cervicales, Nn. lumbales, and upper Nn. sacrales, where fine fibres occur only singly in the anterior roots. On the other hand, in the anterior roots of the Nn. thoracales and lower Nn. sacrales there are numerous fibres of fine calibre often arranged in groups in among the larger fibres. The fibres of the anterior roots of the cervical nerves vary from 1.3 μ to 23.9 μ. Over half the fibres of these roots have a calibre of from 13.3 μ to 16 μ. The large fibres predominate in the lumbar region, where one-half of all the fibres measure from 21.3 to 23.9 μ (Siemerling). If fibres of more than 5 μ are called *coarse*, and fibres of smaller size are called *fine*, there are five times as many coarse as fine fibres in the anterior roots of the cervical nerves; three times as many fine as coarse in the anterior roots of the thoracic nerves; six times as many coarse as fine in the lumbar roots; four times as many coarse as fine in the sacral roots; and three times as many fine as coarse in the coccygeal nerve root. According to Schwabel the greater the length of a nerve, the larger the calibre of its root fibres, a conclusion which he drew largely from the predominance of the coarser fibres in the cervical and lumbo-sacral roots.

The total number of anterior root fibres in a woman twenty-six years old was found by Stilling to be 303,265. The older counts of Birge in the frog have been extended through the researches of Hardesty. For the details the original article of the latter may be consulted.

The fibres of the anterior roots are surrounded by a myelin sheath before they leave the cord, but only from the point where they leave the pia are they surrounded by a neurilemma and by the connective-tissue sheath, sometimes called the sheath of Henle.

Single nerve cells or small groups of ganglion cells have been observed occasionally outside the spinal cord among the fibres of the fila radicularia of an anterior root. His and Dohrn demonstrated that some neuroblasts could, in the embryo, pass through the marginal veil and get out into the anterior roots. Whether the nerve cells which have been observed in these roots in the adult are derivatives of neuroblasts from the anterior horns, or are dislocated spinal ganglion cells or sympathetic ganglion cells, has not yet been decided. Islands of glia cells have been seen among the anterior roots (Petrone) and the peculiar plaques observed by Hoche in anterior roots may be glial in nature. Ziehen suggests that they are to be looked upon as cone-like dislocations of the glial sheath of the spinal cord.

References.

Birge, E. A.: Die Zahl der Nervenfasern und der motorischen Ganglienzellen im Rückenmark des Frosches. Arch. f. Anat. u. Physiol., Physiol. Abthl., Leipzig, 1882, SS. 435–480.
Hardesty, I.: The Number and Arrangement of the Fibres Forming the Spinal Nerves of the Frog (Rana virescens). Journ. Comp. Neurol., Granville, vol. ix., 1899, pp. 64–112.—Further Observations on the Conditions Determining the Number and Arrangement of the Fibres Forming the Spinal Nerves of the Frog (Rana virescens). Journ. Comp. Neurol., Granville, vol. x., 1900, pp. 323–354.
Hoche, A.: Beiträge zur Kenntniss des anatomischen Verhaltens der menschlichen Rückenmarkswurzeln im normalen und im krankhaft veränderten Zustande, Heidelberg, 1891.
Petrone, L. M.: Sur la structure des nerfs cérébro-rachidiens. Internat. Monatschr. f. Anat. u. Physiol., Leipz., v., 1888, pp. 39–47.
Schwalbe, G.: Ueber die Kaliberverhältnisse der Nervenfasern, Leipzig, 1882.
Siemerling, E.: Anatomische Untersuchungen über die menschlichen Rückenmarkswurzeln, Berlin, 1887.

The Posterior Roots.—In general the fibres of the posterior roots represent the central axones of the peripheral sensory neurones, the cell bodies or perikaryons of which are situated within the spinal ganglion. The fibres of the posterior roots are in general of finer calibre than those of the anterior roots, though the actual measurements vary between 1.3 and 23.9 μ; the same extremes are noted for the anterior roots (Siemerling). In the cervical posterior roots three-quarters of all the fibres have a calibre varying between 8 and 13.3 μ. In the thoracic posterior roots, two-thirds of all the fibres measure 13.3 μ or more. In the lumbar roots a fifth of all the fibres measure 21.3 μ, about one-quarter of them 18.6 μ, and still another quarter 16 μ. The proportion of fine fibres to coarse fibres in the cervical roots is as 21:20; in the thoracic roots as 7:5; in the lumbar roots as 8:9; in the sacral roots as 4:3; and in the coccygeal root as 17:14. The posterior root bundles are somewhat constricted at the point where they pass through the pia and enter the glial sheath of the cord. According to a much considered theory, proliferation of the connective tissue at this spot with increased constriction of the dorsal root fibres is the primary pathological change in tabes dorsalis (Obersteiner and Redlich).

According to Stilling, the number of all the posterior root fibres in a woman, twenty-six years old, was 504,473. Birge's counts concern the frog only. Lewin and Bühler have made counts, the former stating that in the rabbit the number of fibres peripheral from the ganglion is larger than that of the fibres entering the cord by 19 per cent. in the rabbit, and the latter maintaining an excess of 25.5 per cent. in the frog. Hardesty has shown for the frog that the number of fibres in the dorsal root decreases as the fibres pass from their cells of origin in the spinal ganglion. Dale made counts of the fibres on both sides of the spinal ganglion and found an average excess of only 0.5 per cent. on the distal side. The theories explaining the distal excess have been discussed by Hardesty, who made many counts, and whose article is referred to above.

A most important study of the medullated nerve fibres in the dorsal roots of the spinal nerves of man is that of Ingbert. In brief he has found:

1. The total area of the cross-sections of the dorsal roots of the left spinal nerves of a large man is 54.93 mm.
2. The total number of medullated nerve fibres in the dorsal roots of the left spinal nerves of the same man is 653,385; and the total number on both sides would therefore be about 1,306,770.
3. There are, on the average, 11,900 medullated nerve fibres to every square millimetre of the cross-sections of the dorsal roots of man.
4. There is a close relation between the area of the cross-sections of the dorsal roots and the number of nerve fibres which they contain (see Chart III.).
5. The small fascicles of a dorsal spinal root in general contain nerve fibres of small calibre.

Spinal Cord.

6. The number of nerve fibres per square millimetre of the cross-section may vary considerably in the different fascicles of the same dorsal spinal root.

7. According to the estimate made, about sixty per cent. of the medullated nerve fibres in the dorsal roots of the spinal nerves of both sides, or 784,062 fibres, go to innervate the dermal surface, and about forty per cent., or 522,708, are sensory fibres distributed to muscles and deep tissues. The afferent fibres of spinal-ganglion origin, passing in the rami communicantes, are not separately considered in this estimate, but for the moment are classed with those passing to the deeper tissues.

8. According to Ingbert's estimate, one cutaneous nerve fibre in the dorsal spinal roots innervates on the average 1.7 mm.^{2} of the dermal surface of the arm, 1.4 mm.^{2} of that of the head and neck, 2.7 mm.^{2} of that of the entire body, 3.2 mm.^{2} of that of the leg, and 4.1 mm.^{2} of that of the trunk; and for each additional class of nerve fibres assumed, we must increase the area proportionately.

9. If we assume with Foster four classes of cutaneous nerve fibres, then each fibre will have to innervate on the average 5.6 mm.^{2} of the dermal surface of the head and neck and 16.4 mm.^{2} of the dermal surface of the trunk.

Very interesting, too, are the discussions of Dunn on the number and on the relation between diameter and distribution of the nerve fibres innervating the leg of the frog. A description of these findings would exceed the limits of the space here provided, but references to the original articles are given below.

According to Lewin, there are in the rabbit many more spinal ganglion cells than there are fibres in the dorsal root. Thus for 3,200 dorsal root fibres, he found as many as 10,400 spinal ganglion cells. The neurilemma as well as Henle's sheath is arrested at the moment each posterior root fibre passes through the pia. The intramedullary continuations of the posterior root fibres are devoid of neurilemma, though they possess myelin sheaths.

Groups of ganglion cells in the dorsal roots at some distance from the spinal ganglion have been over and again demonstrated. Hyrtl spoke of them as *ganglia aberrantia*. Some of these may be true spinal ganglion cells; others may be sympathetic ganglion cells dislocated from the posterior horn of the gray matter of the cord.

REFERENCES.

Bühler, A.: Untersuchungen über den Bau der Nervenzellen. Verhandl. d. physik.-med. Gesellsch. zu Würzburg., n. F., Bd. xxxi., 1896.

Dunn, Elizabeth H.: The Number and Size of the Nerve Fibres Innervating the Skin and Muscles of the Thigh in the Frog (Rana virescens brachycephala Cope). Journ. Comp. Neurol., vol. x., 1900, pp. 218-242.—On the Number and on the Relation between Diameter and Distribution of the Nerve Fibres Innervating the Leg of the Frog (Rana virescens brachycephala Cope). Journ. Comp. Neurol., vol. xii., 1902, pp. 297-328.

Hyrtl, J.: Topographische Anatomie.

Ingbert, C.: On the Number of the Medullated Nerve Fibres in the Dorsal Roots of the Spinal Nerves of Man. Journ. Comp. Neurol., Granville, vol. xiii., 1903.

Lewin, Th.: Ueber die Zahlen der Nervenfasern und Ganglienzellen des Kaninchens. Centralb. f. Physiol., Bd. x., 1896, SS. 437, 465.

Obersteiner, H., and Redlich, E.: Ueber Wesen und Pathogenese der tabischen Hinterstrangsdegeneration, Wien, 1894.

Anterior Funiculus.—The total number of fibres in the anterior funiculus in the frog has been counted by Gaule. In human beings a rather rough estimate has been made by Ziehen, whose numbers are as follows: Intumescentia cervicalis, 46,000; midthoracic region, 28,000; intumescentia lumbalis, 42,000. The same investigator has studied carefully the calibre of the nerve fibres in the anterior funiculus. He finds that fine and coarse fibres are mixed in the upper cervical region, the coarser fibres being toward the periphery and close to the fissura mediana anterior; the finer fibres being relatively more numerous near the gray matter (Figs. 4386 and 4387). The same is true of the cervical enlargement; in fact this mode of distribution holds more or less also through the whole of the pars thoracalis. In the intumescentia lumbalis and in the conus medullaris the distribution of fine and coarse fibres is more even, though on the whole the coarser fibres are somewhat diminished in numbers. It is rare to find fibres measuring more than 20 μ in diameter in the anterior funiculus in any part of the cord. Fibres of 9–12 μ are very numerous. Of the finer fibres some have a diameter no greater than 1.5 μ.

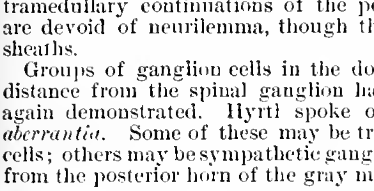


FIG. 4386.—Fibre Grouping in the Funiculus Anterior Near the Anterior Horn. (After T. Ziehen.)

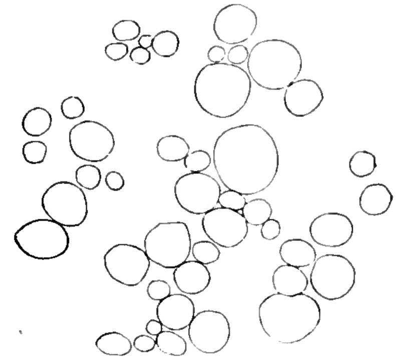


FIG. 4387.—Fibre Grouping in the Periphery of the Funiculus Anterior, Intumescentia Cervicalis. Nigrosin staining. Zeiss Oc. 2, Obj. F. (After T. Ziehen.)

The longitudinal fibres which make up the majority of the fibres of the funiculus anterior run for long distances. A careful study reveals fibres, especially in the medial posterior portion, turning partly posteromedialward to run in the commissura alba anterior, partly lateralward or posterolateralward, to turn into the columna grisea anterior or anterior horn. The fibres which go from the anterior horn to the anterior root are to be seen, running horizontally through the funiculus anterior. Very numerous collaterals are given off in a horizontal or a slightly inclined direction from the fibres of the funiculus anterior.

The distribution of the glia in the anterior funiculus has been described by Gierke, by Weigert, and by Ziehen. True nerve cells are seldom found among the fibres of the funiculus anterior except in the lowermost part of the conus medullaris. Even here they may be confused with large glia cells.

It is in the funiculus anterior that the so-called colossal fibres of lower vertebrates are found. In Teleosts two colossal fibres, often called Mauthner's fibres, are found between the so-called commissura accessoria of fishes (which run from the ventral horn transversely through the funiculus anterior accompanied by gray substance) and the central part of the gray substance. Each of these fibres may have a diameter measuring as much as 110 μ.

REFERENCES.

Gaule, Justus: Zahl und Vertheilung der markhaltigen Fasern im Froschrückenmarken. Abhand. d. math.-phys. Cl. d. k. Sächs. Gesellsch. d. Wissensch., Leipz., Bd. xv., 1890, S. 739.

Gierke, Hans: Stützsubstanz des Centralnervensystems. Arch. f. mikr. Anat., Bonn, Bd. xxv., S. 547.

Weigert, C.: Kenntniss der normalen menschlichen Neuroglia. Festschrift z. fünfzigjährigen Jubiläum des ärz. Vereins zu Frankfurt a/M., 1895.

Ziehen, T.: *Loc. cit.*

Lateral Funiculus.—There are counts of the nerve fibres available for the frog (Gaule) and for human beings (Ziehen). In man exclusive of Lissauer's fasciculus it is estimated that the numbers are about as follows: Intumescentia cervicalis, 275,000; midthoracic region, 240,000; intumescentia lumbalis, 260,000. If the region through which the anterior root fibres pass be added to the lateral funiculus, the numbers just given must be increased by 35,000, 24,000, and 37,000 respectively.

There are great differences in the calibre of the fibres in different parts of the lateral funiculus. Indeed a low-

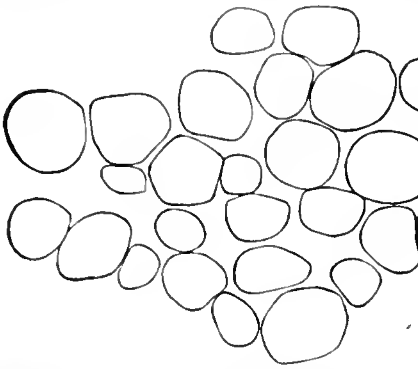


Fig. 4388.—Fibre Grouping in the Periphery of the Funiculus Lateralis. (After T. Ziehen.)

power study of the healthy lateral funiculus will permit one by means of the calibre of the fibres alone to delimit with some degree of accuracy the topographical distribution of the main fasciculi of which the lateral funiculus is made up. At the periphery the coarse fibres predominate, the dorsal portion of the periphery consisting almost exclusively of very coarse fibres (direct cerebellar tract). In the inner portions fine fibres predominate (pyramidal tract and ground bundle) (Figs. 4388 and 4389). The finest fibres in the lateral funiculus, at least in the pars cervicalis, are close to the gray substance (Flechsig's seitliche Grenzschicht der grauen Substanz).

While the majority of the fibres in the lateral funiculus run longitudinally, some fibres running transversely can

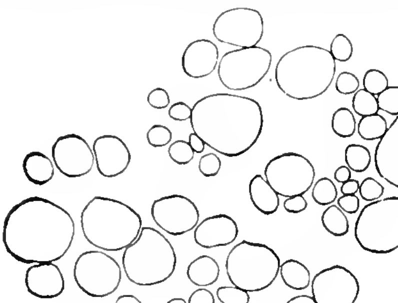


Fig. 4389.—Fibre Grouping in the Interior of the Area of the Lateral Pyramidal Tract; Intumescentia Cervicalis. Nigrosin staining. Zeiss Oc. 2, Obj. F. (After T. Ziehen.)

be seen. Among these may be mentioned the lateral fibres of the anterior root, fibres from the lateral margin of the anterior horn which pass lateralward or dorsolateralward and later assume a longitudinal direction, fibres from the lateral horn which pass dorsolateralward or lateralward, and especially fibres which pass from the neighborhood of the nucleus dorsalis for a short distance transversely and then obliquely upward and lateralward toward the direct cerebellar tract at the dorsolateral periphery. Bundles of fibres belonging to the root of the N. accessorius are to be seen in the upper and middle cervical region. They emerge from the gray matter in the region of the formatio reticularis.

Coming off from the fibres of the lateral funiculus, there can be seen, especially in vertical sections, large numbers of collaterals. They are particularly numerous as the gray substance is approached.

The glia distribution in the lateral funiculus presents no remarkable features.

A relatively large number of ganglion cells stand in close relation to the lateral funiculus. They are situated in the formatio reticularis and in the columna grisea lateralis.

In lower animals "colossal fibres" in various groups have been described in the lateral funiculus.

Posterior Funiculus.—Ziehen's counts of the nerve fibres yield for the posterior funiculus, exclusive of Lissauer's fasciculus, the following figures: Intumescentia cervicalis, 174,000; midthoracic region, 75,000; intumescentia lumbalis, 85,000.

The calibre of the nerve fibres in the posterior funiculus varies greatly and the distribution of the coarse and fine fibres is irregular. It is not easy to set up a sharp distinction between the distribution in Goll's fasciculus (Fig. 4390) and that in Burdach's. At the junction of Goll's and Burdach's fasciculi, the fibres are more closely crowded together than elsewhere. This is the so-called "band of condensation" of Sherrington.

The calibre of the fibres in Lissauer's fasciculus is very small, the average diameter probably not exceeding 2 or 3 μ. This seems to be due to the fact that when the fibres of the posterior root enter the white matter of the cord, the coarse fibres become separated from the fine, the former going into the so-called "entry zone" medial from the posterior horn, the latter accumulating in the interval between the substantia gelatinosa and the periphery of the cord to form Lissauer's fasciculus.

The main stems of the posterior root fibres may run for some distance forward and medialward before undergoing bifurcation into an ascending and a descending limb. In addition to these transverse fibres, one meets at all levels of the cord some longitudinal fibres, which are becoming transverse in order to run in and terminate in the gray matter, and more especially great groups of collaterals given off from different parts of the white matter to run horizontally or somewhat obliquely toward the gray substance. The collaterals of the posterior root fibres are confined chiefly, in the upper part of the cord, to Burdach's fasciculus. It is rare to find them given off from the fibres of Goll's fasciculus. The collaterals of the posterior funiculus are of the highest importance and will be described more fully farther on.

For a description of the glia of the posterior funiculus Weigert's book should be consulted.

It is rare to find dislocated ganglion cells among the fibres of the posterior funiculus, though Sherrington has occasionally met with isolated nerve cells, presumably derived from the nucleus dorsalis (Clarkii).

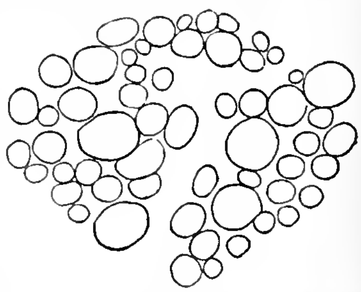


Fig. 4390.—Fibre Grouping in the Fasciculus Gracilis Golli; Intumescentia Cervicalis. Nigrosin staining. Zeiss Oc. 2, Obj. F. (After T. Ziehen.)

The "colossal fibres" so often found in the anterior lateral funiculus of lower vertebrates apparently do not occur in the posterior funiculus.

Each posterior root fibre bifurcates at an angle of from 120° to 160° into a short descending limb and a long ascending limb. The bifurcation takes place at a node of Ranvier. Some collaterals are given off from the root fibre before its bifurcation, but more from the limbs of bifurcation near their origin. It is these limbs of bifurcation which make up the majority of the fibres of the white matter of the posterior funiculus. Since these fibres have their origin in the cell bodies situated in the spinal ganglia, that is, outside the spinal cord, they are often referred to as *exogenous* fibres. As we shall later see, the posterior funiculi contain in addition some *endogenous* fibres, that is, fibres which are processes of cell bodies that are situated within the gray matter of the cord.

REFERENCES.

Flatau, E.: Das Gesetz der excentrischen Lagerung der langen Bahnen im Rückenmark. Ztschr. f. klin. Med., Berl., Bd. xxxiii., 1897, SS. 55-152.

Lenhossék, M. von: Der feinere Bau des Nervensystems im Lichte neuester Forschungen, Berlin, 1895.

Lissauer, H.: Beitrag zum Faserverlauf im Hinterhorn des menschlichen Rückenmarks und zum Verhalten desselben bei Tabes dorsalis. Arch. f. Psychiat. u. Nervenkr., Berl., Bd. xvii., 1886, SS. 377-438.

Sherrington, C. S.: Notes on the Spinal Portion of Some Ascending Degenerations. Journ. of Physiol., Lond. and Camb., vol. xiv., 1893, p. 289.—On Outlying Nerve Cells in Mammalian Spinal Cord. Proc. Roy. Soc., Lond., vol. xlvii., 1889, pp. 144-146.

Waldeyer, W.: Das Gorilla-Rückenmark. Abhandl. d. k. Akad. d. Wissensch. z. Berlin, Berl., 1889, S. 91.

Westphal, C.: Anatomischer Befund bei einseitigem Kniephänomen. Arch. f. Psychiat., Berl., Bd. xviii., 1887, S. 629.

Ziehen, T.: *Loc. cit.*

Columna Grisea Anterior.—The form and size of the columna grisea anterior or anterior horn varies much, as seen in transverse section, at different levels of the cord. There is a type of form, however, which is characteristic of each segment, and for corresponding parts of segments in different cords, as will be easily seen by a study of the accurate photographic reproductions of sections through each of the segments of the human spinal cord pictured in Alexander Bruce's "Topographical Atlas." An examination of these figures shows that all the motor cells of the anterior horn in the cervical and lumbar regions and in the first thoracic segment may be divided into a *medial* and a *lateral* column of cells. I shall follow Bruce's description closely.

The *medial column* of cells is present throughout the whole length of the cord above the level of N. sacralis V., with the exception of the levels of N. lumbalis I., N. sacralis I., and the upper level of N. sacralis II. This medial column of cells in some sections forms a single group, but in others, especially in the pars thoracalis, is differentiable into an anterior medial column and a posterior medial column. The cells of the latter are smaller than those of the former.

The greatest development of the *anterior medial group* is met with in the levels of the N. cervicalis IV. et V., where besides the cells ordinarily present there is a large group of cells just lateral from them, possibly corresponding to the spinal centre for the N. phrenicus.

Below the level of the N. cervicalis V., the cells of the medial column gradually diminish in number in the cervical segment. In some sections only one or two cells, or even none at all, may be found. The number is again suddenly increased in the lower part of the eighth cervical segment, and this increase, according to Bruce, is maintained throughout the whole of the pars thoracalis.

It is well represented also in the four upper lumbar segments. In the first three lumbar segments Bruce described a few cells in a small anterolateral angle which may be included along with the medial group, or may be regarded as a special anterior group. The medial group of cells is absent in the fifth lumbar, first sacral, and upper part of the second sacral segments, but reappears in the lower part of this segment and is continued as far as the fourth sacral segment. It is absent again below this level.

The *lateral column* of cells is subdivisible in the cervical region into an *anterolateral* (ventrolateral) and a *posterolateral* (dorsolateral) cell column. In the lowermost part of the pars cervicalis an additional group, sometimes designated the *post-posterolateral*, exists. It is also to be found in the first thoracic segment, though the lateral cell column appears to be otherwise entirely unrepresented in the pars thoracalis. In the pars lumbalis, however, in the levels of origin of the Nn. lumbales and upper Nn. sacrales, both an anterolateral and a posterolateral column of cells are present. There is also to be made out, from the level of N. lumbalis II. to the upper part of the segment corresponding to N. sacralis II., a *central* group of nerve cells. Further, a post-posterolateral group of nerve cells (Onufrowicz) exists in the first, second, and third sacral segments. This is the group designated by van Gehuchten as the secondary posterolateral group.

In the pars cervicalis the anterolateral group is really subdivisible into two sections: an *upper anterolateral* section, which extends from the upper limits of the fourth to the upper part of the second segment, attaining its maximum development in the fifth segment; and a *lower anterolateral* group, which extends from the upper third of the sixth to the middle of the eighth segment (Fig. 4391), attaining its maximum development at the seventh segment. The two anterolateral groups thus coexist in the sixth segment (Bruce).

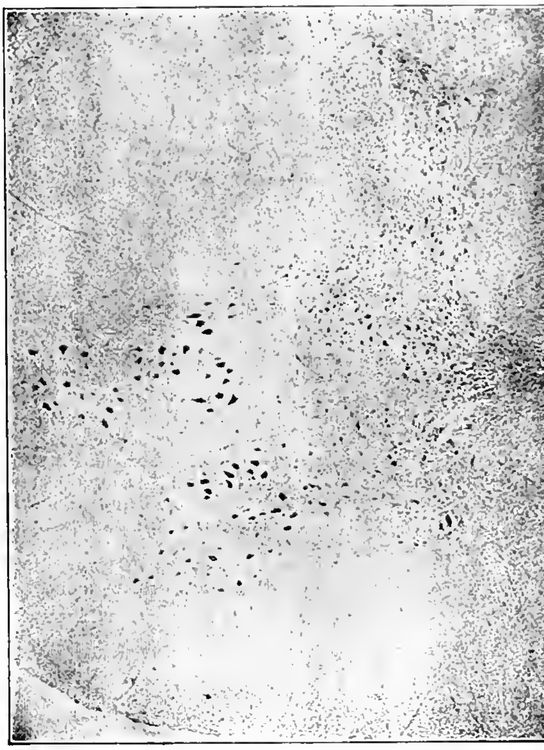


FIG. 4391.—Toluidin Blue Preparation of the Upper Part of the Eighth Cervical Segment of the Human Spinal Cord. (After A. Bruce, "A Topographical Atlas of the Spinal Cord," Edinburgh, 1901.) The anterior mesial group consists of four cells. The posterior mesial is not represented. The antero-lateral and posterolateral groups are more sharply differentiated than in any other segment. The (lower) anterolateral group contains twenty-nine cells. Eleven of these are concentrated into an apparently distinct group at the posterior part of the main group, and consist of larger and more deeply stained cells. The posterolateral group consists of thirty cells, and shows a tendency to division into an inner group consisting of sixteen cells, and an outer group consisting of fourteen cells. Behind there is a post-posterolateral group of three cells.

In the fifth and eighth segments there is an indication of subdivision of the anterolateral group into three subordinate nuclei, one anterior, one medial, and one posterior.

The posterolateral cell column is not present above the fourth cervical segment. Below this level, the cells increase in number rapidly, reaching their maximum at the fifth and sixth segments, where they form the prominent posterolateral angle. This posterolateral cell column is not well marked in the seventh segment, but is increased in size again in the eighth cervical segment, coincident with the marked increase in size of the posterolateral angle in this segment.

The post-posterolateral group begins in the eighth cervical segment and extends through the first dorsal segment. The posterolateral segment gradually disappears from the lower part of the eighth cervical segment, and is absent in the first thoracic segment, although the post-posterolateral group is so well developed in the first thoracic segment that the posterolateral angle still remains prominent in spite of the disappearance of the posterolateral group proper.

In the region of the Nn. lumbales and Nn. sacrales the lateral group of cells first appears at the second lumbar segment, though a small central anterior group of cells is present at the anterolateral angle of the first three lumbar segments.

The anterolateral cell group is enlarged in the fourth and fifth lumbar segments, causing there a special projection of the anterolateral angle; its maximum size, however, is attained at the level of N. sacralis I., below which the group rapidly decreases in size, disappearing entirely before the third sacral segment is reached.

The posterolateral cell group begins rather abruptly in the second lumbar segment, increases rapidly in size below this level, becoming largest in the fourth and fifth lumbar segments. The group undergoes some reduction in size in the first sacral segment, and this diminution goes on gradually through the second and third segments, the cell group disappearing entirely at the lower part of the third sacral segment.

As the researches of Onuf, van Gehuchten, and Bruce have shown, there is some difficulty in deciding upon the lower limits of the anterolateral and posterolateral cell groups in the sacral region, owing to the fact that the posterolateral and post-posterolateral cell groups become displaced forward so that they come to occupy the position previously held by the anterolateral and posterolateral cell groups respectively.

The post-posterolateral cell group has its upper limit in the lumbosacral region in the first sacral segment. It is remarkably developed in the lower half of the second sacral segment, but rapidly diminishes in size again through the third sacral segment, to cease entirely at its lower limit.

The central cell group, peculiar to the lumbosacral region of the spinal cord, extends from the level of N. lumbalis II. to the level of N. sacralis II. It is a tolerably compact column of cells, situated medial from and between the anterolateral and posterolateral groups of cells. It is best developed at the level of N. lumbalis V. and N. sacralis I.

Before leaving the arrangement of cells in the columna grisea anterior, we should say a word or two about a special group of motor cells situated in the upper cervical segments, viz., the *nucleus nervi accessorii*. In sections through the first cervical segment, the posterolateral group of about sixteen cells per section represents the nucleus N. accessorii; in sections through the second cervical segment this nucleus is situated near the middle of the anterior horn, and consists of about eight cells per section; in the third cervical segment the nucleus occupies a position near the middle of the lateral margin of the anterior horn, and there are about five cells per section; in the fourth cervical segment the cells of the nucleus lie slightly behind the anterolateral angle. Some authors class these cells as belonging to the columna intermedio-lateralis rather than to the columna grisea anterior. The relations are well shown in Bruce's "Atlas," Plates I. to IV. The lateral groups of motor cells so richly represented in the enlargements, corresponding to the innervation of the muscles of the extremities, are spoken of collectively in the intumescentia cervicalis as the *nucleus extremitatis superioris*; and in the intumescentia lumbalis as the *nucleus extremitatis inferioris*.

The number of ganglion cells present in the anterior horn of human beings has been estimated for several segments by Kaiser. His figures are as follows:

In the fourth cervical segment, 28,440; in the fifth, 61,230; in the sixth, 44,560; in the seventh, 36,850; in the eighth, 47,970; in the first thoracic segment, 27,600. Kaiser's article contains also the figures for several segments in the spinal cord of the five-months' embryo and of the new-born. Birge's article contains enumerations of the anterior horn cells of the frog.

The form of the anterior horn cell is irregularly polygonal when seen in cross-section, the multangular shape being dependent upon the origin of the dendrites and axones from the cell body.

Anterior horn cells vary in diameter in human beings between 11 and 110 μ (Stilling), though the majority measure from 67 to 135 μ, according to newer measurements. The cells of the posteromedial group average smaller, the diameter varying between 30 and 80 μ (von Kölliker). Ziehen has collected from the literature measurements made in a whole series of animals and he has combined them in a table given on pp. 130–131 of his article (*loc. cit.*).

The growth in size of the anterior horn cells in human beings is well illustrated by Kaiser's measurements in the lateral group of cells of the anterior horn: Fœtus at beginning of fifth month, 16–27.5 μ; at sixth month, 17–33 μ; at seventh month, 23–44.5 μ; at eighth month, 23–48 μ; newly born, 17.5–53 μ; fifteen-year old boy, 26–53 μ; adult 23–59 μ.

Not all the cells of the anterior horns give rise to axones of fibres of the anterior root. Some of them send their axones to the white funiculi of the spinal cord itself, chiefly to the funiculi of the opposite side of the cord through the commissura anterior alba and hence designated "commissural cells" or "heteromeric neurones,"

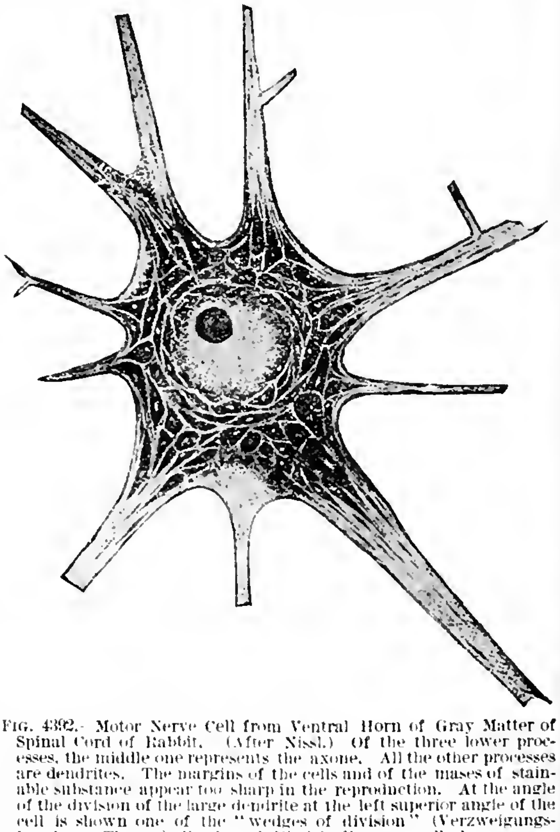


FIG. 4392.—Motor Nerve Cell from Ventral Horn of Gray Matter of Spinal Cord of Rabbit. (After Nissl.) Of the three lower processes, the middle one represents the axone. All the other processes are dendrites. The margins of the cells and of the mases of stainable substance appear too sharp in the reproduction. At the angle of the division of the large dendrite at the left superior angle of the cell is shown one of the "wedges of division" (Verzweigungskegeln). The spindle-shaped Nissl bodies are well shown, especially in the dendrites. This cell is classed by Nissl as a stichochrome nerve cell in the apyknomorphous condition.

but partly to the white funiculi of the same half of the spinal cord, and hence called "tautomeric funicular cells." According to von Lenhossék, the medial group of cells in the anterior horn is made up of commissural cells; he therefore calls it the commissural group, while

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the cells whose axones go into anterior root fibres are chiefly limited to the lateral group of nerve cells.

As to the large motor cells of the anterior horn, they form the most prominent elements in cross-sections of the spinal cord. They are typical multipolar stichochrome cells in the sense of Nissl (Fig. 4392). The dendrites pass out in all directions from the cell body, medialward, dorsalward, and some lateralward. They may reach the surface of the cord, having passed through the whole thickness of the white matter; in some animals there is a definite subpial plexus of dendrites. The axone, single for each cell, arises at the axone hillock, and shortly after leaving the cell becomes medullated and passes more or less horizontally through the white matter to enter one of the fila radicularia of the anterior root at the sulcus lateralis anterior. One to four delicate branches, the so-called side fibrils of Golgi, come off from the non-medullated portion of the axone and run back toward the cell body in the gray matter. The differences in calibre of the anterior root fibres have been mentioned above. According to von Bechterew the coarser fibres are medullated earlier than are the finer. It is the opinion of Gaskell and Mott that the coarse fibres are distributed to the voluntary muscles, the fine fibres to the involuntary muscles, by way of the systema nervorum sympathicum. An immense amount of work has been done upon the finer internal structure of the anterior horn cells, a very full résumé of which may be found in my book on the "Nervous System," pp. 101–157. Too much space would be required to introduce the details of structure here.

The glia cells in the anterior horn consist chiefly of typical astrocytes, some with long fibres, some with short. Of the processes of ependymal cells so abundantly present in the gray matter of the embryo cords, relatively little is to be made out in the adult.

In among the nerve cells and glia cells of the anterior horn are to be seen a very large number of medullated nerve fibres and collaterals. These include the medullated proximal portions of anterior root fibres, the medullated axones of tautomeric neurones, the cell bodies of which are situated in the gray matter of the anterior horn, the medullated axones of fibres going to or coming from the commissura anterior alba, the medullated axones and collaterals entering the anterior horn from the anterior and lateral funiculi, and lastly, but among the most important, the reflex collaterals from the posterior root fibres, which pass forward through the gray matter to terminate, as Golgi preparations from the embryo demonstrate, in end-arborizations around the anterior horn cells.

The researches dealing with the relations of the special groups of anterior horn cells to function are numerous. Among others may be mentioned those of Ferrier and Yeo, Risien Russell, Waldeyer, Sano, and Kaiser. M. Allen Starr's table of localization of function in the different segments of the spinal cord is invaluable in clinical diagnosis. (Vide Plate LII. in the present volume.)

REFERENCES.

On the Distribution of the Nerve Cells.

Barker, L. F.: The Nervous System and Its Constituent Neurones, New York, 1899, pp. 883–914.
Bruce, A.: A Topographical Atlas of the Spinal Cord. Edinburgh, 1901.
Collins, J.: A Contribution to the Arrangement and Functions of the Cells of the Cervical Spinal Cord, to which is Appended a Note on Central Changes Secondary to Long-continued Disuse of One Extremity. New York Med. Journ., vol. lix., 1894, pp. 40, 98.
Gehuchten, A. van: Les noyaux moteurs de la moëlle lombosacrée chez l'homme. Le nevraxe, Louvain, 1900, pp. 201–233.
Kaiser, O.: Die Funktionen der Ganglienzellen des Halsmarkes. Gekrönte Preisschrift. Haag, Mart. Nijhoff, 1891, p. 71.
Sano, F.: Les localisations motrices dans la moëlle lombosacrée. Journ. de neurol. et hypnol., Par., t. ii., 1897, pp. 253–290.—Les localisations des fonctions motrices de la moëlle épinière. Ann. Soc. méd.-chir. d'Anvers.—De la constitution des noyeaux moteurs médullaires. Journ. de neurol. et hypnol.—Localizations médullaires motrices et sensitives. Journ. de Neurol.
Onufrowicz, B.: Notes on the Arrangement and Function of the Cell Groups in the Sacral Region of the Spinal Cord. Journ. of Nerv. and Ment. Dis., 1899, pp. 498–504.
Onuf, B., and Collins J.: Experimental Researches on the Localization of the Sympathetic Nerve in the Spinal Cord and Brain, and Contributions to its Physiology. Journ. of Nerv. and Ment. Dis., 1898, pp. 661–676.
Waldeyer: Das Gorilla-Rückenmark, *loc. cit.*, p. 52.

On Number of Cells in the Anterior Horn.

Birge, E. A.: *Loc. cit.*
Kaiser, G.: *Loc. cit.*

On Measurements of Anterior Horn Cells.

Kölliker, A. von: Handbuch der Gewebelehre des Menschen., 6th ed., Leip., 1889–96.
Stilling, B.: *Loc. cit.*

On Localization of Function to Groups of Anterior Horn Cells.

Ferrier, D., and Yeo, G. F.: The Functional Relations of the Motor Roots of the Brachial and Lumbo-sacral Plexuses. Proc. Roy Soc., Lond., vol. xxxii., 1881, pp. 12–20.
Russell, J. S. R.: An Experimental Investigation of the Nerve Roots which enter into the Formation of the Brachial Plexus of the Dog. Phil. Trans. Roy. Soc., Lond., vol. clxxxiv. (B), Lond., 1894, pp. 39–63.
Starr, M. Allen: Syringomyelia; its Pathology and Clinical Features, with a Study of a Case and Remarks upon its Diagnosis. Am. Journ. Med. Sci., Phila., n. s., vol. xcv., 1888, pp. 456–468.
Sano, F.: *Loc. cit.*

On Glia Cells in the Anterior Horn.

Kölliker, A. von: *Loc. cit.*
Lenhossék, M. von: *Loc. cit.*
Weigert, C.: *Loc. cit.*

Columna Grisea Posterior (Posterior or Dorsal Horn).—The structure of the posterior gray column is much less well understood than that of the anterior gray column. Its gross subdivision into cervix, apex, substantia gelatinosa, and nucleus dorsalis have been described above under the macroscopic appearances. The prominent posterior part, just ventral from the substantia gelatinosa, sometimes called the caput and badly designated, by Waldeyer, *Kern des Dorsalhorns*, is a striking feature in Weigert preparations, since it is closely crowded with medullated fibres and contains relatively small nerve cells.

The nerve cells in the posterior horn are, on the whole, much smaller than those of the anterior horn. The total number of nerve cells present is probably smaller and their distribution and arrangement are irregular. The most constant cell group is the nucleus dorsalis or column of Clarke, which lies at the medial margin of the base of the posterior horn. The nucleus dorsalis is best developed in the lower segments of the thoracic region, and in the segments corresponding to the two uppermost Nn. lumbales. In the intumescentiæ the cells are scanty or absent altogether. In the gray matter of the sacral segments the cells are again more numerous (sacral nucleus of Stilling). There is also a good representation of Clarke's nucleus in the uppermost portion of the cervical cord (cervical nucleus of Stilling). The exact position of the nucleus dorsalis varies in different animals, having a tendency to be situated more dorsalward in human beings than in lower forms. The number of cells in the nucleus dorsalis has not yet been determined. The greatest number in any one cross-section is usually to be met in sections from the segment corresponding to the twelfth thoracic nerve, at which level the nucleus dorsalis measures as much as 0.75 mm. in diameter.

In ordinary carmine or hæmatoxylin preparations the cell bodies of Clarke's nucleus look rounded or elliptical, sometimes polygonal. In Golgi preparations they are shown to be actually multipolar, having very numerous dendrites and a single axone. The dendrites, however, are much less coarse at their roots than are the dendrites of the anterior horn cells, and this accounts for the difference in appearance in carmine preparations. The individual cell bodies vary greatly in diameter, according to Ziehen, between 15 and 70 μ. Von Kölliker's figures are 45–90 μ, while Mott gives as the average diameter 50 μ in the eighth thoracic segment, 109 μ in the twelfth thoracic segment (longitudinal sections).

The single axone from the cell body of a cell of Clarke's nucleus usually arises on the anterior or lateral margin of the cell; occasionally it comes off from the posterior margin. From its origin it runs ventralward, makes a hook-shaped bend, and becoming medullated, either just before or just after making the bend, runs as a transversal nerve fibre to the posterior periphery of the lateral funiculus, where it turns so as to run longitudinally toward the cerebrum in the direct cerebellar tract of Flechsig, the tract which I have designated the fasciculus spinocerebellaris dorsolateralis. These axones, in that horizontal part of their course which is situated between the dorsal horns and the dorsolateral periphery of the cord, make distinct bundles, spoken of as the "horizontal cerebellar bundle" by Flechsig, or as "Flechsig's bundle" by von Lenhossék. Collaterals do not appear to be given off from these axones, at any rate in their proximal portions. As we shall see later, these axones pass through the corpus restiforme of the medulla oblongata to terminate in the cerebellum.

The nerve cells in the caput of the posterior horn, that is, in the so-called *Kern des Dorsalhornes* of Waldeyer, are not well understood. Ziehen designates them *Innenzellen des Hinterhornkopfs.* These cells tend to be triangular in the anterior portion of the group, but become more spindle-shaped in the posterior portion. The smaller cells are partly spindle-shaped, partly polygonal. The size varies greatly. It is rare to find a cell with a diameter of more than 50 μ, while the smallest cells are almost as small as the minute nerve cells of the substantia gelatinosa. The dendrites are long, but not of large calibre. The axone passes in a straight line or in a curve lateralward and becomes a longitudinal fibre, usually ascending, of the lateral funiculus of the same side. Accordingly these cells are to be looked upon chiefly as tautomeric funicular neurones. An occasional axone may pass into the anterior or posterior funiculus, or rarely through the commissure to the opposite side of the cord.

The substantia gelatinosa (Rolandi) contains an enormous number of minute nerve cells, so small that for a long time these cells were believed to be glia cells until Weigert demonstrated that glia cells are really relatively rare in this situation, and Ramón y Cajal, with Golgi's method, demonstrated the exact characters of the nerve cells and their processes situated there. These cells have been very well described by Gierke, and some authors refer to them as *Gierke's cells.* They are usually stellate, though sometimes more spindle-shaped. They are very small; it is rare to find one exceeding 20 μ in diameter. The size varies between 6 and 20 μ. The arrangement in rows is very well shown in Ramón y Cajal's drawings. Each cell has numerous dendrites which have no regular arrangement, though sometimes they form bush-like masses at two extremities of a spindle-shaped cell. The axone arises, nearly always, from the posterior pole of the cell and runs backward, but can seldom be followed beyond the so-called zonal layer, that is, the outermost portion of the substantia gelatinosa which stains less intensely in carmine preparations (*Zonalschicht* of Waldeyer). Ramón y Cajal believes that some of the axones go to form longitudinal fibres of the fasciculus of Lissauer; others to form endogenous fibres of the posterior funiculus; some, doubtless, run longitudinally in the posterior horn itself. Golgi cells of type II., so-called dendraxones, have been described by various authors in the substantia gelatinosa (Rolandi). The finer structure of the cells of the substance of Rolando has been studied by Levi, to whose article we refer for a description of the nucleus and nucleolus.

As early as 1859 Clarke drew attention to the peculiar position occupied by certain cells of the zonal layer of the substantia gelatinosa. These cells, which have been called *marginal cells* by von Lenhossék, and *cellules limitantes* by the French writers, form an uninterrupted row, closest together at the medial margin of the substantia gelatinosa of the posterior horn. Some of them can be followed beyond the substantia gelatinosa, along the medial margin of the posterior horn, even as far as Clarke's nucleus. The individual cells are spindle-shaped, the long axis of the cell running parallel to the margin of the substantia gelatinosa. A few pyramidal cells can be seen, the apex of the pyramid being turned toward the interior of the substantia gelatinosa. These cells are larger by far than the Gierke cells of the substantia gelatinosa itself. The dendrites come off chiefly from the poles of the cells; the axone may arise from the cell body or from a dendrite. It usually passes ventralward through the substantia gelatinosa (Rolandi), where it gives off collaterals (Ramón y Cajal) and then bends lateralward to become a longitudinal fibre of the lateral funiculus. In animals like the chick, mouse, and pig, some axones bifurcate into two, both going to the lateral funiculus, or one going to the lateral, the other to the posterior funiculus. These axones have not yet been followed in human beings.

A very careful study of the glia cells of the posterior horn has been made by Weigert. He it was who demonstrated the relatively small amount of glia in the substantia gelatinosa (Rolandi), a view quite opposed to the older descriptions. There is more glia in the caput of the posterior horn; the nucleus dorsalis is tolerably rich in glia cells. The appearances of the glia of the posterior horn and of the substantia gelatinosa (Rolandi), as revealed by Golgi's method, are well described and pictured by von Lenhossék, to whose article the reader is referred.

The study of the finer and coarser medullated fibres appearing in the posterior horn, made by von Lenhossék, is also one of the best at our disposal. Every one who has studied Weigert preparations of the posterior horn has been struck by the radial bundles of medullated fibres which pass through the substantia gelatinosa (Rolandi), and by the great number of fine fibres present in different parts of the posterior horn.

A large number of the fibres entering the posterior horn of the gray matter are to be looked upon as the terminals of the fibres of the posterior funiculi. As manifold observations have shown, the fibres coming into the posterior funiculus through any given posterior root, vary greatly in their length. Some run into the gray matter to terminate almost at the level of entrance; others run longitudinally in the posterior funiculus, to terminate in the gray matter a few or several segments distant from the level of entrance, while still others run for long distances lengthwise in the posterior funiculus, passing by a great many segments before terminating in the gray matter of the cord, some of them even passing the whole length of the spinal cord above the level of the entrance to find a termination first in the gray matter of the medulla oblongata. Accordingly the posterior root fibres seen terminating in the gray matter at any given level of the cord may have come in through a posterior root near this level, or through a number of posterior roots at variable distances below. A few posterior root fibres instead of running lengthwise in the posterior funiculus assume a longitudinal course within the gray matter of the posterior horn itself.

Much interest has been manifested with regard to the medullated fibres which run in from the fasciculus cuneatus to terminate in the nucleus dorsalis. Von Lenhossék and von Kölliker describe these fibres going to the nucleus dorsalis as collaterals of the posterior root fibres, though Schaffer, of Budapest, maintains that these fibres are the main fibres and not collaterals, and his observations, together with those of Redlich, indicate that it is the fibres from the sacral and lumbar nerve roots which chiefly end in the nucleus dorsalis. The number of fine medullated fibres to be seen in among the cell bodies of the nucleus dorsalis is a striking feature of Weigert preparations.

Whatever may be the facts in the dispute about the nature of the fine medullated fibres in the nucleus dorsalis, there can be no doubt that in addition to the terminals of the stem fibres of the posterior root running into the gray substance, there are immense numbers of collaterals from the posterior root fibres and their limbs of bifurcation passing into the dorsal horn, some of them to end there, others to pass through it and to terminate in the anterior horn. These collaterals are most numerous on the fibres of the fasciculus cuneatus; but they rarely come from the fibres of the fasciculus gracilis; in other

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words, the collaterals are given off from the proximal portions of the posterior root fibres rather than from their distal portions.

A group of these collaterals about which we know most is that of the reflex collaterals which come off in a flat curve, slightly convex lateralward, from the root entrance zone and enter the gray matter at the medial margin of the head of the posterior horn, some of them passing through the most medial portion of the substantia gelatinosa (Rolandi). These fibres lie lateral from Clarke's nucleus and from the posterior root fibres which run into the nucleus dorsalis to terminate there. Once inside the posterior horn these reflex collaterals run either straight ventralward or ventralward and slightly lateralward, sometimes forming a second slight curve, the concavity of which is directed medialward. In the anterior horn the collaterals undergo fan-like dispersion and end in terminal arborizations upon the cell bodies and dendrites of the anterior horn cells.

A large number of the radial bundles passing through the substantia gelatinosa are terminals and collaterals from the fibres of Lissauer's fasciculus to the caput of the posterior horn. A certain number of terminals and collaterals from the fibres of the lateral funiculus have been shown by Golgi's method to run into the gray matter of the posterior horn and to end there.

Doubtless some of the medullated fibres seen in the posterior horn are the medullated axones of posterior horn cells on their way to the funiculus lateralis, the funiculus posterior, or the commissure. The horizontal cerebellar path of Flechsig met with at tolerably regular intervals and representing the medullated axones of the cells of the nucleus dorsalis belong to this category.

References.

On the Nucleus Dorsalis.

Clarke, J. L.: Phil. Tr., London, 1851, Pt. ii.
Flechsig, P.: Die Leitungsbahnen im Gehirn und Rückenmark des Menschen, Leipzig, 1876, S. 296.
Laura, J. R.: Sur la structure de la moëlle épinière. Arch. ital. de biol., Turin, vol. i., 1882, pp. 147–175.
Mott, F. W.: Microscopical Examination of Clarke's Column in Man, the Monkey and the Dog. Journ. Anat. and Physiol., Lond., vol. xxii., 1888, pp. 479–495.
Stilling, B.: Ueber die Medulla Oblongata, Erlangen, 1843.

On Nerve Cells in the Caput of the Posterior Horn.

Waldeyer, W.: Das Gorilla-Rückenmark. *Loc. cit.*, p. 52.
Lenhossék, M. von: Der feinere Bau des Nervensystems im Lichte neuester Forschungen, Berlin, 1895.

On Nerve Cells of Substantia Gelatinosa.

Gierke, Hans: Die Stützsubstanz des Centralnervensystems. Arch. der micro. Anat., Bonn, Bd. xxvi., p. 144.
Levi, G.: Richerche citoligiche comparate sulla cellula nervosa dei vertebrati. Riv. di patol. nerv. e ment., Firenze, vol. ii., 1897, pp. 193–225.
Ramón y Cajal, S.: Pequenas contribuciones al conocimiento del sistema nervioso, Madrid, 1891.—Textura del Sistema Nervioso del Hombre y de los Vertebrados, Madrid, 1899.

On Cells of the Zonal Layer.

Clarke, J. L.: Phil. Tr., Lond., 1851, p. 608: 1859, p. 444.
Lenhossék, M. von: *Loc. cit.*, p. 358.
Ramón y Cajal, S.: *Loc. cit.*

On the Glia of the Posterior Horn.

Lenhossék, M. von: *Loc. cit.*
Weigert, C.: *Loc. cit.*

On Medullated Fibres of the Posterior Horn.

Golgi, C.: Untersuchungen über den feineren Bau des centralen und peripherischen Nervensystems, Jena, 1894.
Kölliker, A. von: *Loc. cit.*
Lenhossék, M. von: *Loc. cit.*
Ramón y Cajal, S.: Textura del Sistema Nervioso del Hombre y de los Vertebrados, Madrid, 1899.
Waldeyer, W.: Das Gorilla-Rückenmark, etc., *loc. cit.*

Columna Grisea Lateralis seu Intermediolateralis.—This column, especially developed throughout the thoracic portions of the spinal cord, includes the nerve cells of the so-called "lateral horn" and of the adjacent reticular formation. J. Lockhart Clarke described it as the tractus intermediolateralis, and pointed out that it was most marked in the upper portion of the pars thoracalis. Many authors have made the mistake of confusing the cells of this lateral column of gray matter with those of the posterolateral group of the anterior horn, and in the cervical and lumbar regions there is still some ground for doubt as to which cells shall be counted as belonging to the columna lateralis and which to the columna anterior.

The bodies of the nerve cells tend to lie in compact groups; the individual cells are usually multipolar, sometimes spindle-shaped. The measurements in the long axis of the cell body are given as varying between 12 and 45 μ, those of the short axis between 5 and 15 μ.

The dendrites which often run far out into the white substance tend to be arranged in oppositipolar groups corresponding to the spindle shape of many of these cells. The single axone goes as a rule to become a longitudinal (ascending or descending) fibre of the lateral funiculus of the same side. The cell bodies of the columna lateralis must therefore be regarded as being those of tautomeric neurones. A few axones probably go to the anterior funiculus of the same side. It has been suggested that some of these cells become anterior root fibres, which go to innervate the abdominal and perineal muscles; but the results of studies by the method of Golgi are opposed to such a view.

Columna Intermedia.—I use this term to designate an important area of gray substance situated between the anterior and posterior horns, and variously named by different authors (*Mittelzone der grauen Substanz*, von Lenhossék; *Zwischentheil* or *Zwischenzone der grauen Substanz*, Ziehen). Here are situated groups of nerve cells which may be called intermediate cells (*Mittelzellen* of Waldeyer, *Zwischenzellen* of Ziehen). They lie anterolateralward from the nucleus dorsalis Clarkii. The arrangement of these cells is more regular and continuous in the upper part of the spinal cord, while in the lower part it is far less regular, the cells being scattered. Argutinsky has described and pictured peculiar aggregations of these cells, which have, however, as he maintains, no segmental significance. The cell bodies are, as a rule, polygonal in shape and vary in size between about 10 and 24 μ in the long diameter. The axones of these cells go chiefly to become fibres of the lateral funiculus, though some have been followed into the anterior funiculus and others into the commissura anterior alba. The corresponding neurones are therefore to be regarded as tautomeric and heteromeric respectively.

Substantia Grisea Centralis.—This includes the gelatinous gray matter surrounding the central canal. The ependymal cells which line the central canal play a large part in the formation of this portion of the gray matter. Some one hundred ependymal cells are required to build up the circumference of the central canal at any one level (Stilling). These cells vary from 10 to 25 μ in breadth, and from 25 to 55 μ in length; these figures refer to the swollen main portion of the cell body and do not, of course, include the long processes (ependymal fibres). The cells are ciliated at their distal end; these cilia are much easier to make out in the embryo than in the adult. The so-called ependymal fibres are really the distal processes of the ependymal cells. The appearance of these fibres in embryonic tissues, stained by the method of Golgi, is very remarkable. The careful descriptions of von Lenhossék and Ramón y Cajal may be consulted in this connection.

In addition to the ependymal cells a larger number of glia cells exists in this region than in the more peripheral parts of the gray matter. The large number of nuclei visible in this region in iron-hæmatoxylin preparations is probably accounted for by the presence of large numbers of glia cells, and the gelatinous appearance around the central canal is due to the large number of ependymal glia cells in the neighborhood. Weigert's glia stain demonstrates an extraordinary richness in glia in this region, the whole area coming out dark blue in the section.

The mode of obliteration of the central canal has been described in detail by Weigert and by Brissaud, to whose descriptions the reader is referred.

True nerve cells would appear to be absent in the immediate neighborhood of the central canal. In the more peripheral portions of the substantia grisea centralis a few cell bodies can be found, part of them those of neurones whose axones go to the lateral funiculus, others those of commissural neurones.

In the gray commissure there are many white fibres which appear to be independent of the commissura anterior alba. These tend to be combined into two delicate white commissures which run in the gray commissure, one in front of the central canal (commissura intracentralis anterior), and one behind the central canal (commissura intracentralis posterior).

The *commissura intracentralis anterior*, identical with Stilling's commissura anterior accessoria, is sharply separable from the commissura anterior alba, lying as it does behind the latter in the gray matter. Its constituent fibres are very much finer than those of the anterior white commissure. The bundle is most marked in the intumescentia lumbalis and in the conus terminalis. According to Ziehen, the majority of the fibres, namely, those more anteriorly situated, are connected (by origin or termination) with the anteromedial group of nerve cells in the anterior horn. The more posterior fibres of this little commissure he follows to the junction of the columna intermedia with the substantia grisea centralis, and concludes that they here assume a longitudinal direction.

The *commissura intracentralis posterior* consists of very fine fibres, and is best developed in the proximal portion of the pars cervicalis and in the conus medullaris, being only feebly represented in the thoracic cord and in the intumescentiæ. Exact measurements of the sagittal diameter are given by Stilling.

Much work has been done upon the origin and termination of the fibres of this posterior intracentral commissure. The view now held is that many of them represent reflex collaterals from the posterior root fibres of one side of the cord, which go through this commissure to terminate in the opposite anterior horn. In addition, some collaterals from fibres of the lateral and posterior funiculi pass through this commissure to end in the posterior horn. Again, some of the cells in the posterior horn give off axones which, becoming medullated, pass through this commissure to the opposite posterior horn, to end there, or to become endogenous fibres of the opposite posterior funiculus. Ziehen also describes in the commissure fibres which arise from the cells of the columna intermedia and from the cells of the columna intermediolateralis, but the termination of these fibres he could not ascertain.

References.

Hannover, A.: Recherche Microscopique sur les Systèmes Nerveux, Copenhagen, 1841.
Ramón y Cajal, S.: *Loc. cit.*
Retzius, G.: Ependym und Neuroglia. Biol. Untersuch., Stockholm, N. F., Bd. v., 1893.
Stilling, B.: Neue Untersuchungen über den Bau des Rückenmarks, Cassel, 1859.

On Obliteration of the Central Canal.

Brissaud, E.: Leçons sur les maladies nerveuses, Paris, 1895, p. 206 *et seq.*
Weigert, C.: Beiträge zur Kenntniss der normalen menschlichen Neuroglia, Frankfurt a M., 1895.

On the Intracentral White Commissures.

Lenhossék, M.: *Loc. cit.*
Stilling, B.: *Loc. cit.*
Ziehen, T.: *Loc. cit.*

The Conduction Paths of the Spinal Cord.

We have thus far considered the white matter and the gray matter more or less separately without any special reference to the interrelations of the nerve cells to the nerve fibres. Investigations have shown that functionally similar nerve fibres tend to run in definite bundles of the white matter, and that functionally similar groups of nerve cells tend to lie in common masses or columns in the gray matter. The bundles of fibres of common function are known as *fibre systems*. The functional groups of nerve cells are known as *nerve centres* or *nuclei*. Histological examination proves that these nerve centres or nuclei are connected with specific fibre systems. Each nerve cell of a particular nucleus gives off an axone, which becomes the medullated nerve fibre of a definite fibre system. Since the nerve-cell body or perikaryon with its dendrites and axone, with the collaterals and termination of the latter, is, as a whole, known as a *neurone*, it is obvious that we may speak of a nerve centre, or nucleus, together with its corresponding fibre system, as a *neurone system* (systema neuronicum). It is to the various neurone systems and the modes of localizing them in the spinal cord that it is our intention next to turn. We shall see that the term *conduction path* is used in a wider sense to include a chain of superimposed or subimposed neurone systems, the end arborizations of the axones of one neurone system transferring the nerve impulses to the dendrites and cell bodies of the neurone of the next neurone system in the chain. A good spatial sense is necessary for the proper understanding of the conduction paths; unless one is capable of thinking of the three dimensional relations inside the central nervous system, he will have great difficulty in understanding the problems connected with them.

While, as we have said, there is a marked tendency to aggregation of fibres of similar function in localized areas of the white matter of the cord, it must not be thought that this localization is as sharp as many of the diagrams in the text-books would lead one to believe. Indeed, there is undoubtedly much mixing of fibre systems in given areas of a cross-section, and when we designate a certain area as that of the lateral pyramidal tract, for example, it must be understood that this nomenclature is employed for *a fortiori* reasons, for we know that in the area a few fibres other than those belonging to the pyramidal tract exist.

The methods which are employed for the localization of the conduction paths are as follows:

1. *Weigert's Myelin-Sheath Method.*—This method, described in the article *Brain, Histology of*, permits one in serial sections to follow medullated axones for very considerable distances. Unfortunately, it is not of great service in demonstrating the connection of the nerve cells with the nerve fibres, for even when carmine or other dyes are used as a contrast stain for the cell body and axones, it is often very difficult to follow an axone into its corresponding medullary sheath.

References.

Weigert, C.: Ueber eine neue Untersuchungsmethode des Centralnervensystems. Centralbl. f. d. med. Wissensch., Berl., Bd. xx., 1882, pp. 753, 772.—Ueber Schnellhärtung der nervösen Centralorgane zum Zwecke der Säurefuchsinfärbung. Centralbl. f. d. med. Wissensch., Berl., Bd. xx., 1882.—Ausführliche Beschreibung der in No. 2 dieser Zeitschrift erwähnten neuen Färbungsmethode für das Centralnervensystem. Fortschr. d. Med., Berl., Bd. ii., 1884, p. 190.—Eine Verbesserung der Hämatoxylin-Blutlaugensalzmethode für das Centralnervensystem. Fortschr. d. med. Berl., Bd. iii., 1885, pp. 236-239.—Zur Markscheidenfärbung. Deutsche Med., Leipz., Bd. xvii., 1891, pp. 1184-1186.—Die Markscheidenfärbung. Ergebn. d. Anat., Merkel-Bonnet, Wiesb., Bd. vi., 1896, SS. 3-25.

2. *Method of Golgi.*—This method, chiefly applicable to embryonic tissues, has proved to be of exrtraordinary value in demonstrating developing dendrites, axones, collaterals, and telodendrions. It permits us to follow the axones of the various anterior horn cells to the anterior roots or to the anterior white commissure, or to the funiculi. It, more than any other method, has permitted the determination of the funicular relations of the axones of the posterior horn cells, and has given us most precise information regarding the intramedullary course of the axones of the fibres of the posterior roots. Finally, by means of this method, we have gained an entirely new conception of the relations of the terminals of the axones of one neurone system to the cell bodies and dendrites of the next neurone system in given conduction paths. The method has, unfortunately, a limited application in the study of the adult spinal cord.

References.

Golgi, C.: Sulla struttura della sostansa grigia del cervello. Gazzetta medica italiano-lombardia, t. vi., 1873. Golgi's contributions to the bibliography of the nervous system have been collected and translated into German by Teuscher. *Cf.* Golgi, C.: Untersuchungen über den feineren Bau des centralen und peripherischen Nervensystems, Jena, Fischer, 1894.—Sulla fina anatomia degli organi centrali del sistema nervoso. Riv. sper. di freniatr., Reggio-Emilia, 1882, vol. viii., pp. 165, 361; 1883, vol. ix., pp. 1, 161, 385; 1885, vol. xi., pp. 72, 193.

Ramón y Cajal, S.: Estructura de la rétina de las aves. Revista trim. de histologia normal, etc., Nos. 1 y 2, Mayo y Agosto de 1888. Quoted by von Lenhossék.—Sobre las Fibras Nerviosas de la Capa Molecular del Cerebello. Revista trim. de hist., etc., Agosto, 1888. Quoted by von Lenhossék.

I have references to no less than nine articles on the nervous system bearing his name, published during the year 1890 alone. It would occupy too much space to give here a complete list of his publications. An epitome of his views is to be found in "Les nouvelles idées sur la structure du système nerveux chez l'homme et chez les vertébrés," French by Azoulay, Paris, 1894; and in the Croonian Lecture, "La fine structure des centres nerveux," Proceedings of the Royal Society, London, vol. lv., 1894, pp. 444–468. This lecture was delivered in French and published in the same language. A brief but inaccurate abstract of it in English was printed in the British Medical Journal, 1894, i., p. 543.

Weigert, C.: Die Golgische Methode. Ergebn. d. Anat. u. Entwickelungsgesch., Wiesb., Bd. v., 1896, S. 7–29.

3. *Method of Flechsig* (Observations of Serial Medullation).—Though a number of investigators before Flechsig had observed that different portions of the white substance developed their myeline sheaths at different periods, it was Flechsig who first took advantage of this fact in a large way for determining the serial sequence of medullation. He also utilized the facts discovered for drawing inferences with regard to the topographical localization of conduction paths. Flechsig's studies proved that in human embryos of the same age the same groups of nerve fibres are medullated in the white substance, while embryos at different ages reveal an entirely different grouping of the medullated fibres. In other words, the medullation of the different fasciculi is temporarily constant and follows a definite law. After studying a series of embryos, one can, if he knows the age of the embryo, say off-hand what bundles of fibres in the cord will on examination be found to be medullated, and what bundles will still lack myelin sheaths. Flechsig further found that nerve fibres having the same origin and termination, that is, nerve fibres of the same fibre system, and which therefore probably have the same function, become medullated at the same period, while other fibres, with different anatomical connections and different functions, become medullated at other times.

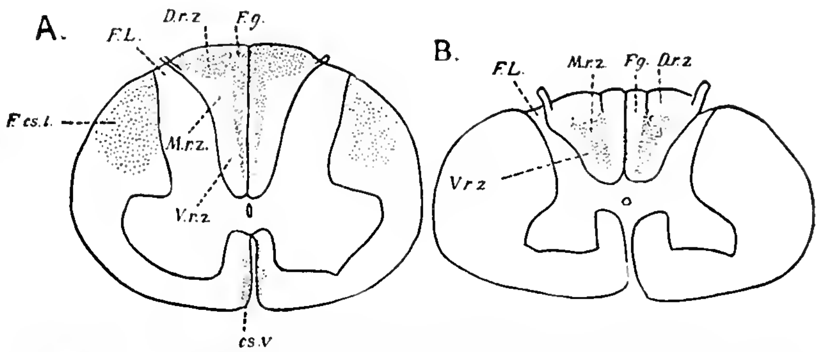


Fig. 4393.—Middle of Intumescentia Cervicalis. *A*, Memberment of dorsal funiculi as revealed by study of myelinization; *B*, lesion in a case of incipient tabes.

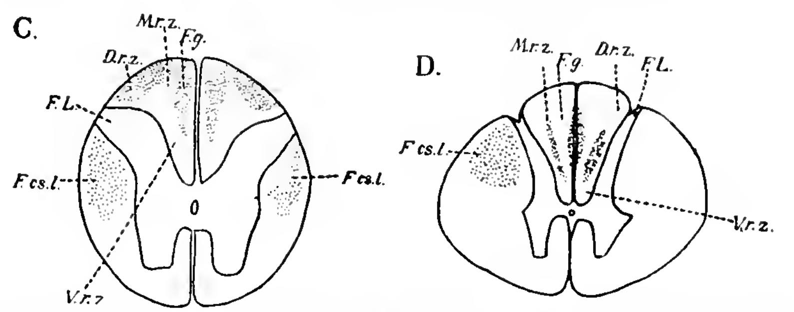


Fig. 4394.—Pars Thoracalis. *C*, Section through midthoracic region illustrating myelinization memberment; *D*, section through upper thoracic region showing lesion in a case of incipient tabes.

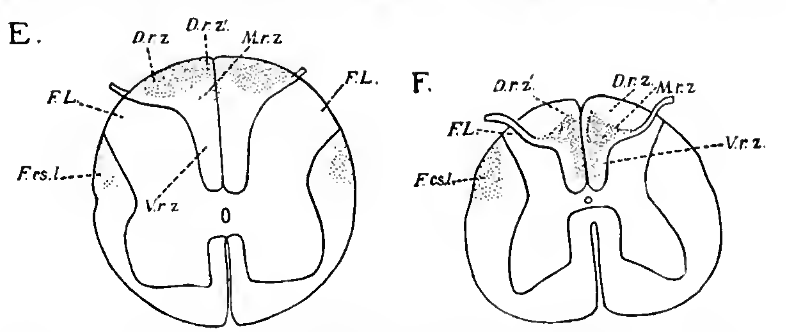


Fig. 4395. Intumescentia Lumbalis. *E*, Memberment as revealed by study of myelinization; *F*, lesion in a case of incipient tabes.

Figs. 4393, 4394, and 4395.—Figures Illustrating the Dorsal Funiculi in the Cervical, Thoracic, and Lumbar Regions of the Spinal Cord. Those on the left side illustrate the embryological memberment, those on the right side the lesions in cases of incipient tabes. (After P. Flechsig, *Neurolog. Centralbl.*, Leipzig, Bd. ix., 1890, S. 73.) Lettering explained in text.

Flechsig, by this method, was able to distinguish easily in the funiculus anterior two parts: (1) the pyramidal tract of the funiculus anterior; and (2) the ground bundle or fasciculus lateralis proprius of this funiculus. In the lateral funiculus a study of the medullation separates sharply (*a*) the pyramidal tract of the lateral funiculus (*fasciculus cerebrospinalis lateralis*); (*b*) the direct cerebellar tract (*fasciculus cerebrospinalis*,) or, better, *fasciculus spinocerebellaris dorsolateralis*); and (*c*) the ground bundle of the lateral funiculus (*fasciculus lateralis proprius*). This embryological method goes even further and divides the fasciculus lateralis proprius into an internal part, the lateral limiting layer of the gray matter (*seitliche Grenzschicht der grauen Substanz*), and an external part, the anterior mixed zone of the lateral funiculus (*vordere gemischte Seitenstrangzone*). In the posterior funiculus the fasciculus gracilis (Golli) becomes medullated, on the whole, at a different period from that for the fasciculus cuneatus (Burdachi). The embryological method, however, permits of a much finer analysis still of the posterior funiculus, as we shall have occasion to point out later on.

In general it may be said that a study of embryos in four stages, at lengths of 25 cm., 28 cm., 32 cm., and

50 cm. respectively, gives a tolerably clear idea of the medullation sequence in the spinal cord. Thus, in human embryos 25 cm. long, there are myelin sheaths upon the fibres of (1) the commissura anterior alba; (2) the fibres of the anterior roots and some of the fibres of the posterior roots; (3) the fibres of the fasciculus anterior proprius; (4) the fibres of the anterior mixed zone of the lateral funiculus; and (5) many of the fibres of the fasciculus cuneatus (Burdachi). In embryos 28 cm. long the fibres of the fasciculus gracilis (Golli) have also largely acquired their myelin sheaths. In embryos 32 cm. in length the lateral limiting layer of the gray matter in the fasciculus lateralis proprius is medullated, and in embryos a little older the direct cerebellar tract and Gowers' tract are found to be medullated. Finally, the anterior and lateral pyramidal tracts become medullated only at birth, when the fœtus has attained a length of about 50 cm.

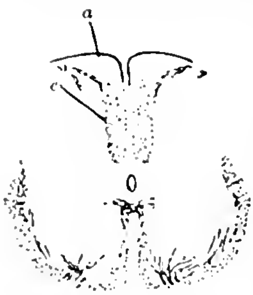


FIG. 4396. Lumbar Portion of Spinal Cord of Human Fœtus 24 cm. Long. *a*, Dorsal part of funiculus posterior; *c*, ventral part. (After Trepinski.)

It will have been noticed that the sequence of medullation corresponds to the probable development serially of the more sharply defined nervous functions. Thus, as we should expect, the peripheral nerves become medullated first, and the apparatus for central excitation in the cord (not in the brain) is furnished. The provision for the simpler reflexes is followed by myelinization of the fasciculus lateralis proprius and the fasciculus lateralis anterior, thus permitting of the connection of adjacent and somewhat distant segments with one another corresponding to the neural apparatus underlying the more complex reflexes. The longer centripetal tracts connecting the cord with the medulla and cerebellum become medullated later, corresponding to still more complex reflexes and to the coördination of movements and the maintenance of equilibrium. It is at a very late period when the fibres connecting the cord with the cerebral cortex are medullated, and even later when the fibres of the pyramidal tracts, throwing the anterior horn cells under the influence of the cerebral cortex, receive their myelin sheaths.

FIG. 4397. — Thoracic Portion of Spinal Cord of Human Fœtus 24 cm. Long. (After Trepinski.)

It is necessary to give a few details bearing upon the sequence of medullation. The fibres of the posterior roots do not begin to be medullated until after the process has well begun in the anterior roots. Indeed the myelinization of the posterior root remains, on the whole, dilatory as compared with that of the anterior root. Von Bechterew has divided the posterior roots into two fibre systems, the first corresponding to medullation at the fourth month of fœtal life, the second to a medullation process most marked near the end of intra-uterine life. Later studies by Flechsig and Trepinski make it seem certain that at least five fibre systems are to be distinguished in the posterior roots. As they correspond to five similar systems in the posterior funiculus, they need no further description.

FIG. 4398. Lumbar Portion of Spinal Cord of Human Fœtus 28 cm. Long. (After Trepinski.)

Flechsig divided each funiculus posterior, exclusive of the fasciculus gracilis (Golli), into the following areas: (1) the anterior root zone (*vordere Wurzelzone*); (2) the middle root zone (*mittlere Wurzelzone*); (3) the posterior or dorsal root zone (*hintere Wurzelzone*); (4) the median zone (*mediane Zone der Hinterstränge*). Flechsig gives the name *ovales Centrum* to the oval area in the lumbar region made up of the median zones of the two sides. The middle root zone contains two fibre systems which develop at different periods and are called the *first and second systems of the middle root zone*. Similarly the posterior or dorsal root zone contains two fibre systems, the *medial and lateral systems of the dorsal root zone* (Figs. 4393, 4394, and 4395). The fibre systems receive their myelin sheaths in the following sequence: (1) the anterior or ventral root zone (*V.r.z.*); (2) the first system of the middle root zone (*M.r.z.*) and the median zone; (3) the fasciculus gracilis (Golli), the second system of the middle root zone and the medial portion of the posterior or dorsal root zone (*D.r.s.*); (4) lastly, the lateral portion of the dorsal root zone, namely, Lissauer's fasciculus.

FIG. 4399.—Thoracic Portion of Spinal Cord of Human Fœtus 28 cm. Long. (After Trepinski.)

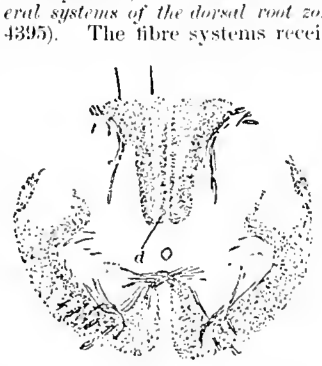


FIG. 4400.—Cervical Portion of Spinal Cord of Human Fœtus 28 cm. Long. (After Trepinski.)

A still more careful analysis has been made by Trepinski, who makes out, exclusive of Lissauer's fasciculus, four distinct fibre systems in the posterior funiculus. These fibre systems are medullated in fœtuses 21 cm., 28 cm., 35 cm., and 42 cm. long respectively. The areas of the different systems overlap somewhat.

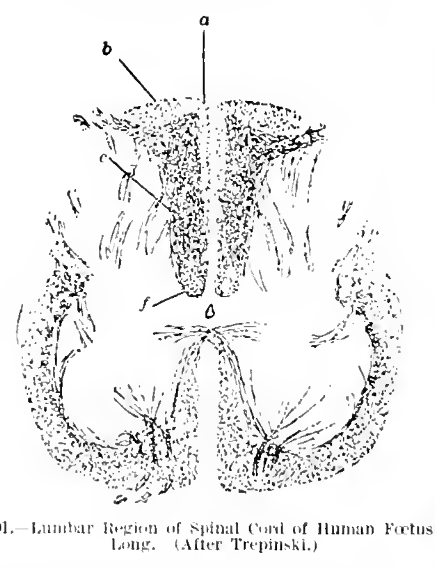


FIG. 4401.—Lumbar Region of Spinal Cord of Human Fœtus 35 cm. Long. (After Trepinski.)

In fœtuses 24 cm. long (Figs. 4396 and 4397) the poste-

Spinal Cord.

rior part of the funiculus in the lumbar region shows no medullated fibres, though the more ventral parts show evenly scattered medullated fibres. In the pars thoracalis and pars cervicalis the medullated fibres form a narrow stripe along the septum medianum posterius (Flechsig's median zone) and a somewhat broader stripe along the posterior horn (Flechsig's anterior root zone). These medullated stripes go over into one another in the most anterior region of the funiculus.

In fœtuses 28 cm. long (Figs. 4398, 4399, and 4400) the posterior funiculus in the lumbar region is medullated throughout, the second fibre system obviously being distributed over the whole cross-section. In the thoracic cord medullated fibres have appeared throughout the cross-section, but a light area is visible in the middle region of the funiculus, forming a stripe which goes from the posterior periphery almost to the anterior extremity of the funiculus. In the cervical cord of the fœtus 28 cm. long, the fasciculus gracilis looks pale, except for a narrow stripe near the median septum (Flechsig's median zone). This darker area is continuous anteriorly with the medullated area corresponding to the fasciculus cuneatus which is now well medullated.

In fœtuses 35 cm. long (Figs. 4401, 4402, and 4403) the third fibre system is medullated. A large number of new fibres have appeared in the lumbar cord in an area corresponding to Flechsig's middle root zone. In the cross-section this area is limited posteriorly by a curved line, behind which the posterior funiculus is pale in Weigert sections. There is another light stripe near the median septum, and a third light area in the most anterior part of the funiculus. The thoracic cord of the 35 cm. fœtus presents an entirely different appearance from that of the fœtus of 28 cm. The anterolateral part of the fasciculus cuneatus has received many new fibres; the posterolateral part of this fasciculus looks light in Weigert preparations. In the cervical cord at this stage the third fibre system is seen to be distributed throughout the greater part of the fasciculus cuneatus; a small area in the most posterior region of the funiculus shows no increase in fibres. The fibres in the medial portion of the fasciculus gracilis are increased. The lateral part of this fasciculus now looks light.

In fœtuses 42 cm. long the whole posterior funiculus (with the exception of Lissauer's fasciculus) is evenly medullated; the fibres which fill up the light areas of the fœtus 35 cm. long may therefore be regarded as belonging to Trepinski's fourth fœtal system. Lissauer's fasciculus is not wholly medullated even in fœtuses 47 cm. long.

To recapitulate, Trepinski's studies indicate that there are at least five fibre systems in the posterior funiculus.

1. A fibre system, including a part of the anterior portion of the funiculus in the lumbar cord, and a stripe along the posterior horn, along the gray commissure and along the posterior median septum in the thoracic and cervical cord.

FIG. 4402.—Thoracic Portion of Spinal Cord of Human Fœtus 35 cm. Long. (After Trepinski.)

2. A fibre system distributed over the whole area of the posterior funiculus, the fibres being more numerous in the posterior than in the anterior part of the lumbar cord, most scanty near the septum intermedium in the thoracic cord and in the fasciculus gracilis in the cervical cord, though the median zone of Flechsig is well medullated.

3. A fibre system distributed over the whole funiculus in the lumbar cord, except in Flechsig's median zone and the medial part of his posterior zone; spread all over the thoracic and cervical posterior funiculus with the exception of Flechsig's median zone, the medial part of his posterior zone, and the lateral part of the fasciculus gracilis.

4. A fibre system distributed in the posterior portion of the lumbar cord (medial posterior root zone of Flechsig), the anterior part of the funiculus and a stripe along

FIG. 4403.—Cervical Portion of Spinal Cord of Human Fœtus 35 cm. Long. (After Trepinski.)

the posterior part of the median septum; in the thoracic and cervical cord this fibre system is also distributed in the lateral part of the fasciculus gracilis.

5. A fibre system corresponding to Lissauer's fasciculus.

REFERENCES.

Flechsig, P.: Die Leitungsbahnen im Gehirn und Rückenmark, Leipzig, 1876, and especially in his article, Ist die Tabes dorsalis eine "System-Erkrankung"? Neurol. Centralbl., Leipz., Bd. ix., 1890, SS. 33, 72.

Trepinski: Die embryonalen Fasersysteme in den Hintersträngen und ihre Degeneration bei der Tabes dorsalis. Arch. f. Psychiat. u. Nervenkr., Berl., Bd. xxx., 1897, SS. 54-81.

4. *Method of Waller or Türck* (Study of Secondary Degenerations).—This method takes advantage of the fact that if a medullated axone be interrupted anywhere in its course by cutting, pressure of a tumor or the like, secondary or Wallerian degeneration takes place in the cellulifugal portion of the fibre, the portion of the fibre between the point of injury and the cell body which gives origin to the axone remaining uninjured for a considerable period of time. The finer changes characterizing this secondary or Wallerian degeneration have already been described in a previous article in this HANDBOOK (see *Neurone, General Pathology of*, in Vol. VI.).

As a rule, the secondary degeneration does not extend beyond the telodendrion of the axone concerned, that is to say, it is confined to the neurone which is injured. There are certain exceptions to this rule, exceptions which have been used in an absurdly unfair way as arguments against the existence of neurones, but in general the rule given holds. This method of the study of secondary degeneration has been one of the most fruitful of all the methods employed for the unravelling of conduction paths. It is applicable to degeneration in human beings, following disease or injury, and also to degenerations experimentally produced in animals by section or other modes of experimental injury. For a long time the application of this method was confined to cases in which the degeneration had gone far enough and was extensive enough to be studied by Weigert's myelin-sheath method, but more recently much greater advances have been made through the application of the extremely delicate method of Marchi, which permits of the detection of small groups of fibres, and even of single degenerated fibres a very short time (twelve to fifteen days) after the injury.

The method of secondary degenerations permits us, for example, to make out, at any given level of the cord, the number of fibres which are passing centripetally at that point, that is, ascending, and the number of fibres which are passing centrifugally at that level, that is, descending. Since every nerve fibre is dependent somewhere upon the nutritive influence of a nucleus in the cell body or perikaryon, that is to say, is a prolongation of a cell, when the nerve fibre is separated from its cell of origin, the peripheral part, being cut off from its trophic centre, necessarily undergoes degeneration.

If we cut through the spinal cord of an animal at any given level, all the nerve fibres cut through will inevitably degenerate on the cellulifugal side from the lesion. Thus above the plane of section there will be degeneration of all the ascending nerve fibres, that is to say, of all the fibres whose axones come from the nerve cells situated below the level of the section. On the other hand, below the plane of section there will be degeneration of all the descending fibres, that is to say, of all the fibres whose axones come from nerve cells situated above the plane of the lesion. The majority of the ascending fibres will be sensory; the majority of the descending fibres will be motor. Some of the ascending and some of the descending fibres will belong to neurones whose function it is to connect neighboring segments of the cord for participation in complex reflexes; it would be difficult to designate these axones as specifically sensory or specifically motor.

An excellent list of the most important observations on degeneration after transverse lesions of the human spinal cord is given by Ziehen on pages 246 and 247 of his monograph. There are observations for nearly every segment down as far as the second lumbar. The list is too long to be included here, but it will be found convenient for reference.

If transverse lesion of the human spinal cord has taken place in the pars thoracalis, there will, in general, be found degeneration, above the plane of the lesion, of the following centripetal bundles:

1. The whole of the posterior funiculus, including Lissauer's fasciculus, with the exception of a few centrifugal fibres to be described among the descending degenerations.

2. The peripheral zone of the lateral funiculus, including the direct cerebellar tract (fasciculus cerebellospinalis) in the dorsolateral periphery and Gowers's tract (fasciculus anterolateralis superficialis) in the ventrolateral periphery.

3. A part of the fibres of the lateral limiting layer of the gray matter (*zone cornumarginale* of French authors).

4. A part of the fibres of the anterior mixed zone of the lateral funiculus (funiculus lateralis proprius).

5. A large part of the fibres of the anterior ground bundle (fasciculus anterior proprius).

6. A large part of the fibres of the peripheral zone of the anterior funiculus, not only on the surface, but also along the fissura mediana anterior.

7. A few fibres scattered throughout the region occupied by the fasciculus cerebrospinalis lateralis or lateral pyramidal tract.

Below the level of the lesion there will be found degenerated the following:

1. The lateral pyramidal tract in the lateral funiculus (fasciculus cerebrospinalis lateralis).

2. A part of the fibres of the peripheral zone of the more ventral portion of the lateral funiculus.

3. A few of the fibres of the lateral limiting layer of the gray matter.

4. A part of the fibres of the anterior mixed zone of the lateral funiculus (fasciculus lateralis proprius).

5. A few of the fibres of the anterior ground bundle (fasciculus anterior proprius).

6. A few of the fibres of the peripheral zone of the anterior funiculus (Loewenthal's tract) from the cerebellum to the cord.

7. The pyramidal tract of the anterior funiculus (fasciculus cerebrospinalis anterior).

8. A comma-shaped layer of fibres at the junction of the fasciculus gracilis (Golli) with the fasciculus cuneatus (Burdachi) in the posterior funiculus.

9. A narrow layer near the septum medianum posterius (Flechsig's centrum ovale).

10. Lower down, a triangular field in the posteromedial portion of the posterior funiculus (dorsomedial sacral bundle of Obersteiner, *triangle médian* of Gombault et Philippe).

11. A few fibres in the most anterior portion of the posterior funiculus (*zone cornucommissurale* of Marie).

The method of the study of secondary degenerations has also been most useful in determining the exact intramedullary distribution of the fibres of the posterior roots of spinal nerves. Further reference to this fact will be made when the individual conduction paths are taken up.

REFERENCES.

Marchi, V., and Alghieri, G.: Sullo degenerazioni discendenti consecutive a lesioni sperimentali in diverse zone della corteccia cerebrale. Riv. sper. d. freniat., Reggio-Emilia, vol. xii., 1886-87, pp. 208-252.

Singer, J., und Münzer, E.: Beiträge zur Anatomie des Centralnervensystems insbesondere des Rückenmarkes. Denkschr. der Wiener Akad., Bd. lvii., 1890-91, S. 569.

Türck, Ludwig: Ueber secundäre Erkrankung einzelner Rückenmarksstränge und ihrer Fortsetzungen zum Gehirne. Ztschr. d. k-k. Gesellsch. d. Aerzte zu Wien., 1852, ii., 511; 1853, ii., 289.

Waller, A.: Experiments on the Section of the Glossopharyngeal and Hypoglossal Nerves of the Frog, and Observations of the Alterations Produced thereby in the Structure of their Primitive Fibres. London, Edinburgh, and Dublin Philosophical Magazine, vol. xxxvii., No. 247, p. 65, July, 1850. Also in Philosophical Transactions of the Royal Society of London, 1850, p. 423, and in the Edinb. Med. and Surg. Journ., vol. lxxvi., 1851, pp. 369-376.—Sur la reproduction des nerfs et sur la structure et les fonctions des ganglions spinaux. Arch. f. Anat., Physiol. u. wissensch. Med., Berl., 1852, SS. 392-401: Compt. rend. hebd. des séances de l'Acad. des sc., Par., t. xxxiv., p. 675.—Nouvelle méthode pour l'étude du système nerveux applicable à l'investigation de la distribution anatomique des cordons nerveux, et au diagnostic des maladies du système nerveux, pendant la vie et après la mort. Compt. rend. hebd. des séances de l'Acad. des sc., Par., t. xxxiii., 1851, p. 606.—Expérience sur les sections des nerfs et les altérations. Compt. rend. Soc. de biol., Par., 2me s., t. iii., 1857, pp. 6-8.

5. *Method of von Gudden* (Method of Development Inhibition).—Von Gudden's observations led him to believe that in a new-born animal a fibre system extending between two centres would atrophy if either centre were destroyed. But while the fibre system atrophies in either case, if one of the two centres be destroyed, the other will atrophy, not if it be the exciting one, but only if it be the one excited. For example, destruction of the retina, he maintained, would lead to an inhibition of the development of the whole visual path as far as the colliculus superior and the lateral geniculate body, but destruction of the superior colliculus itself would not inhibit the development of the retina, and destruction of the cortical visual area would not hinder the development of the superior colliculus, or the optic nerve or the retina. Observations and experiments since his time indicate that sometimes, at least, the extirpation of the centre excited is followed by an inhibition of the development of the exciting centre; thus the extirpation of the visual area in the cortex may be followed by imperfect development of the optic nerve. It has further been shown that amputations in the new-born cause some inhibition of development of the motor regions of the cortex and of the pyramidal tract, besides causing atrophy of the corresponding anterior horn cells in the spinal cord. On the other hand, extirpation of the motor area of the cortex in the new-born does not lead necessarily to atrophy of the anterior horn cells of the spinal cord, as von Gudden believed, but clinical and pathological observations render it probable that such atrophy is sometimes produced. Ziehen formulates the modified law as follows: If, in a new-born animal, before the central nervous system is fully developed, a conduction path be cut through, a centre destroyed, or a sense organ or a muscle extirpated, the conduction paths and centres therewith connected suffer an inhibition of development in so far as and in the degree that they are deprived of excitations. Thus centres and tracts which, as a result of the injury, receive no impulses, or almost none, fail to develop. This explains why the motor cells of the anterior horn often remain intact after cortical lesions, for even after the cortical injury they receive impulses continuously by way of the reflex collaterals from the posterior root fibres. The occasional occurrence of inhibited

development of sensory nerves after cortical extirpation might be explained on the theory that as a result of the loss of conscious sensations, for example from the eye, conscious movements of the same, on account of their uselessness, would gradually cease to occur, and with the limitation of the movements an important nutritive stimulus would disappear. Whether an inhibition of development would then occur, and in what degree, would depend upon the number of accidental circumstances (number of stimuli of reflex movements, etc.) (Ziehen).

In the application of the method Weigert's myelinesheath procedure and carmine staining are to be employed. A reduction in size of one-third on one side of the nervous system, as compared with the normal opposite side, traceable through a series of sections, is the criterion to be observed.

By this method most important information has been gained with regard to the visual conduction paths, the auditory conduction paths, the lemniscus, and the pyramidal tract.

REFERENCES.

Gudden, B. von: Gesammelte und hinterlassene Abhandlungen. Herausgegeben von H. Grashey, Wiesbaden, 1889.
Monakow, C. von: Gehirnpathologie, Wien, 1897.

6. *Method of Gotch and Horsley* (Electrophysiological Method).—This method is a physiological one and depends upon the variation of the electrical current on excitation of a conduction path; it determines the path followed by the impulses and hence the course followed by the axones of the fibre systems themselves.

REFERENCES.

Gotch, F., and Horsley, V.: On the Mammalian Nervous System, its Functions and their Localization Determined by an Electrical Method. Phil. Tr., 1891, London, 1892, vol. clxxxii. (B.), pp. 267–526.

By means of these various methods the centripetal and centrifugal conduction paths of the spinal cord have been and are being worked out. The centripetal paths include the paths carrying sensory impulses to cerebellar and cerebral centres, the sensory limbs of reflex arcs in the cord and the centripetal intersegmental paths. The centrifugal paths include the pyramidal tracts, the cerebello-spinal paths, and other centrifugal paths connecting the infracortical nuclei of the cerebrum with spinal centres, as well as the centrifugal intersegmental paths of the cord itself. To a description of some of the principal paths here mentioned we shall now turn.

A. *The General Sensory or Centripetal Paths in the Spinal Cord.*

It seems natural to begin with a description of the neurone systems concerned in the construction of the general sensory conduction paths from the skin, muscles, and organs to the nerve centres of the cord and to the higher centres in the brain. The conduction paths here concerned are very complex, but this is not to be wondered at when one recalls the complexity of reflex, instinctive, and voluntary reactions in which they participate, and when he remembers that these paths are the recipients of all the impulses from the skin, mucous membranes, and muscles below the head—impulses which probably vary in origin and character according as they are interpreted in consciousness, as touch, muscle sense, heat, cold, or pain. We might, from physiological observations, expect to find anatomically in the spinal cord separate conduction paths for touch, for heat, for cold, for muscle sense, and for pain. It is easy to demonstrate anatomically a large number of different centripetal fibre systems in the cord, but as to just how these differ in function and as to just what paths subserve the various modalities of sensation we are very poorly informed. It is true that there is some evidence for the view that tactile sensory impulses run in the lateral funiculi, and preferably though not exclusively, after crossing from the side of the cord in which they enter to the opposite side; and, further, that the muscle sense impulses (kinæsthetic excitations) run in the posterior funiculi, chiefly on the side of entrance. Anatomy teaches that all the centripetal impulses, no matter the sensation modality to which they correspond, enter the spinal cord through the fibres of the posterior roots. Most of the fibres of the posterior roots terminate at some level or another in the spinal cord or medulla oblongata. These fibres we know to be the axones of neurones, the cell bodies of which are situated in the spinal ganglia. By means of the terminals and collaterals of these axones the impulses arriving along them in the spinal cord may be transferred to several sets of central neurones; these latter carry the impulses farther and are designated as neurones of the second order in the general centripetal path. On the way from the periphery to the cortex of the brain the centripetal impulses have to pass through a chain of at least three superimposed neurone systems, and in many instances a very much larger number of neurone systems may take part in the concatenation.

It will be convenient to describe, first, the centripetal neurone systems of the first order, and to go on afterward with the description of the sensory neurone systems of the second and of higher orders, as far as these are present in the spinal cord.

1. *Peripheral Sensory Neurone Systems* (Centripetal Neurone Systems of the First Order).—These neurone systems include all the neurones which send processes to the periphery of the body below the head, to receive impulses from the skin, mucous membranes, muscles, tendons, and joints, and which send their central axones through the posterior roots of the spinal nerves into the posterior funiculi of the spinal cord. The cell bodies of these neuroné systems are all situated in the spinal ganglia. The proximal portions of the central axones as well as the whole extent of the peripheral axones of these neurones are situated outside the spinal cord. Only those portions of the central axones which extend from the pia onward are intramedullary; the intramedullary axones, being derived from cell bodies extramedullary in situation, are designated "exogenous fibres of the spinal cord."

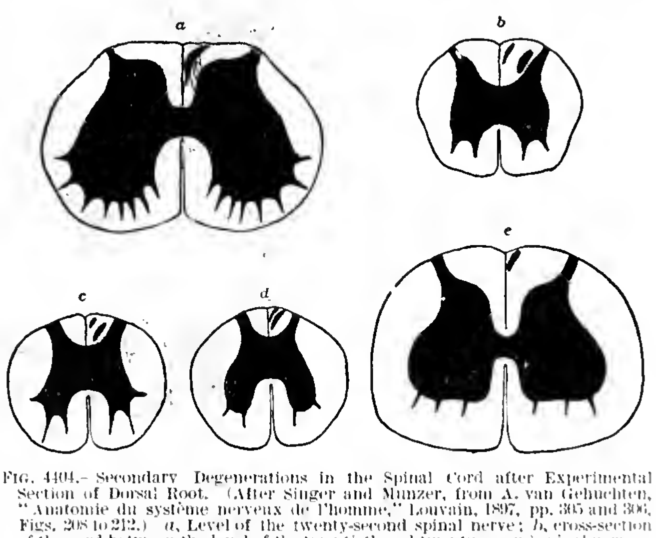
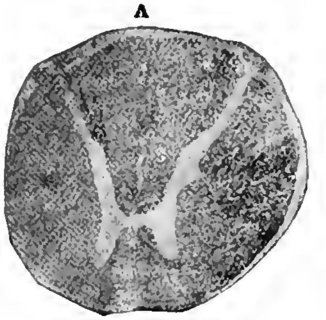


FIG. 4404.—Secondary Degenerations in the Spinal Cord after Experimental Section of Dorsal Root. (After Singer and Munzer, from A. van Gehuchten, "Anatomie du système nerveux de l'homme," Louvain, 1897, pp. 305 and 306, Figs. 208 to 212.) *a*, Level of the twenty-second spinal nerve; *b*, cross-section of the cord between the level of the twentieth and twenty-second spinal nerves; *c*, transverse section through the cord at the level of the eighteenth spinal nerve; *d*, transverse section of the cord in the thoracic region; *e*, transverse section of the cord at the level of the intumescentia cervicalis.

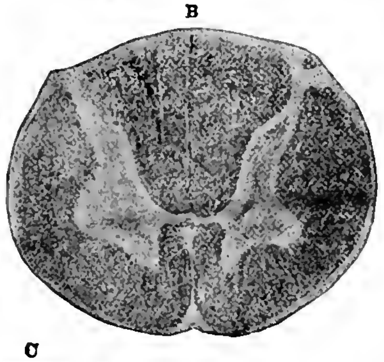
The study of secondary degenerations occurring in disease in human beings, or produced experimentally in animals, has thrown much light upon the distribution of the intramedullary continuations of the posterior root fibres, particularly since the method of Marchi has been applicable. Section of a posterior root in an animal causes complete degeneration of the intramedullary continuation of the fibres of that root to their termination. Serial sections show a progressive diminution in the number of fibres which are the continuations of the fibres of a given root as the cord is ascended, owing partly to a progressive diminution in the calibre of the fibres, but chiefly to the fact that the fibres of each root as they ascend stop at different levels to end in the gray matter. Moreover, there is a gradual change in the position occupied by the degenerated fibres as the cord is ascended. Thus fibres which low down in the cord are situated in the "entry zone" near the gray matter, come, higher up, to occupy a more medial and more posterior position; they pass gradually medialward through the fasciculus cuneatus until finally they come to lie, at higher levels, in the fasciculus gracilis. Each posterior root as it enters the spinal cord displaces the fibres of the fasciculus cuneatus in a posterior and medial direction, so that the long ascending fibres gradually approach the posterior median septum. Fig. 4404 shows the results of section of the posterior roots of the twenty-sixth, twenty-seventh, and twenty-eighth spinal nerves on one side and the posterior roots of the twentieth, twenty-first, and twenty-second nerves of the same side in a dog.

A number of human cases are on record in which injuries affecting posterior roots at different levels have been observed. The following list is important for reference:

A



B



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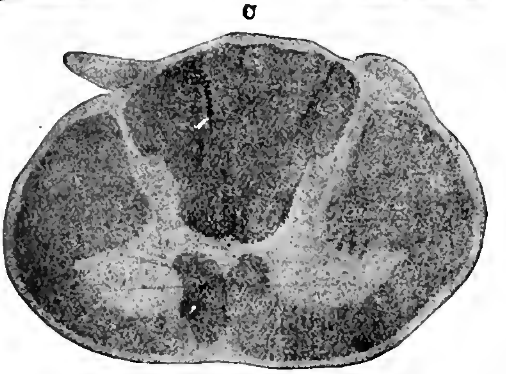

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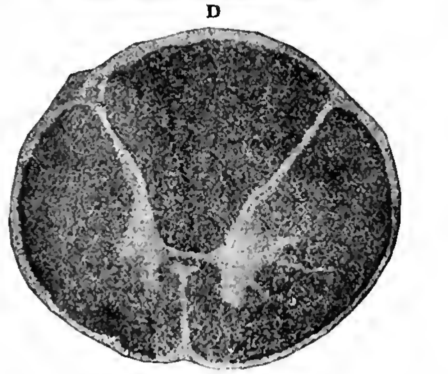

Fig. 4405.—Transverse Section of the Human Spinal Cord, showing Secondary Degenerations Following Isolated Lesion of the Sixth Thoracic Spinal Nerve. (After A. Marguliés, "Neurol. Centralbl.," Leipz., Bd. xv., 1896, SS. 348 and 349, Figs. 1-4.) *A*, Transverse section at the level of the sixth thoracic root; *B*, transverse section at the level of the first thoracic root; *C*, transverse section at the level of the seventh cervical root; *D*, transverse section at the level of entrance of the third cervical root.

Radices posteriores Nn. cervicalium IV. and V.

Gombault, A., et Philippe, C.: Contribution à l'étude des lésions systématisées dans les cordons de la moelle épinière. Arch. de méd. expér. et d'anat. path., Par., t. vi., 1894, pp. 365, 538.

Radix posterior Nn. cervicalium VI. and VII.

Sotta, J.: Contribution à l'étude des dégénerescences de la moelle consécutives aux lésions des racines postérieures. Rev. de méd., Par., t. xiii., 1893, pp. 290-313.

Radix posterior N. cervicalis VII.

Souques, A.: Dégénération ascendante du faisceau de Burdach et du faisceau cunéiform, consécutive à l'atrophie d'une racine cervicale postérieure. Compt. rend. Soc. de biol., Par., 10. S., t. ii., 1895, pp. 407-410.

Russell, J. S. R.: Contributions to the Study of Some of the Afferent and Efferent Tracts in the Spinal Cord. Brain, Lond., vol. xxi., 1898, p. 148.

Radix posterior N. cervicalis VIII.

Dejerine, J., et Thomas, A.: Contribution à l'étude du trajet intramédullaire des racines postérieures dans la région cervicale et dorsale supérieure de la moelle épinière; sur l'état de la moelle épinière dans un cas de paralysie radiculaire inférieure du plexus brachial d'origine syphilitique. Compt. rend. Soc. de biol., Par., 10. S., t. iii., 1896, pp. 675-679.

Radix posterior Nn. thoracalium I. and II.

Pfeiffer, R.: Zwei Fälle von Lähmung der unteren Wurzeln des Plexus brachialis (Klumpke'sche Lähmung). Deutsche Ztschr. f. Nervenh., Leipz., Bd. i., 1891, SS. 345-370.

Radix posterior N. thoracalis III.

Nageotte, J.: Étude sur un cas de tabes uniradiculaire chez un paralytique général. Rev. neurol., Par., t. iii., 1895, pp. 337, 369, 401.

Radix posterior N. thoracalis VI.

Marguliés, A.: Zur Lehre vom Verlaufe der hinteren Wurzeln beim Menschen. Neurol. Centralbl., Leipz., Bd. xv., 1896, SS. 347-351.

Radices posteriores Nn. lumbalis IV. et N. sacralis II. (III?).

Mayer, C.: Zur pathologischen Anatomie der Rückenmarkshinterstränge. Jahrb. f. Psychiat., Leipz., u. Wien, Bd. xiii., 1894, SS. 57-107.

Radix posterior N. lumbalis V.

Schaffer, K.: Ueber Faserverlauf einzelner Lumbal- und Sacralwurzeln im Hinterstrang. Monatschr. f. Psychiat. u. Neurol., vol. v., 1899, pp. 22, 95.

Radix posterior N. sacralis I.

Russell, J. S. R.: *Loc. cit.*

Radix posterior N. sacralis II.

Mayer, C.: *Loc. cit.*

Radices posteriores Nn. sacralium I.-V. (right side), III. and IV. (left side).

Sottas, J.: *Loc. cit.*

Radices posteriores Nn. sacralium IV. and V. and N. coccygei.

Gombault, A., et Philippe, C.: *Loc. cit.*

Radix posterior N. Sacralis V. et N. coccygei.

Schaffer, K.: *Loc. cit.*

The lesions at various levels following an isolated lesion of N. thoracalis VI. are shown well in Fig. 4405, *A* (Margulies' case).

P. Marie has divided the posterior root fibres into short fibres, long fibres, and fibres of intermediate length (*fibres courtes, fibres longues, et fibres moyennes*).

The exact course followed by the descending limbs of bifurcation of the posterior root fibres has not been ascertained satisfactorily as yet in any human case. Experiments on animals indicate that the descending limbs of bifurcation are short, running in to terminate in the gray matter within one or two segments of the level of entrance of the corresponding posterior root.

By Marchi's method it has been demonstrated that the fibres of the fasciculus gracilis which reach the medulla oblongata, nearly all turn in to end in the nucleus funiculi gracilis, while those of the fasciculus cuneatus which reach the medulla oblongata turn in to end in the nucleus funiculi cuneati. A certain number, however, of those fibres which ascend in the fasciculus gracilis are continued as posterior external arcuate fibres into the restiform body to end in the cerebellum, while others go as internal arcuate fibres to decussate in the raphe. Some of the fibres of the fasciculus cuneatus also go by way of the retiform body to end in the cerebellum without being interrupted in the nucleus funiculi cuneati.

Sections of the spinal cord stained by Weigert's myeline sheath method show many fibres extending from the posterior funiculi into the gray matter of the cord. These have been proven by other methods to be partly terminals, partly collaterals of the posterior root fibres.

Golgi's method has helped us a great deal in the interpretation of these fine medullated fibres of the Weigert's specimens, and indeed has revolutionized our conception of the mode of branching and termination of the posterior root fibres in general. By Golgi's method it is very easy to demonstrate the Y-shaped bifurcation of each posterior root fibre, soon after its entrance into the cord, into an ascending and a descending limb, each of which turns to run in the longitudinal direction, the ascending limb for a long distance, the posterior limb for a short distance, both ultimately terminating in the gray matter (Fig. 4406). This method, too, has revealed the large number of collaterals given off by the stem fibres, by the descending limb of bifurcation, and by the proximal portion of the ascending limb of bifurcation; it has also shown us how the terminals of the limbs of bifurcation themselves as well as the collaterals come into relation with the dendrites and cell bodies of the centripetal neurones of the second order, situated in the various groups of nerve cells of that gray matter.

It is very hard to state definitely in all cases how many of the fine fibres going from the posterior funiculi into the gray matter of the cord, as seen in Weigert preparations, are collaterals and how many are terminals of posterior root fibres. Of the groups to be immediately considered the reflex bundles appear to be made up chiefly of medullated collaterals, while the fine fibres going to end in the nucleus dorsalis are probably chiefly terminals of ascending limbs of bifurcation of posterior root fibres.

The fine medullated fibres going into the gray matter are divisible into at least four principal groups: (1) those ending in the columna grisea posterior and in the columna grisea intermedia; (2) those passing from the fasciculus cuneatus partly through the substantia gelatinosa, partly medial from it, forming S-shaped curves and ending in the anterior horns; these bundles, largest in the intumescentiæ, make up the reflex collaterals, each of which terminates by multiple division in among the cell bodies and dendrites of the lower motor neurones of the anterior horn; (3) those coming from the middle area of the fasciculus cuneatus and ending in the nucleus dorsalis (Clarkii); the bundles, reaching the posterior surface of the gray column, split into two divisions, one of which passes to each side of the nucleus, so that in cross-sections the nucleus dorsalis reminds one of a berry on a stem; (4) those running into the posterior intracentral commissure and ending chiefly in the opposite posterior horn.

The studies of Flechsig and Trepinski on the successive medullation of the intramedullary continuations of the posterior root fibres have already been referred to. We know that the fibres of a given root are not medullated all at once, but we are not sure in how far the differentiation of the posterior funiculus, yielded by Flechsig's method of study, is due to the successive medullation of groups of fibres as wholes, and how much of it is due to the successive medullation of different parts of the same fibres. It might very well be that the proximal portion of the posterior root fibres are medullated earlier than the distal portions; or, again, it is easily conceivable that the stem fibres and the two limbs of bifurcation may become medullated before the collaterals, or that some collaterals from one fibre become medullated before other collaterals from the same fibre. Until we are better informed upon these points we shall be at a loss in the making of classifications for the subdivisions of the peripheral neurone systems now under consideration.

At present two subdivisions are justifiable, but in how far one corresponds to the other we do not know. The

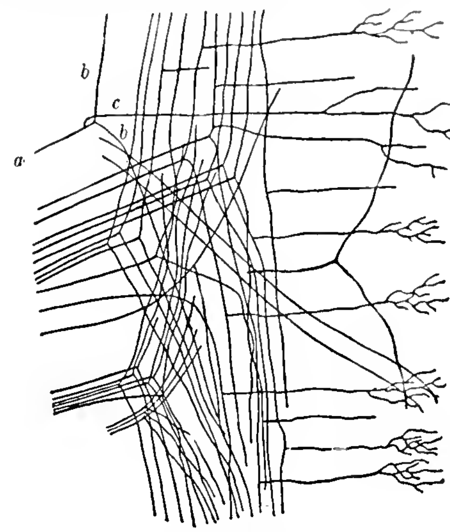

FIG. 4406.—Entrance of the Fibres of the Dorsal Roots into the Dorsal Funiculus of the Spinal Cord of an Embryo Calf. (After A. van Gehuchten, "Anatomie du système nerveux de l'homme," Louv., 2 ed, 1897, p. 302, Fig. 205.) A stem fibre, *a*, is seen dividing into two branches, *b*, *b*, the ascending and descending limbs of bifurcation. From the stem fibre, *a*, a collateral, *c*, is seen to arise. A number of collaterals arising from the limbs of bifurcation of other fibres are illustrated.

first subdivision, based upon successive medullation, has already been discussed. The second subdivision, that usually given in the text-books, is based upon the distribution of the terminals and collaterals of the posterior root fibres in different gray centres (*nuclei terminales*). Thus there may be distinguished (1) a direct ascending posterior funicular path (*direkte aufsteigende Hinterstrangbahn* of the Germans), including the long fibres of the fasciculus gracilis and fasciculus cuneatus which terminate in the rhombencephalon, chiefly in the nucleus funiculi gracilis and nucleus funiculi cuneati; (2) the path ending in the nucleus dorsalis (Clarkii); (3) the path ending in the posterior horn; (4) the reflex path ending in the anterior horn.

The *direct ascending path of the posterior funiculus* probably corresponds to several of Flechsig's fibre systems, not to any one of them. It is quite possible, therefore, that this path will, in the future, be further subdivided, inasmuch as its fibres are being medullated throughout the whole latter half of intra-uterine life. Clinical observations in tabes dorsalis and in transverse myelitis indicate that the muscle sense of the corresponding half of the body runs in the direct ascending path of each posterior funiculus—a view quite in accord with the observations in Brown-Séquard's paralysis, and with Mott's experimental hemisections in monkeys.

The *fibres running in to end in the nucleus dorsalis (Clarkii)* are, as Schaffer has shown, in all probability the terminals of ascending limbs of bifurcation of posterior root fibres rather than collaterals, although both may be concerned. Weigert preparations and Golgi preparations indicate that these fibres, as they ascend in the posterior funiculus, tend to run in Flechsig's middle root zone. My studies on hereditary ataxia lead me to think that at any rate a large part of these fibres correspond to the third fœtal system of Trepinski. Since the funiculus dorsalis is largely confined to the thoracic levels of the cord, it seems very likely that the fibres of the posterior funiculi which terminate in this nucleus are derived principally from the posterior roots of the Nn. lumbales and Nn. sacrales. They seem to correspond to the "fibres of intermediate length" of P. Marie's classification. His "long fibres" belong to the direct ascending path of the posterior funiculus, and his "short fibres" to the path to the posterior horn. Against the view that the path to Clark's nucleus corresponds to the third fœtal system of Trepinski, it might be urged that Flechsig states that medullation of these fibres begins in fœtuses 19–20 cm. long. Redlich has, however, expressed the opinion that the majority of fibres going to Clark's nucleus become medullated at a much later period—a view which my studies tend to corroborate. It is of course quite thinkable that the path to Clark's nucleus may later have to be subdivided into a number of different fibre systems, corresponding to different periods of medullation and perhaps to differences in functional significance. The individual fibres running in to end in the nucleus dorsalis are of small calibre, and each fibre breaks up into an end arborization which comes into relation with several cells of the nucleus. As to their function, the findings in cases of hereditary ataxia above referred to indicate that these fibres carry the impulses which, when transmitted through the direct cerebellar tract to the cerebellum, prevent that coarse variety of ataxia so pronounced in the individuals affected in the family described by Dr. Sanger-Brown. They can be concerned, however, only with impulses derived from the lower extremities and the trunk.

The *path to the posterior horn* includes the fibres which ascend in the posterior horn itself, the fibres which run in the posterior funiculus and turn in to end in the posterior horn, and the terminals and collaterals of the fibres of Lissauer's fasciculus. The majority of them appear to be fibres which end a short distance above the level of the posterior root, to which they belong. As they become medullated at very different periods, they probably consist of a series of embryological fibre systems. The majority of the fibres are small; they end in telodendrions about the cells of the substantia gelatinosa, the cells of the zonal layer, and the cells of Waldeyer's nucleus of the posterior horn. It is believed that the impulses concerned in tactile, painful, and thermic sensations enter the cord through these fibres, but the evidence has been gained *per exclusionem* rather than in any other way.

The *reflex path to the anterior horn* consists chiefly of collaterals which come off from the posterior root fibres and run forward in S-shaped curves, partly through the medial portion of the substantia gelatinosa, partly through the interval between the substantia gelatinosa and the nucleus dorsalis in regions of the cord in which the latter is present. They end in telodendrions about the anterior horn cells. It seems probable that each ascending limb of bifurcation of a posterior root fibre may give off several such reflex collaterals; others doubtless come off from the descending limb of bifurcation, and some from the stem fibres themselves before the bifurcation. The majority of the reflex collaterals go to the anterior horn of the same side of the cord, but some of them pass through the posterior intracentral commissure to reach the anterior horn of the opposite side. These reflex collaterals begin to be medullated in fœtuses 28 cm. long, but the medullation continues through several months. The fibres are of fine calibre; on their integrity depend the superficial and deep reflexes. It seems very probable that the main fibres which go to form the direct ascending path of the posterior funiculus give off the reflex collaterals—that is to say, the same neurones which serve to conduct impulses to the cerebral centres which are concerned in consciousness are utilized also to carry the impulses which set free reflexes.

A word must be said about the *descending limbs of bifurcation of the posterior root fibres.* In the case of secondary degeneration, studied by Dejerine and Thomas, in the cervical region the descending fibres of a posterior root extended over three segments in the form of an anteroposterior stripe situated in the lateral part of the fasciculus cuneatus. In Schaffer's case of lesion of the fifth lumbar root the degeneration was slight, being represented by an anteroposterior stripe extending from the posterior commissure to the posterior surface of the funiculus, and running parallel to the posterior median septum. The comma-shaped degeneration met with in the posterior funiculus after transverse lesion of the cord appears to be due to degeneration of endogenous fibres (which I have designated as the fasciculus posterior proprius) rather than to descending fibres of the posterior root.

REFERENCES.

Barbacci, O.: Die secundären, systematischen, aufsteigenden Degenerationen des Rückenmarks. Centralbl. f. allg. Path. u. path. Anat., Jena, Bd. ii., 1891, SS. 353–365.
Dejerine, J., et Spiller, W. G.: Contribution à l'étude de la texture des cordons postérieurs de la moelle épinière; du trajet intramédullaire des racines postérieures sacrées et lombaires inférieures. Comp. rend. Soc. de biol., Par., 10. S., t. ii., 1895, pp. 622–628.
Gehuchten, A. van: La moelle épinière et le cervelet. Cellule, Pierre et Louvain, 1891.
Golgi, C.: Studi istologici sul midollo spinale. Arch. ital. per le mal. nerv., Milano, vol. xviii., 1881, pp. 155–165.
Kölliker, A. von: Ueber den feineren Bau des Rückenmarks. Sitzungsb. d. phys.-med. Gesellsch. zu Würzb., 1890, 44–56.
Lenhossék, M. von: *Loc. cit.*
Marie, P.: Leçons sur les maladies de la moelle, 8vo, Par., 1892 (G. Masson).—De l'origine exogène ou endogène des lésions du cordon postérieur étudiées comparativement dans le tabes et dans le pellagre. Semaine méd., Par., t. xiv., 1894, pp. 17–20.
Ramón y Cajal, S.: Contribución al estudio de la estructura de la médula espinal. Rev trimest. de histol., 1889, Nos. 3 y 4.
Redlich, E.: Pathologie der tabischen Hinterstrangserkrankung, Jena, 1897.
Schultze, F.: Beiträge zur Lehre von der secundären Degeneration im Rückenmark des Menschen nebst Bemerkungen ueber die Anatomie der Tabes. Arch. f. Psychiat. u. Nervenkr., Berl., Bd. xiv., 1883, SS. 359–390.
Singer, J., u. Münzer, E.: Beiträge zur Anatomie des Centralnervensystems insbesondere des Rückenmarkes. Denkschr. der Wiener Akad., Bd. lvii., 1890–1900, S. 569.
Tschermak, A.: Ueber den centralen Verlauf der aufsteigenden Hinterstrangbahnen und deren Beziehungen zu den Bahnen im Vorderseitenstrang. Arch. f. Anat. u. Physiol., Anat. Abth., Leipz., 1898, SS. 291–400.

2. *Central Sensory Neurone Systems* (Centripetal Neurone Systems of the Second Order).—We have seen that the central axones of the peripheral neurone systems (centripetal neurone systems of the first order) end in various masses of the gray matter of the spinal cord and medulla—the so-called terminal nuclei of the peripheral sensory spinal nerves. Among these terminal nuclei we have mentioned the nucleus funiculi gracilis and nucleus funiculi cuneati of the medulla oblongata, the nucleus dorsalis (Clarkii) on each side, and the gray matter of the posterior horn or columna grisea posterior. In these terminal nuclei are situated the cell bodies and dendrites of neurones of the second order, the axones of which carry the impulses farther.

The medullated fibres which correspond to the axones coming from the nuclei of the posterior funiculi in the medulla oblongata go to form, after decussation, the medial lemniscus (cf. article *Brain, Histology of*). It will not be further discussed here.

The medullated axones coming from the cell bodies situated in the nucleus dorsalis (Clarkii) form a very important fibre system, the so-called "direct cerebellar tract," or Flechsig's bundle. It is sometimes described as the fasciculus cerebellospinalis, but I prefer to designate it the *fasciculus spinocerebellaris dorsolateralis.* This fibre bundle, recognized by Foville, Türck, and Meynert, was first exactly described by Flechsig. The axones come off from the cells in Clarke's nucleus, turn horizontally lateralward in curves to reach the posterolateral periphery of the funiculus lateralis, and then turn in the longitudinal direction to run the whole length of the cord and pass through the corpus restiforme to end in the cerebellum. The fibres receive their myeline sheaths at about the sixth or seventh month of fœtal life. The fibres are of very large calibre, measuring from 3 to 10 μ in diameter, the majority measuring from 6 to 8 μ. They stand close together and are often sharply recognizable in normal Weigert preparations as a distinct compact mass, which contrasts with the neighboring pyramidal bundles.

As the nucleus dorsalis is represented below the thoracic cord only by the sacral nucleus of Stilling, only a few fibres corresponding to the direct cerebellar tract are to be found below the twelfth thoracic segment (Fig. 4407).

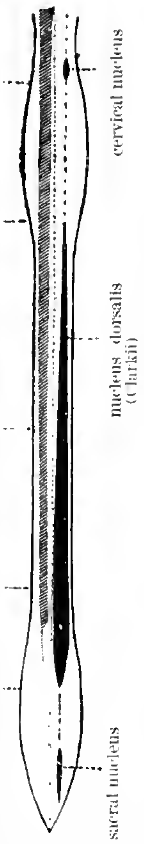

FIG. 4407.—The Column of Clarke and the Direct Cerebellar Tract. The situation and volume of the column of Clarke are shown as a heavy black band on the right; those of the direct cerebellar tract are represented by a striated black band on the left. (From Poirier et Charpy, "Traité d'anatomie humaine," t. iii., 2 ed., Paris, 1901, p. 206, Fig. 146.)

The bundle of fibres occupies a comma-shaped field in the lower thoracic cord corresponding to the third and fourth fifths of the periphery of the lateral funiculus, counting from the front. In the upper thoracic cord it may displace the lateral pyramidal tract from the periphery and extend backward as far as Lissauer's fasciculus. In the cervical region it occupies the whole dorsal half of the periphery of the lateral funiculus except at the level of N. cervicalis II., where the posterior seventh of the periphery is occupied by the lateral pyramidal tract. The medial portion of the area of the tract throughout its whole extent is overlapped slightly by the area of the lateral pyramidal tract, the fine fibres of the latter being mixed with the coarser fibres of the former. On the whole, however, the limitation as seen under a low power is tolerably sharp.

The area of the tract increases steadily in the cross-sections, as the cord is ascended. There has been some dispute as to whether all of the fibres of the tract go to the cerebellum, or whether some end at different levels in the gray matter of the cord; the weight of opinion, at present, is in favor of the former view. The fibres ultimately terminate in the vermis superior (Flechsig, von Monakow, Mott). As has already been pointed out, the tract always undergoes ascending secondary degeneration in transverse lesions of the thoracic cord. I have called attention in another place to the marked liability of this tract to injury in acute cerebrospinal meningitis, owing doubtless to its exposed position on the surface of the cord ("On Certain Changes in the Cells of the Ventral Horns and of the Nucleus Dorsalis [Clarkii] in Epidemic Cerebrospinal Meningitis," *Brit. Med. Jour.*, London, 1897, ii., pp. 1839–41). Studies in tabes and in hereditary ataxia make it seem probable that the neurone system of the second order, to which the fibres of this tract belong, conducts to the cerebellum the group of centripetal impulses concerned in the automatic regulation by the cerebellum of the body equilibrium.

The medullated fibres which correspond to the axones coming from the cells of the gray matter of the posterior horn, give rise to several fibre systems, among which may be mentioned the superficial anterolateral fasciculus of Gowers, the fasciculus anterior proprius, the fasciculus lateralis proprius, and the fasciculus posterior proprius.

The *fasciculus anterolateralis superficialis (Gowersi)* is also, in the main, an ascending tract from the spinal cord to the cerebellum. I have suggested that this main part of it be called, therefore, the *fasciculus spinocerebellaris ventrolateralis*. Developmentally, it is a part of Flechsig's anterior mixed zone of the lateral funiculus. The exact position of the cells in the gray matter, which give off these axones, is not yet known. It seems probable that they are in the posterior horn, or in the columna intermedia between the posterior horn and the anterior horn, and it is certain that while some of the cells of origin are in the gray matter of the same side, many of them are in the gray matter of the opposite side of the cord, the crossing taking place through the commissura anterior alba. Hence the neurones, to which the fibres of Gowers' tract belong, are partly tautomeric, partly heteromeric neurones. The fibres become medullated at the beginning of the eighth fœtal month (von Bechterew). The calibre of the fibres varies a good deal; some of them are coarse, others fine.

The tract begins in the lumbar portion of the spinal cord, where it lies in the middle of the periphery of the lateral funiculus, occupying about one-seventh of that periphery. Higher up, as the area of the tract increases in size, the additions are made chiefly anteriorly. In the cervical and upper thoracic cord the area occupied by the tract extends from the anterior extremity of the area of Flechsig's direct cerebellar tract to near the sulcus lateralis anterior. The shape of the area as seen in cross-section varies a good deal in different human cases. The area is not sharply limited, either medialward or dorsalward, as it is overlapped slightly by the area of the direct cerebellar tract of Flechsig and by other fibre systems of the fasciculus lateralis. Mixed up with the fibres of Gowers' tract, which are ascending, are some fibres of descending tracts, as secondary degenerations show.

There is a good deal of evidence in support of the view that not all of the fibres of Gowers' tract reach supraspinal terminations, many of them ending in the gray matter of the cord on the way up. It is possible that some of them pass dorsalward to run farther upward in the direct cerebellar tract of Flechsig. The course of Gowers' tract through the medulla oblongata and pons has been followed by Patrick and by Hoche. It goes cerebralward as far as the colliculus inferior and then runs backward through the velum medullare anterius, along with the fibres of the brachium conjunctivum to end in the vermis superior, partly on the same side, partly on the opposite side (Fig. 4408).

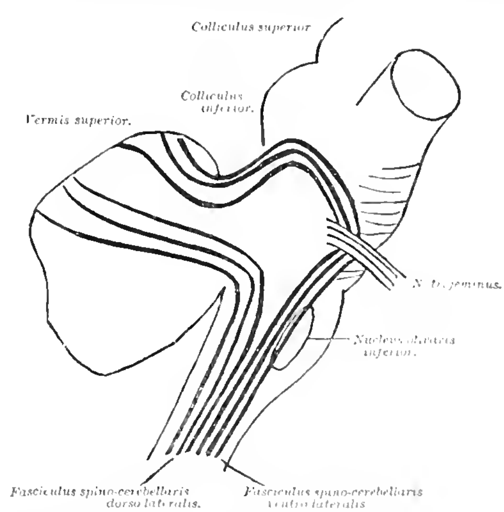

FIG. 4408.—Diagrammatic Representation of the Course of the Fibres of the Two Principal Tracts Ascending from the Spinal Cord to the Cerebellum. (After F. W. Mott, *Brain*, Lond., vol. xv., 1892, p. 219, Fig. 1.) The fasciculus spinocerebellaris ventrolateralis Gowersi and the fasciculus spinocerebellaris dorsolateralis are united in the cord and in the lower part of the medulla. The latter passes into the corpus restiforme and terminates in the dorsal portion of the superior vermis. The former remains ventrally situated until it reaches the level of the N. trigeminus; passing beyond this it forms a loop backward to reach the dorso-lateral surface of the brachium conjunctivum. The fibres then course backward and sweep round into the anterior portion of the superior vermis.

In addition to the main portion of Gowers' tract, which represents a spinocerebellar neurone system by way of the brachium conjunctivum (systema neuronicum spinocerebellare ventrolaterale conjunctivale), there are in the tract fibres which end in the superior colliculus of the corpora quadrigemina (systema neuronicum spinoquadrigeminum superius), fibres which end in the thalamus (systema neuronicum spinothalamicum), and fibres which go to the cerebellum by way of the corpus restiforme (systema neuronicum spinocerebellare ventrolaterale restiformale). If Rossolimo's observations should be confirmed, there are also, in Gowers' tract, fibres which terminate in the inferior colliculi, in the substantia nigra, and in the nucleus lentiformis.

As to the function of Gowers' tract there is much dispute. Gowers himself thought that the tract might conduct pain impulses. It seems more probable, however, that the function of this tract is similar to that of the direct cerebellar tract of Flechsig.

The *fasciculus anterior proprius*, *fasciculus lateralis proprius*, and *fasciculus posterior proprius* may next be discussed. Secondary degenerations show that these fasciculi are made up partly of ascending fibres, partly of descending fibres; partly of fibres coming from cells of the gray matter of the same side of the cord, partly of fibres coming from cells of the gray matter of the opposite side of the cord. Of these three fasciculi, the fasciculus lateralis proprius is by far the most voluminous. The fasciculi proprii become medullated early in fœtal life and are of great interest to the clinician, since in them are to be sought, as far as we can now see, the paths which conduct the impulses concerned in the sensations of touch, temperature, and pain.

The centripetal neurones of the second order, whose axones run in the fasciculus anterior proprius, may be divided into two sets: (1) those of ascending axones (*ascending centripetal path of the fasciculus anterior proprius*), and (2) those of the descending axones (*descending centripetal path of the fasciculus anterior proprius*). The ascending path is made up of medullated axones coming chiefly from the cells in the interior of the posterior horn, partly from the same side, partly from the opposite side, through the anterior white commissure. In the anterior funiculus these fibres are situated at the periphery in front and along the anterior median fissure (*zone sulcomarginale* of Marie). The fibres are mixed up with the descending path of Loewenthal, and with the path which corresponds to the medullated axones of the commissural cells of the anterior horn. These fibres probably terminate at various levels of the gray matter of the cord, sending their impulses on through centripetal neurone systems of the third order, though this view is hypothetical. We have but few facts as yet to record concerning it. The descending path has been shown by Golgi's method to be made up of axones which come from cells in the interior of the posterior horn of the same or of the opposite side. These descending fibres are practically all descending limbs of bifurcating axones, so that the path pertains to the same set of neurones which gives rise to the ascending path. The fibres end in all probability after a shorter or longer (though never very long) course in the gray matter of the anterior horn. Whether they enter into conduction relation chiefly with the motor cells or with the commissural cells of the anterior horn is not known, but in either case they would participate in the setting free of the more complex spinal reflexes.

The centripetal neurones of the second order, whose axones run in the fasciculus lateralis proprius, may also be divided into two sets: (1) those with ascending axones (*ascending centripetal path of the fasiculus lateralis proprius*); and (2) those with descending axones (*descending centripetal path of the fasciculus lateralis proprius*). The ascending path corresponds to the medullated axones of the marginal cells of the posterior horn and of the nerve cells in the caput of the posterior horn, partly of the same side, partly through the posterior intracentral commissure of the opposite side. The fibres of this path run partly in the anterior mixed zone among the fibres of Gowers' tract and of Marchi's descending cerebello-spinal path, partly in the lateral limiting layer of the gray matter. These fibres are very fine in calibre. Most of them are short, extending over only one, two, or three segments, after which they run in to end in the gray matter of the cord, where they come into conduction relation with centripetal neurones of the next higher order (columna intermedia, columna intermediolateralis). It is this path, made up of a whole series of neurones with relatively short axones superimposed upon one another, that has to do, in all probability, with the conduction of tactile, painful, and thermic sensory impulses. Since tactile sensations developed presumably phylogenetically, it is perhaps not surprising that the neurones forming the path for them should have axones which extend over only one to three metameres. This path is designated by Ziehen the "*aufsteigendes Binnenbahnsystem des Seitenstrangs.*" The descending path of the fasciculus lateralis proprius consists of the medullated descending limbs of bifurcation of those axones from the cells of the posterior horn which go to the lateral funiculus and bifurcate into ascending and descending branches. They run chiefly in the lateral limiting layer of the gray matter, though some of them are mixed up with the fibres of the lateral pyramidal tract. They probably have a reflex function.

The centripetal neurones of the second order, whose axones go to the posterior funiculus, give rise similarly to *an ascending and a descending centripetal path in the fasciculus posterior proprius*. The ascending path corresponds to the medullated axones of all three kinds of cells in the posterior horn—Gierke's cells, the zonal or marginal cells, and the cells of the caput. The axones come partly from the same side of the cord, partly from the opposite side through the posterior intracentral commissure. They run longitudinally in the most ventral portion of the posterior funiculus. This path remains intact in tabes dorsalis. It is the endogenous bundle of the posterior funiculus and does not degenerate after posterior root lesions, though some posterior root fibres may be mixed up with the fibres of this tract. Most of the fibres are short, turning in to end in the gray matter of adjacent levels; among them, however, are some fibres which are much longer. Their function is unknown; it may perhaps be assumed that they have to do with the more complex reflexes. The descending path in the fasciculus posterior proprius has been much better studied. Being endogenous, it often remains intact in tabes; it may be found degenerated in cases of syringomyelia. The tract is made up of fibres from the posterior horn cells, and corresponds chiefly to the descending limbs of fibres which undergo T-shaped bifurcation in the posterior funiculus. These fibres correspond to the comma-shaped area of degeneration of the upper part of the cord, to the "oval field" of Flechsig lower down, and still lower to the "triangle" of Gombault and Philippe. This tract, in all probability, corresponds to the "descending septomarginal tract" of Bruce and Muir, and to the *dorsomediales Sacralbündel* of Obersteiner. It must not be forgotten that circumscribed as this bundle is, there are always some fibres derived from the posterior roots mixed with its endogenous fibres. The function of the descending tract in the posterior funiculus is unknown, though Mann has suggested that it has something to do with the innervation of the Mm. intercostales.

REFERENCES.

On the Direct Cerebellar Tract.

Flechsig, P.: Die Leitungsbahnen im Gehirn und Rückenmark, Leipz., 1876, S. 295.

Foville: Traité complet d'anatomie et de physiologie du systême nerveux cérébro-spinal, Par., 1844.

Mott, F. W.: Die zuführenden Kleinhirnbahnen des Rückenmarks bei dem Affen. Monatsschr. f. Psychiat. u. Neurol., Berl., Bd. i., 1897, SS. 104-121.—Microscopical Examination of Clarke's Column in Man, the Monkey, and the Dog. Journ. Anat. and Physiol., Lond., vol. xxii., 1887-88, pp. 479-495.—The Bipolar Cells of the Spinal Cord and their Connections. Brain, Lond., vol. xiii., 1890, pp. 433-448.

Sherrington, C. S.: Note on the Spinal Portion of Some Ascending Degenerations. Journ. Physiol., Lond., vol. xiv., 1893, pp. 255-302.

Spinal Cord.

On Gowers' Tract.

Gowers, W. R.: Diagnosis of the Diseases of the Spinal Cord, Lond., 1897.—Bemerkungen ueber die antero-laterale aufsteigende Degeneration im Rückenmark. Neurol. Centralbl., Leipz., Bd. v., 1886, SS. 97-99.—Weitere Bemerkungen ueber den aufsteigenden anterolateralen Strang. Neurol. Centralbl., Leipz., Bd. v., 1886, S. 150.—On the Antero-lateral Ascending Tract of the Spinal Cord. Lancet, Lond., 1886, i., p. 1153; also in Asclepiad, London, vol. iii., 1886, pp. 278-281.

Hoche, A.: Ueber secundäre Degeneration, speciell des Gowers'schen Bündels, nebst Bemerkungen ueber das Verhalten der Reflexe bei Compression des Rückenmarkes. Arch. f. Psychiat. u. Nervenkr., Berl., Bd. xxviii., 1896, SS. 510-543.

Mott, F. W.: *Loc. cit.*

Patrick, H. T.: Ueber aufsteigende Degeneration nach totaler Quetschung des Rückenmarkes (Anhang zu dem Aufsatze von Dr. Bruns: Ueber einen Fall von totaler traumatischer Zerstörung des Rückenmarkes, etc.). Arch. f. Psychiat. u. Nervenkr., Berl., Bd. xxv., 1893, SS. 831-844; also Journ. Nerv. and Ment. Dis., N. Y., vol. xxiii., 1896, pp. 85-107.

Rossolimo, G. J.: Ueber den centralen Verlauf des Gowers'schen Bündels. Neurol. Centralbl., Leipz., Bd. xvii., 1898, SS. 935-940.

Russell, J. S. R.: Contributions to the Study of Some of the Afferent and Efferent Tracts in the Spinal Cord. Brain, Lond., vol. xxi., 1898, pp. 145-179.

Schaffer, K.: Beitrag zur Histologie der secondären Degeneration; zugleich ein Beitrag zur Rückenmarksanatomie. Arch. f. mikr. Anat., Bonn, Bd. xliii., 1894, SS. 252-266.

On the Endogenous Fibres of the Posterior Funiculi.

Bruce, A., and Muir, R.: On a Descending Degeneration in the Posterior Columns in the Lumbar-Sacral Region of the Spinal Cord. Brain, Lond., vol. xix., 1896, pp. 333-345.

Gombault, A., et Philippe, C.: Contribution à l'étude des lésions systématisées dans les cordons blancs de la moëlle épinière. Arch. de méd. expér. et d'anat. path., Par., t. vi., 1894, pp. 365, 538.—Note relative à la signification de la sclérose descendante dans le cordon postérieur et aux relations qu'elle affecte avec le centre ovale de Flechsig. Progrès méd., Par., 2. S., t. xix., 1894, pp. 255-257.—État actuel de nos connaissances sur la systématisation des cordons postérieurs de la moëlle épinière. Semaine méd., Par., t. xv., 1895, pp. 161-166; also Eng. Transl. in Med. Week., Par., vol. iii., 1895, pp. 433-439.

Hoche, A.: Ueber Verlauf und Endigungsweise der Fasern des ovalen Hinterstrangfeldes im Lendenmarke. Neurol. Centralbl., Leipz., Bd. xv., 1896, SS. 154-156.—Ueber secundäre Degeneration speciell des Gowers'schen Bündels, nebst Bemerkungen ueber das Verhalten der Reflexe bei Compression des Rückenmarkes. Arch. f. Psychiat. u. Nervenkr., Berl., Bd. xxviii., 1896, SS. 510-543.

B. Centrifugal Neurone Systems in the Spinal Cord. (Central Motor Neurones.)

Under this heading are to be considered the neurone systems, the axones of which enter into conduction relations with the cell bodies and dendrites of the lower motor neurones of the anterior horns. The central motor neurones, by means of this conduction relation, which their axones establish with the lower motor neurones, help to form the general motor conduction path from the higher centres of the brain to the muscles of the body. The lower motor neurones have cell bodies and dendrites in the gray matter of the spinal cord, but only the proximal portions of their axones are in the cord itself; the main portions of the axones lie peripheral to the cord, forming the anterior roots and the motor portions of the peripheral nerves; the axones finally terminate in motor end-plates (telodendrions) on the muscle fibres. These lower motor neurones are thrown under the direct influence of the peripheral sensory neurones by means of the reflex collaterals from the posterior root fibres. They are less directly under the influence of the peripheral sensory neurones by means of intercalated associative central neurones in the cord, the axones of which help to make up the ascending and descending fibre systems of the fasciculi proprii. They are still more remotely under the influence of the peripheral centripetal neurones by means of the conduction relations which are established between the central sensory neurones (the axones of which terminate in higher centres) and the upper motor neurones of the general motor conduction path. It is these upper motor neurones which must now be considered.

Cerebrospinal Motor Neurones (Neurones the Axones of which Make up the Fibres of the Pyramidal Tracts).—These are the neurones the cell bodies and dendrites of which are situated in the motor area of the cerebral cortex, and the axones of which run downward to terminate about the motor cells of the anterior horns. These neurones mediate the conscious movement impulses sent out from the brain voluntarily to the spinal cord (and thus toward the muscles). The axones leaving the cortex run through the centrum semiovale of the hemisphere, help to form the corona radiata of the capsula interna and pass through the anterior two thirds of the posterior limb of the capsule. In the capsula interna the fibres governing the movements of the upper extremity are in front of the fibres controlling the movements of the lower extremity. Below the internal capsule the

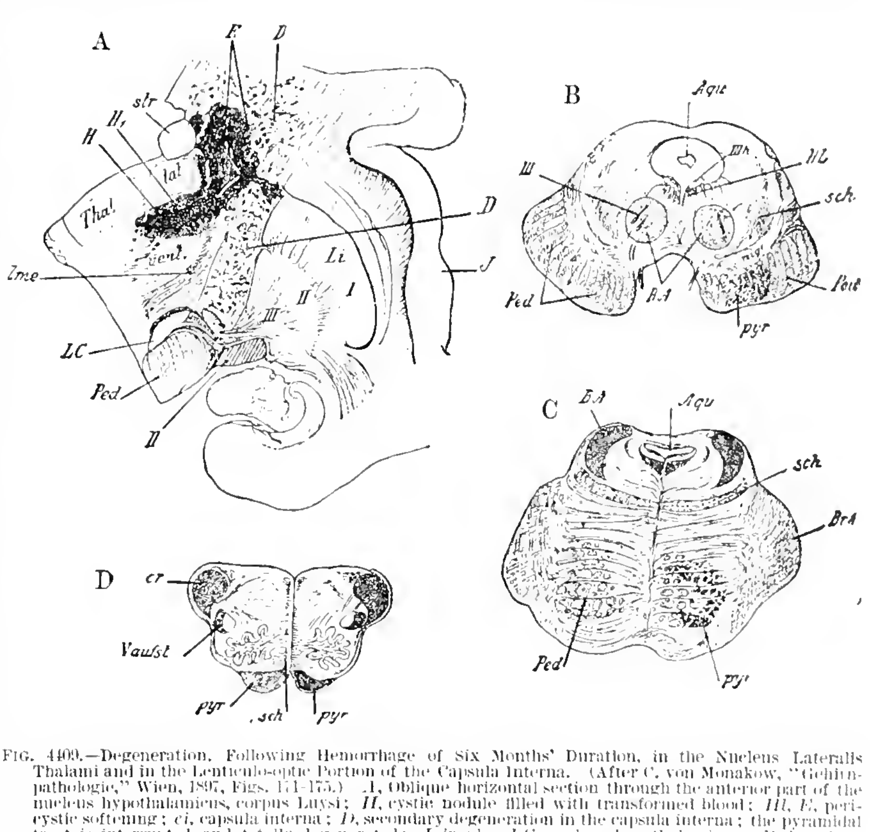

FIG. 4409.—Degeneration. Following Hemorrhage of Six Months' Duration, in the Nucleus Lateralis Thalami and in the Lenticulo-optic Portion of the Capsula Interna. (After C. von Monakow, "Gehirnpathologie," Wien, 1897, Figs. 171-175.) *A*, Oblique horizontal section through the anterior part of the nucleus hypothalamicus, corpus Luysi; *H*, cystic nodule filled with transformed blood; *H1*, *E*, pericystic softening; *ci*, capsula interna; *D*, secondary degeneration in the capsula interna; the pyramidal tract is interrupted and totally degenerated; *J*, insula; *LC*, nucleus hypothalamicus; *Ped*, pedunculus cerebri; *II*, tractus opticus; *Li*, nucleus lentiformis; *str*, corpus striatum; *lat*, nucleus lateralis thalami; *vent*, nucleus ventralis thalami; *lme*, lamina medullaris. *B*, *C*, *D*, fronto-horizontal; *B*, level of the colliculus superior and of the pedunculus cerebri; *C*, middle of pons; *D*, medulla oblongata. *Aqu*, aquæductus cerebri; *III*, nervus oculomotorius; *III K*, nucleus nervi oculomotorii; *sch*, lemniscus medialis; *HL*, fasciculus longitudinalis medialis; *B A*, brachium conjunctivum; *Br A*, brachium pontis; *Ped*, pedunculus cerebri; *pyr*, pyramidal tract degenerated on the right side; *cr*, corpus restiforme; *Vaufst*, tractus spinalis nervi trigemini.

fibres run through the base of the cerebral peduncle at about its middle, plunge through the basilar part of the pons, helping to form the longitudinal fasciculi of that region, to reach the medulla oblongata, where they form the well-known fasciculi pyramidales, which on each side correspond to the pyramis medullæ oblongatæ, which can be seen from the surface. In the lower part of the medulla oblongata the fibres undergo a partial decussation, the so-called decussatio pyramidum, which takes place

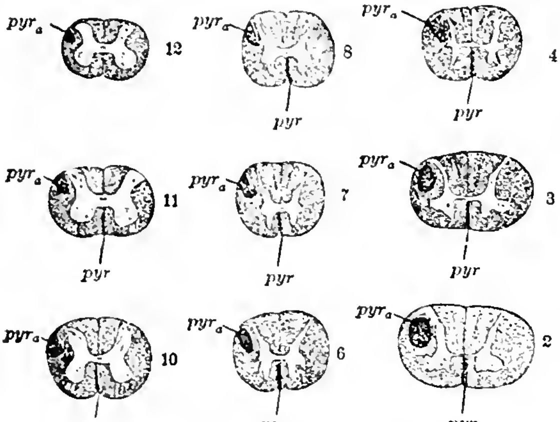

FIG. 4410.—Degenerated Fibres in the Spinal Cord of the Same Case as that shown in (Fig. 4409). 1–3, pars cervicalis; 4–8, pars thoracalis; 9–12, pars lumbosacralis; *pyr*, fasciculus cerebrospinalis ventralis; *pyra*, fasciculus cerebrospinalis lateralis.

throughout a distance of about 1 cm. The fibres, in their crossing, pass through the gray matter of the anterior horn into the opposite lateral funiculus. A portion of the fibres of each pyramid remains uncrossed, going down chiefly as an uncrossed bundle in the funiculus anterior of the same side of the spinal cord. A few fibres, however, pass downward in the funiculus lateralis of the same side. The fasciculus cerebrospinalis anterior or anterior pyramidal tract is therefore an uncrossed fibre system, while the fasciculus cerebrospinalis lateralis is a fibre system chiefly crossed, but containing a few uncrossed fibres (Figs. 4409 and 4410).

The lateral pyramidal tract, or fasciculus cerebrospinalis lateralis in the cervical portion of the spinal cord, occupies a large area in the posteromedial region of the lateral funiculus. Its volume decreases rapidly as the cord is descended and the relative position of the fibres undergoes some alteration. Owing to the fact that the direct cerebellar tract is not present below the thoracic cord, the lateral pyramidal tract in the lumbosacral region comes to lie adjacent to the periphery of the cord.

The decrease in volume as the cord is descended is owing partly to a progressive diminution in the calibre of the fibres, but chiefly to the fact that constituent fibres of the bundle leave it at each segment to turn into the gray matter of the anterior horn, to end there. More fibres turn in to end in the segments which correspond to the cervical and lumbar enlargements than elsewhere in the cord, since it is over the muscles innervated by these segments that the cerebrum exercises the most refined control (muscles of the upper and lower extremities).

The fibres of the anterior pyramidal tract (fasciculus cerebrospinalis anterior) decrease also in number as the cord is descended, the loss in it being very great in the region of the intumescentia cervicalis. The fasciculus is entirely exhausted on its way through the thoracic cord, none of its fibres reaching as far as the lumbar cord. The majority of the axones of the anterior pyramidal tract run in to terminate in the anterior horn of the same side, but a few of them pass through the commissura anterior alba to end in the anterior horn of the opposite side.

The fibre systems of the pyramidal tracts are exquisitely localizable by the embryological method of Flechsig, since at birth practically all the fibres of the spinal cord, with the exception of the pyramidal tracts and the little tract in the upper cervical region known as Helweg's path, are fully medullated. This is an interesting fact, for the medullated axones of the lower motor neurones are among the first of all the nerve fibres of the body to be medullated. Accordingly the corticomuscular conduction path in its lower part (anterior roots and motor nerves) is medullated and presumably ready for function long before its upper part (pyramidal tracts), the explanation being that the lower part of the corticomuscular conduction path also subserves the function of the motor limb of the direct reflex conduction paths.

The embryological method throws much light upon the variations in decussation which occur in the lower part of the medulla oblongata. The lateral pyramidal tracts are never entirely absent. They usually make up from eighty to ninety per cent. of the total volume of the cerebrospinal fasciculi, but the proportion varies a great deal, more fibres crossing in one case than in another. In rare cases as few as ten per cent. of the fibres go over into the lateral funiculus, the remaining ninety per cent. continuing downward in the anterior funiculus. In other rare instances the whole pyramidal tract goes over into the lateral funiculus and the fasciculus cerebrospinalis anterior is absent. There is sometimes asymmetry on the two sides, the asymmetry more often affecting the anterior pyramidal tract than the lateral tract, though it may affect both. Usually the asymmetry is due rather to a unilateral excess in the decussation than to an excess in the total number of fibres. Occasionally a part of the fibres of the pyramidal tract descends at the junction of the anterior and lateral funiculi.

The pyramidal tracts in monkeys appear to have similar relations to those met with in man, uncrossed and crossed fibres being present in the lateral and anterior funiculi. The same is true of the dog, though only a few fibres run in the anterior funiculus, the pyramidal tract being situated almost entirely in the lateral funiculus in this animal. In the rabbit the pyramidal tract is nearly all a crossed tract running in the opposite lateral funiculus. In rats and mice the pyramidal fibres form a definite bundle which runs almost exclusively in the anterior part of the opposite posterior funiculus. Even marsupials have a well marked pyramidal decussation, the majority of the fibres descending in the opposite lateral funiculus. Whether birds possess a pyramidal tract corresponding to that of mammals or not, is still in dispute. Reptiles, amphibia, and fish seem to be devoid of pyramidal tracts—that is, of cortico-spinal motor tracts—though all vertebrates may have a path for throwing the spinal movements under the domain of consciousness.

An examination of the fibres of the pyramidal tracts in the spinal cord shows that a majority of the fibres are fine in calibre, though there are some coarser fibres mixed among the finer fibres. The large fibres of the direct cerebellar tract stand out in marked contrast with the fine fibres of the pyramidal tract. The lateral pyramidal tract (*fasciculus cerebrospinalis lateralis*) in human beings lies always in the posterior part of the lateral funiculus. It rarely goes farther forward than the continuation of a line drawn through the two lateral horns (Flechsig). The relation to the periphery varies in different parts of the cord. At the level of the first cervical segment the area of the pyramidal tract nowhere reaches the periphery. At the level of the second and third cervical segments the area touches the periphery just lateralward from Lissauer's fasciculus. In the cervical enlargement the tract is again separated from the periphery. As the thoracic cord is descended the fasciculus approaches the periphery gradually, the posterior part reaching the surface first, the anterior part last. Below the thoracic cord, the whole lateral margin of the tract lies upon the periphery, there being no direct cerebellar tract below that level. The shape of the cross-section of the tract varies as the cord is descended. The lateral pyramidal tract usually disappears at the level of the Nn. sacrales III. and IV.

The anterior pyramidal tract (*fasciculus cerebrospinalis anterior*) is situated in the medial portion of the funiculus anterior. As was pointed out above, it varies greatly in size, and, corresponding to this variation, it sometimes occupies the whole medial margin of the anterior funiculus; in other cases only the middle or posterior portion of the same. It usually terminates below in the middle of the thoracic cord, but may end as high up as the intumescentia cervicalis, or extend as low down as the middle of the intumescentia lumbalis; in one instance even as far as the conus medullaris.

The fibres of the pyramidal tract end by running into the gray matter, not in bundles but usually as individual fibres, or small groups of fibres. Studies by Golgi's method make it seem probable that the terminals come into relation with the cells of the anterior horn, though their exact pericellular relations are yet to be worked out. Von Monakow believes that at least a part of the fibres end in the formatio reticularis, and that dendraxones (Golgi cells of type II.) are intercalated between the terminals of the pyramidal tract fibres and the cell bodies of the lower motor neurones. Rothmann maintains that the fibres of the pyramidal tract very quickly lose their myeline sheaths on entering the anterior horn, and suggests that this accounts for the difficulty in following them to their termination by Marchi's method in experimental degenerations. Campbell has followed terminals of the pyramidal tract into the gray matter, however, by the method of Marchi. The assumption that many of the fibres of the lateral pyramidal tract do not end in the anterior horn of the same side, but pass through the commissure to end in the gray matter of the opposite side (that is, that the fibres recross), has no strong support. As has been said, at least the majority of the fibres of the anterior pyramidal tract end in the anterior horn of the same side, though some appear to pass through the commissura anterior alba to end in the anterior horn of the opposite side (Hoche).

REFERENCES.

On the Pyramidal Tracts.

Campbell, A. W.: On the Tracts of the Spinal Cord and Their Degenerations. Brain, vol. xx., 1897, pp. 488–535.

Flechsig, P.: Die Leitungsbahnen im Gehirn und Rückenmark des Menschen auf Grund entwickelungsgeschichtlicher Untersuchungen dargestellt. 8vo, Leipzig, 1876.

Franck, F., et Pitres, A.: Des dégénérations secondaires de la moëlle épinière consécutives à l'ablation du gyrus sigmoïde chez le chien. Gaz. méd. de Par., 6. s., t. ii., 1880, pp. 152–154.

Hoche, A.: Beiträge zur Anatomie der Pyramidenbahn und der oberen Schleife nebst Bemerkungen ueber die abnormen Bündel in Pons und Medulla oblongata. Arch. f. Psychiat. u. Nervenkr., Berl., Bd. xxx., 1898, H. i, S. 103.

Mellus, E. L.: Preliminary Note on Bilateral Degeneration in the Spinal Cord of Monkeys (Macacus sinicus) following Unilateral Lesions of the Cortex Cerebri. Proc. Roy. Soc., Lond., 1894, May 23d. —Experimental Degenerations following Unilateral Lesions of the Cortex Cerebri in the Bonnet Monkey (Macacus sinicus) [Abstr.]. Proc. Roy. Soc., Lond., vol. lviii., 1895, pp. 206–214.

Monakow, C. von: Experimentelle und pathologisch-anatomische Untersuchungen ueber die Haubenregion, den Sehhügel und die Regio subthalamica, nebst Beiträgen zur Kenntniss früh erworbener Gross- und Kleinhirndefecte. Arch. f. Psychiat. u. Nervenkr., Bd. xxvii., 1895, SS. 1, 386.

Türck, L.: Ueber secundäre Erkrankung einzelner Rückenmarksstränge und ihrer Fortsetzungen zum Gehirne. Ztschr. d. k.-k. Gesellsch. d. Aerzte zu Wien, 1852, ii., 511; 1853, ii., 289.

C. Spinopetal Neurone Systems Other than those whose Axones Belong to the Pyramidal Tracts.

Of late years a great deal of attention has been paid to the centrifugal spinopetal paths other than those corresponding to the pyramidal tracts. Among these there have been described: (1) a neurone system from the thalamus to the cord (thalamospinal neurone system); (2) a rubrospinal neurone system with cell bodies in the red nucleus, the medullated axones of which go to the lateral funiculus of the opposite side of the cord (von Monakow's bundle); (3) a neurone system with cell bodies in the mesencephalon with medullated axones extending to the cord (mesencephalospinal neurone system); (4) a neurone system with cell bodies in the nuclei pontis and nuclei arcuati with medullated axones extending into the cord (pontospinal or metencephalospinal neurone system); (5) neurone systems from the formatio reticularis and nuclei laterales of the medulla oblongata to the lateral funiculi of the spinal cord (myelencephalospinal neurone systems); (6) a neurone system extending from the inferior olivary nucleus to the cord (olivospinal neurone system); (7) a neurone system the cell bodies of which are situated in the nucleus nervi vestibuli lateralis (Deiters'), the medullated axones going to the spinal cord (vestibulospinal neurone system); (8) various neurone systems with cells in the cerebellum and medullated axones going to the lateral and anterior funiculi of the cord (cerebellospinal neurone systems).

(1) *Thalamospinal Neurone System.*—Such a neurone system has for a long time been postulated. Meynert believed that many of the spinopetal funicular fibres arose in the thalamus, but the investigations which have been made since his time are conflicting. Meynert believed that the portion of the anterior funiculus of the cord, immediately adjacent to the anterior horn, came from the thalamus, but Redlich has destroyed the thalamus in animals and has studied human cases in which the thalamus was extensively diseased, but could obtain no evidence of the existence of thalamospinal fibres. It is still believed, however, by von Bechterew that fibres extend from the thalamus into the fasciculus lateralis proprius of the cord (*Seitenstrangreste*).

(2) *Rubrospinal Neurone System.*—Bouchard as early as 1866 drew attention to the fact that there was a distinct difference between the descending degenerations of the lateral funiculus in brain lesions and that in spinal-cord lesions, the latter being the more extensive. This indicated the presence of spinopetal fibres in the lateral funiculus other than the pyramidal tracts from the pallium. It was later shown, especially by experiments upon dogs, that the place of the pyramidal tracts could be taken in a functional way by these paths, especially by the one extending from the red nucleus and running in the lateral funiculus along with the pyramidal tract. This bundle of fibres, designated by von Monakow as the aberrant bundle of the lateral funiculus (*aberrierendes Seitenstrangbündel*), is usually referred to in the literature as von Monakow's bundle, sometimes as the "tractus tegmentospinalis." This neurone system has been studied by Held in the human fœtus, by Boyce in the cat, by Probst in dogs, by Russell and by Rothmann in monkeys. The medullated axones arise from cell bodies in the nucleus ruber, pass through the ventral decussation of Forel in the tegmentum, pass just medial from the lateral lemniscus and lower down between the superior olivary nucleus and the tractus spinalis nervi trigemini. In the medulla the fibres appear to be mixed up with those of Gowers' tract. In the lateral funiculus of the spinal cord these fibres assume in the cross-section the form of a comma, lying medial from the direct cerebellar tract, in the lateral and ventral part of the area corresponding to the lateral pyramidal tract. Some of the fibres extend into the lowermost part of the cord. It is this fibre system that appears to be able at times to replace the function of the pyramidal tract. It is the subcortical regulator of the movements of the extremities. It itself is under the influence of the cerebellifugal fibres of the brachium conjunctivum.

(3) *Mesencephalospinal Neurone Systems.*—Certain cell bodies in the middle and deep gray matter of the superior funiculus of the corpora quadrigemina (chiefly the nucleus centralis superior and the nucleus lateralis superior) give off medullated axones which run down in the funiculus anterior of the spinal cord. The medullated axones of this tract run through the dorsal decussation

of the tegmentum (*fontaineartige Haubenkreuzung* of Meynert), and having crossed the raphe lie in a separate bundle (in the cat), which runs just ventral from the fasciculus longitudinalis medialis, and is called by Tschermak the "predorsal longitudinal bundle." In human beings the fibres are probably mixed with those of the fasciculus longitudinalis medialis. Collaterals are given off to the eye muscle nuclei and to the gray matter of the formatio reticularis, but the main bundle runs down in the cord, where it occupies the anterior part of the fissural portion of the anterior funiculus. It becomes exhausted by giving off collaterals and terminals to the anterior horn of the same side, and partly by sending axones through the anterior white commissure to the contralateral anterior horn. Some of the fibres extend down as far as the lower part of the lumbar cord. It seems very probable that a part at least of Loewenthal's marginal fasciculus is identical with this system of fibres.

(4) *Pontospinal or Metencephalospinal Neurone System, and* (5) *Myelencephalospinal Neurone System.*—In the medulla and pons are situated groups of perikaryons which give off axones that run down to the spinal cord. Most of these are as yet very imperfectly understood. There is evidence, however, that some of the cells of the nuclei pontis and of the nuclei arcuati give off such axones. If so, we are justified in speaking of pontospinal neurone systems. A good deal of work has been done upon the descending fibre systems in the formatio reticularis—fibre systems which have their origin in perikaryons of the formatio reticularis grisea, specially in the inferior, middle, and superior central and lateral nuclei. Axones from the cells of the nucleus centralis medius run downward in the fasciculus longitudinalis medialis to reach the anterior funiculus of the cord, where they run close to the fissura mediana anterior. This is an uncrossed descending spinal neurone system from the formatio reticularis. Another fibre system from the central nucleus descends in the opposite lateral funiculus of the spinal cord occupying an area in the dorso-lateral region of the lateral pyramidal tract, medial from the rubrospinal fibre system and the direct cerebellar tract.

(6) *Olivospinal Neurone System.*—I have fully described this system on pages 954–958 of my book on "The Nervous System." The fibre system is usually known as Helweg's path, though it was described earlier by Paul Meyer. Its development has been studied by von Bechterew, who designates it the *Olivenstrang*. The path is seen as a triangular area in cross-section; hence Helweg's term (*Dreikantenbahn*). The cells of origin may be in the inferior olivary nucleus, or they may come from higher regions. Golgi studies are still lacking except for meagre statements in von Kölliker's text-book.

(7) *Vestibulospinal Neurone Systems.*—The cell bodies which give rise to the medullated axones of this path are situated chiefly in the nucleus nervi vestibuli lateralis (Deiters), though some of them may be situated in the nucleus nervi vestibuli superior of von Bechterew. The axones pass ventralward from Deiters' nucleus into the formatio reticularis alba and descend. On their way down they pass through the area situated between the nuclei laterales and the remains of the anterior horn. In the spinal cord they lie in the peripheral parts of the zone of exit of the anterior root fibres, and in the lateral portion of the funiculus anterior. Some of the fibres of this system descend as far as the lumbar cord. The axones appear to terminate by running in to end among the cells of the anterior horn of the same side. This neurone system is under the influence of impulses from the vestibular nerve on the one side and from the cerebellum (nucleus fastigii) on the other. Its influence on the cord is probably concerned with the coordination of the axis of the body and orientation in space.

(8) *Cerebellospinal Neurone System.*—Though a vast amount of work has been done with the idea of determining the fibre systems which throw the spinal cord directly under the domain of the cerebellum without the intermediation of any relay station, it must be confessed that our knowledge upon this subject is still, in reality, most meagre. Marchi early described a fibre system in the spinal cord which degenerated after removal of the cerebellar hemisphere. He thought that the fibres came chiefly from the vermis, partly from the hemisphere, that they passed through the brachium pontis, and then by way of the ground bundles into the anterior and lateral funiculi of the cord. He could follow the degeneration throughout the whole length of the cord. In cross-sections this degeneration occupied two areas, one extending along the periphery of the cord from the fissura mediana anterior to the anterior extremity of the direct cerebellar tract, that is, in an area corresponding to the *zone sulcomarginale* of Marie; the other, a more lateral area, situated just in front of the lateral pyramidal tract. It was his opinion that the fibres ran in to end in the anterior horn of the spinal cord. This degeneration, described by Marchi, probably corresponds, at least in part, to the so-called cerebellar tract of Loewenthal.

Ferrier and Turner dispute Marchi's conclusions, inasmuch as they found that when one hemisphere of the cerebellum is extirpated without injury to neighboring parts, no degeneration can be traced to the cord, though degenerated fibres can be followed through the corpus restiforme to the inferior olivary nuclei and the nuclei of the posterior funiculi. When the vermis is extirpated alone, the fibres which run to the nucleus nervi vestibuli lateralis of Deiters degenerate. It is their opinion that the degeneration, described by Marchi, occurs only when Deiters' nucleus is injured in the attempt at cerebellar extirpation. This view is supported also by the experimental work of Risien Russell and by that of Mott.

Marchi has, however, found a supporter in Biedl, who reproduced a degeneration of the fibre systems, described by Marchi, by cutting the corpus restiforme. He thinks, however, that Marchi's tract reaches the cord by way of the inferior cerebellar peduncle rather than by way of the middle cerebellar peduncle, as Marchi asserted.

The experimental work of Thomas tends to support Marchi's observation as far as the fibres in the anterior funiculus are concerned. He thinks that the fibres arise from cells in the nucleus dentatus, and that they pass through the superior vestibular nucleus of von Bechterew and the lateral vestibular nucleus of Deiters into the formatio reticularis, and thence into the anterior and lateral funiculus of the cord. His work was done chiefly upon dogs. Extirpation of the cortex of the cerebellum alone does not cause the degeneration; it is necessary to injure the nucleus dentatus cerebelli. If Deiters' and Bechterew's nuclei are also injured, the degeneration in the cord is much more extensive.

Ramón y Cajal has made an important contribution to the neurone system under discussion by the application of Golgi's method. He finds that the axones of the cells in the nucleus dentatus, passing out in the brachium conjunctivum, give off descending limbs of bifurcation which run to the anterolateral fasciculus of the cord. In his opinion it is these axones which correspond to the descending cerebellar path of Marchi. Ramón y Cajal emphasizes the fact that in frontal sections of the guinea-pig's brain, stained by the method of Weigert-Pal, this cerebellospinal path from the brachium conjunctivum can be clearly seen as isolated bundles. (See Fig. 439 on page 430 of his "Histologia del Sistema Nervioso de los Vertebrados.")

It may be regarded as certain, therefore, that a direct uncrossed cerebrospinal neurone system exists, the cell bodies of which are situated in the nucleus dentatus (and perhaps in the neighboring gray nuclei), the medullated axones of which go through the anterolateral white matter to the anterior horn of the cord. It would appear, too, that the fibre system, making up the spinal portion of this path, or a part of it, is really an offshoot or by-path from the main ascending fibre system of the brachium conjunctivum. The function of the path is doubtless coordinative. It seems probable that it carries to the anterior horn cells at least a part of those cerebellar impulses which maintain the equilibrium of the body.

REFERENCES.

On the Spinopetal Fibre Systems Other than the Pyramidal.

1. On Thalamospinal Fibre Systems.

Bechterew, W. von: Ueber centrifugale aus der Seh- und Vierhügelgegend ausgehenden Rückenmarksbahnen. Neurol. Centralbl., Leipz., Bd. xvi., 1897, SS. 1074-1077.
Meynert, T.: Skizze des menschlichen Grosshirnstammes nach seiner Aussenform und seinem inneren Bau. Arch. f. Psychiat. u. Nervenkr., Bd. iv., 1874, SS. 387-431.
Redlich, E.: Beiträge zur Anatomie und Physiologie der motorischen Bahnen bei der Katze. Monatsschr. f. Neurol. u. Psychiat., Berl., Bd. v., 1899, SS. 41, 112, 192.

2. On Rubrospinal Fibre Systems.

Bouchard, C.: Des dégénérations secondaires de la moëlle épinière. Arch. général de médecine, 1866.
Boyce, R.: A Contribution to the Study of Descending Degeneration in the Brain and Spinal Cord and of the Seat of Origin and Path of Conduction of the Fits in Absinthe Epilepsy. Proceedings of the Royal Society, vol. lv., 1894; Phil. Transact., vol. clxxxvi., Pt. i., 1895.—Weiters: A Contribution to the Study of I. Some of the Decussating Tracts of the Mid- and Interbrain and II. of the Pyramidal System in the Mesencephalon and Bulb; Phil. Transact., 1897, vol. clxxxviii.
Held, H.: Die Beziehungen des Vorderseitenstranges zu Bahnen im Mittellhirn. Abhandl. d. Sächs Gesellsch., Bd. xviii., 1892.
Kohnstamm, O.: Ueber die Coordinationskerne des Hirnstammes und die absteigenden Spinalbahnen. Monatsschr. f. Psychiat. u. Neurol., Berl., Bd. viii., 1900, SS. 261-282.
Monakow, C. von: Experimenteller Beitrag zur Kenntniss des Corpus restiforme des "äusseren Acusticuskerns," und deren Beziehungen zum Rückenmark. Monatsschr. f. Psychiat. u. Nervenkr., Bd. xiv., 1883, SS. 1-16.—Striæ acusticæ und entere Schleife. Monatsschr. f. Psychiat. u. Nervenkr., Bd. xxii., 1891, SS. 1-26.
Probst, M.: Zur Anatomie und Physiologie experimenteller Zwischenhirnverletzungen. Deutsche Ztschr. f. Nervenh., Bd. xvii., 165.—Ueber vom Vierhügel, von der Brücke und vom Kleinhirn absteigende Bahnen. Deutsche Ztschr. f. Nervenh., Bd. xv., 1899, S. 192.
Rothmann, M.: Das Monakow'sche Bündel beim Affen. Monatsschr. f. Psychiat. u. Neurol., Bd. x., 1901, 363-382.

On the Mesencephalospinal Neurone System.

Held, H.: Die centrale Gehörleitung. Arch. f. Anat. u. Physiol., Anat. Abthl., Leipz., 1893, S. 229.
Tschermak, A.: Ueber den centralen Verlauf der aufsteigenden Hinterstrangbahnen und deren Beziehungen zu den Bahnen im Vorderseitenstrang. Arch. f. Anat. u. Physiol., Anat. Abth., Leipz., 1898, SS. 291-400.

On Pontospinal and Myelencephalospinal Neurone Systems.

Bechterew, W. von: Ueber eine bisher unbekannte Verbindung der grossen Oliven mit dem Grosshirn. Neurol. Centralbl., Leipz., iv., 1885, pp. 194-196.
Fusari, R.: Sulle fibre nervose a decorso discendente situate nella substantia reticularis alba del rhombencephalon umano. Riv. sperim. di Fren., vol. xxiii., 1896, pp. 417-424.
Redlich, E.: Beiträge zur Anatomie und Physiologie der motorischen Bahnen bei der Katze. Monatsschr. f. Neurol. u. Psychiat., Bd. v., 1899, S. 1019.
Tschermak, A.: *Loc. cit.*

On the Olivospinal Neurone System.

Bechterew, W. von: Ueber den Olivenstrang des Halsmarks. Neurol. Centralbl., Leipz., Bd. xiii., 1894, No. 12, S. 433.
Bruce, A.: On the Connections of the Inferior Olivary Body. Proc. Roy. Soc., Edinb., 1889-90, 1891, vol. xvii., pp. 23-27.
Helwig, Dr.: Studien über den centralen Verlauf der vasomotorischen Nervenbahnen. Arch. f. Psychiat. u. Nervenkr., Berl., Bd. xix., 1888, SS. 104-183, spec. S. 108.
Kölliker, W. von: Handbuch der Gewebelehre, 3. Aufl., S. 318.
Meyer, P.: Ueber einen Fall von Ponshämorrhagie mit secundären Degenerationen der Schleife. Arch. f. Psychiat. u. Nervenkr., Berl., Bd. xiii., 1882, SS. 63-98.

On the Vestibulospinal Neurone Systems.

Ferrier, D., and Turner, W. A.: A Record of Experiments Illustrative of the Symptomatology and Degenerations Following Lesions of the Cerebellum, etc. Phil. Tr., Lond., vol. clxxxv. for 1894 (B), 1895, pp. 755-761.
Held, H.: Die centralen Bahnen des Nervus acusticus bei der Katze. Arch. f. Anat. u. Physiol., Anat. Abth., Leipz., 1891, SS. 271-291.—Die Beziehungen des Vorderseitenstranges zu Bahnen im Mittelhirn. Abhandl. d. k. Sächs. Gesellsch. d. Wissensch., Leipz., Bd. xviii., 1892.
Monakow, C. von: *Loc. cit.*
Münzer, E., u. Wiener, H.: Beiträge zur Anatomie des Centralnervensystems. Prager med. Wochenschr., Bd. xx., 1895, SS. 143-145.
Russell, J. S. R.: Degeneration Consequent on Experimental Lesions of the Cerebellum. Proc. Roy. Soc., Lond., vol. lvi., 1894, pp. 303-305; and Experimental Researches into the Functions of the Cerebellum. Phil. Trans. Roy. Soc., vol. clxxxv. (B), 1895, pp. 819-861.
Thomas, A.: Le cervelet; Étude anatomique, clinique et physiologique, Paris, 1897.

On the Cerebellospinal Neurone Systems.

Biedl, A.: Absteigende Kleinhirnbahnen. Neurol. Centralbl., Leipz., Bd. xiv., 1895, SS. 434, 493.
Marchi, V.: Sull' origine e decorso dei peduncoli cerebellari e sui loro rapporti cogli altri centri nervosi. 8vo. Firenze, 1891, pp. 1-38; also in Riv. sper. di freniat., Reggio-Emilia, vol. xvii., 1891, pp. 357-368; also Transl. in Arch. ital. de biol., Turin, t. xvii., 1892, pp. 190-201.
Ramón y Cajal, S.: Beitrag zum Studium der Medulla Oblongata des Kleinhirns und des Ursprung der Gehirnnerven. Deutsch von Bresler, Leipz., 1896, S. 121.
See also references under preceding heading.

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SPINAL-CORD DISEASES: ACUTE ASCENDING PARALYSIS.—(Synonym: Landry's Paralysis.) In 1859 Landry described the symptom complex which has since then been known both as Landry's paralysis and as acute ascending palsy. The clinical picture he portrayed was the following: The sudden development in a previously healthy individual of a flaccid paralysis of the legs, which generally began first in one and then within a few hours or a day affected the other. When the paralysis of the legs had become complete, the trunk muscles became paralyzed, and then in the space of a few days the arms were involved in like manner. Next there was involvement of the deglutition, articulation, and respiratory musculature, and in a short time death followed from asphyxiation. There are milder cases, however, in which there is restitution of function. Landry described prodromes, such as general malaise and paræsthesia in the extremities, and during the course of the illness slight disturbances of sensation. He laid particular stress on the absence of muscular atrophy, the presence of normal electrical reactions, and negative findings at the autopsies.

Since Landry's original cases were published, many cases, either similar to his or varying from the type in one essential or another, have been reported, until to-day our conception of the disease has broadened so as to include cases exhibiting a wider range of symptoms; so that, as Oppenheim says, the only essential symptom necessary to the disease is the rapid development of a flaccid paralysis, commencing in the lower extremities and affecting successively the arm and the bulbar nerves, though in rare cases the order of involvement is reversed.* In the literature under this heading have been included many cases which undoubtedly belong to other diseases, principally acute anterior poliomyelitis and multiple neuritis.

ETIOLOGY.—The disease is rather uncommon in its occurrence. Men are affected more often than women, and as a rule between the ages of twenty and forty, though instances of its occurrence in children and old people have been observed.

The view most generally held as to the etiological factor of the disease is that it is due either to some form of toxæmia or to bacterial infection. Landry himself was under the impression that it was caused by poisoning, and this opinion was accepted by many subsequent observers, but especially by Westphal. The following facts Diller regards as pointing in this direction: First, the presence in some cases of enlargement of the spleen and lymph glands, hemorrhagic spots in the lungs and intestines, and albuminuria; second, the finding of bacteria in some of the cases. The varieties found include anthrax, typhoid, and other unclassified bacilli, streptococcus, varieties of staphylococci, diplococci, and the Fränkel pneumococcus. No specific form of micro-organism has been isolated, but the disease seems to be capable of development after diphtheria, typhoid, variola, anthrax, pneumonia, pertussis, the puerperium, malaria, and probably also upon septicæmia as a basis. Oppenheim thinks it doubtful whether the entrance of the micro-organisms themselves into the spinal cord, medulla, and peripheral nerves can produce the disease, but he believes that probably their toxins injure the motor tracts in such a manner as to cause paralysis, without as a rule producing recognizable lesions. Thoinot and Masseline and Remlinger have produced in rabbits symptoms similar to Landry's paralysis by the injection of micro-organisms into the circulation.

* In recent years some authors have regarded Landry's paralysis as being merely a symptom complex due to various causes and not a disease or clinical entity with a definite pathological basis.

One case has been reported in which the disease followed a kick from a horse affected with septicæmia.

Alcohol has been mentioned as an etiological factor in some cases, and exposure to cold and overexertion likewise. Syphilis was formerly regarded as being a not uncommon cause of the disease, though if the question be looked at in the light of our present knowledge of syphilis and its pathology, it seems highly improbable, as Nonné points out, that it could cause the paralysis and yet leave no evident lesion.

Pathological Anatomy.—Landry postulated as one of the characteristics of acute ascending paralysis the absence of any lesion in the spinal cord, and as a matter of fact in many of the earlier reported cases no changes were found. Since then, however, through our better technique and in the light of our greater knowledge of the nervous system and its pathology, morbid changes in the spinal cord have been found in many cases. The lesions reported are very numerous and varied in their nature, and do not show any considerable uniformity. Disseminated areas of inflammation have been observed in the medulla oblongata by Omerod and Prince, while Eisenlohr, Schultze, Ketli, and others have found similar changes in the spinal cord. In some cases the axis-cylinder processes in the antero lateral columns of the cord were swollen; in others there were changes of varying intensity in the anterior horns, similar to those found in poliomyelitis. One case showed only a degeneration in the anterior roots, while in another there was a focus of myelitis.

In addition to these changes in the cord itself the peripheral nerves have been found to be affected. Sometimes the peripheral neuritis has been the only lesion found, and this has led one set of observers (Dejerine, Barth, Ross, Putnam, and others) to regard it as the characteristic morbid condition of Landry's palsy. They explain the alterations in the anterior horn cells, when they occur in conjunction with peripheral neuritis, as due to trophic disturbances. Dejerine and Thomas, in their recent work on spinal-cord diseases, go so far as to say that it is a disease of the peripheral neurones, and is poliomyelitis when the cell body is affected and polyneuritis when the axis-cylinder processes are implicated. Diller states, as an argument against this theory, that the cases in which there is no peripheral neuritis are frequent, and that the changes found in the nerves are usually those of degeneration, not of inflammation.

The spleen is usually acutely enlarged, the lymphatic glands swollen, and in some cases there is acute degeneration of the viscera.

Oppenheim sums up our knowledge of the pathology of Landry's paralysis by saying that the changes in the spinal cord, especially in its gray matter, are the predominant ones; and that they sometimes consist of inflammatory conditions and vascular disturbances (disease of vessels, hemorrhage, exudation, thrombosis, softening, and infiltration); sometimes of changes in the nerve cells, as described by Marinesco and by Bailey and Ewing.

Symptomatology.—The disease commences suddenly with paralysis of the extremities, or it is preceded by prodromes. These latter consist of a chill or chilly sensations, slight fever, pain in the back and in the extremities, and paræsthesia, more rarely hyperæsthesia and general malaise.

Pain and general weakness may occur fully a month before the actual onset of the disease. The paresthesia is usually in the fingers or toes, and may be very marked and distressing.

The *paralysis* as a rule marks the beginning of the disease. It is generally ascending in type, that is, it affects the lower extremities first. The feet are first affected, either both at once or successively. Then the legs, thighs, the lumbar, abdominal, and chest muscles are successively involved; next in order are the muscles of the hand, forearm, and arm, then those of the neck, and finally there occurs paralysis of the muscles innervated by the bulbar nerves, viz., those of speech, deglutition, and respiration.

The paralysis manifests itself first as a weakness in one or both legs, then becomes complete and flaccid, there being no spastic phenomena. The paraplegia can develop in a day, and the involvement of the other muscles takes place within eight or ten days, rarely in three or four.

Cases have been described in which there has been a descending paralysis, and also all four extremities have been affected at the same time. These cases are rare. Westphal reported a case in which only bulbar symptoms appeared. Cases have been reported in which the cranial nerves were involved, the paralysis affecting the muscles controlled by the facial, the eye muscles and those of accommodation; as a rule, however, these nerves are not involved. The pulse rate is usually increased in frequency because of the affection of the vagus, and attacks of asphyxia due to paralysis of the respiratory muscles cause death.

The *electrical reaction* is generally prompt and normal, especially in those cases which run a short course. Sometimes there are quantitative variations in the electrical reaction, and the reaction of degeneration has also occurred. Oppenheim noted the following peculiar electric reaction in one of his cases: it was impossible to increase the intensity of contractions by increasing the strength of the current used. Examination of a piece of this muscle showed waxy degeneration.

The absence of muscular atrophy * was regarded as one of the characteristics of the disease, and in the majority of cases this holds true. Some authors have regarded its development in the later stages of the disease, when it runs a protracted course, as being due to inactivity. But there have been undoubted cases of Landry's paralysis in which the wasting of the muscles was an early occurrence. Fibrillary twitchings are sometimes seen.

Sensibility is usually but slightly disturbed. Landry described the presence of slight changes. Bailey and Ewing describe thirteen cases of sensory involvement out of the forty-four genuine cases which they found in literature up to 1896. As a rule, marked disturbance is absent. Hypæsthesia in the extremities, and more rarely hyperæsthesia, have been described. In some instances delayed transmission of pain or temperature sense, or failure to discriminate between pain and touch sense, and diminution in the acuteness of the muscular sense, have been observed. Trophic disturbances are not present.

Patellar and superficial reflexes are lost, though they may be present for some time in the early stages of the disease. As a rule the bladder and rectum are unaffected. Cases have been reported in which either one of the sphincters has been weakened or paralyzed. Sometimes at the onset there may be temporary retention of urine, or later, when the abdominal muscles are paralyzed, there may be constipation.

It is characteristic of Landry's paralysis that there is either no rise of temperature, or only a very slight rise, throughout the course of the disease. Regarding this, again, exceptions have been reported. Sweating is said by some to occur frequently. Albuminuria generally occurs, and in one case there was hæmatoporphyruria.

The sensorium remains almost invariably clear until the end. Delirium has been present in those cases which have fever.

Prognosis.—The prognosis is grave. Most of the cases end fatally. The disease may terminate abruptly at the end of two or three days, death being due to bulbar paralysis; as a rule, however, the duration of the disease is prolonged to eight days before the onset of bulbar symptoms. The disease may assume a subacute character and last for two months or more. Some of the cases have terminated in complete or partial recovery. Oppenheim regards it as a sign of favorable outcome when there is a remission in the bulbar symptoms. Generally the paralysis first disappears in the part which was

* What has been said of the electrical reaction can with equal truth be said of the occurrence of muscular atrophy.

first affected. Convalescence may last for many months. Remissions and relapses with a fatal termination are possible.

Therapy.—There is no therapeutic agent which is specific in its action. The application of the actual cautery to the back has been recommended. In cases in which syphilis is suspected vigorous mercurial and iodide treatment should be used. Electricity, especially galvanism, has been used. The chief attention of the physician should be directed to the nourishment and stimulation of the patient during the acute stage; and then, if he survive, an effort should be made to restore the functions of the paralyzed parts by means of hydrotherapy, massage, electricity, nutritious food, change of scenery, etc.

Israel Strauss.

SPINAL-CORD DISEASES: ACUTE SPINAL MENINGITIS.—The membranes of the spinal cord consist of an outer dense fibrous sheath, the dura mater, and an inner delicate vascular sheath, the pia mater. The web-like fibres connecting these two, and known as the arachnoid, may be conveniently reckoned together with the pia mater. The spinal dura is not adherent to the inner surface of the bones forming the vertebral canal. Between the periosteum and this membrane is a loose connective tissue of interlaced bundles with delicate slender elastic fibres and spindle-shaped connective-tissue cells, and within the meshes of this tissue there is a greater or less amount of fat, which is often gelatinous in appearance. The dura mater itself is a dense white sheath composed of bundles of white fibrous and of elastic tissue in about equal numbers, running lengthwise. Both outer and inner surfaces are covered with endothelium, and between the meshes are lymph spaces which open upon these surfaces, thus establishing a connection between the outer surface of the dura and the space between dura and pia. Binding the dura to the pia mater are the delicate fibres which form the arachnoid, fibres of connective tissue bound together into lamellæ surrounded by very fine elastic fibres and covered with endothelial cells. The outer layer of the pia is of the same structure as the arachnoid, the inner is separated from this by the pial capillaries and vessels, which, surrounded by prolongations of the fibrous and elastic reticulum composing the inner layer, pass into the substance of the cord. Golden-brown pigment cells with branching processes are found in this layer, especially in the cervical region, where they may lend a brown color to the membrane. Both membranes are supplied with nerves, the pia more abundantly. The lymphatics of the pia are continuous with those of the cord.

The inflammation of the membranes of the cord may affect the outer membrane, the inner, or both. Internal meningitis, or leptomeningitis, always extends to the arachnoid also, although an effort has been made by some authors to distinguish a pure arachnitis, so called, without involvement of the pia. External meningitis or pachymeningitis also usually extends to the pia-arachnoid, at least in acute inflammations; the chronic processes may remain limited to one or the other. As the symptoms in all forms of acute meningitis are very similar and certain symptoms are common to all, it will simplify matters to describe first in full detail the symptoms of the typical variety, acute purulent leptomeningitis, and then, in the less important varieties, the symptoms will not need to be described in full again.

I. *Acute purulent leptomeningitis, acute cerebro-spinal meningitis, acute cerebro-spinal fever, epidemic cerebro-spinal meningitis.*

A. Hirsch has given an excellent historical survey of this disease ("Die Meningitis Cerebro-spin. epidemica," Berlin, 1866). The first well-authenticated epidemic appeared in France among the soldiers of the army in 1805, and was followed by sixty-two epidemics in that country, forty-eight of which began in the army. The disease first appeared in epidemic form in the United States probably in 1806, and from then on until 1830 there were frequent outbreaks in this country, and seven years later in France again, then throughout Europe. The latest epidemic which has been carefully studied was that in Boston in 1896-97, to the report of which by Councilman, Mallory, and Wright we shall have occasion to refer frequently. The later epidemics have usually been less severe than the earlier, and show less tendency to develop among the standing armies.

Winter and spring seem the seasons most favorable for the development of an epidemic. It is not a disease of cities; some of the severest epidemics have been in country districts. Children are not as susceptible as young adults; the disease is rare before the first year. The mode in which infection takes place is not known; but the nasopharyngeal passage is supposed to be the place of entrance for the micro-organisms. Apparently it is not contagious, for it is rare to find more than one case in the same family. Insanitary surroundings, overcrowding, exhausting exertion, exposure, etc., seem to aid in its spread. There are isolated sporadic cases, probably of the same character as those occurring in the course of epidemics, which are scattered along in the intervals between outbreaks.

Bacteriology.—The causative agent of cerebro-spinal meningitis is still in question. The diplococcus intracellularis meningitidis or meningococcus intracellularis of Weichselbaum, the pneumococcus of Fraenkel, the streptococcus meningitidis of Bonome the meningococcus of Foà, the streptococcus pyogenes and the staphylococcus pyogenes, have all been isolated by different observers. The colon bacillus has been stated to be the etiological factor in cerebro-spinal meningitis of the new-born.

Weichselbaum found the organism which bears his name in six out of eight cases examined by him in 1887. These six cases were all primary. In the other two cases, which were secondary to pneumonia, he isolated the pneumococcus only. His results, corroborated by Goldschmidt and by Edler, were more strongly confirmed by Jäger, who, in 1895, found the organism in twelve cases during an epidemic. Councilman also looks upon the diplococcus intracellularis as the cause of the epidemic form, and lays great stress on this fact from the point of view of both diagnosis and prognosis, inasmuch as, in his opinion, all cases are fatal except those caused by this diplococcus. When the pneumococcus or the streptococcus was found there was associated with the meningitis some other lesion, in lungs or heart usually, and none of these cases recovered. Sporadic cases are probably not caused by the Weichselbaum organism. Councilman's conclusions are based upon the largest number of bacteriological examinations ever made by one observer —thirty-eight positive results from fifty-five lumbar punctures, thirty-one positive results from thirty-five autopsies.

On the other hand, Fraenkel isolated the pneumococcus which bears his name from the pia-arachnoid in spinal meningitis, and his results have been confirmed many times. Wolff claims that it is present in forty-two per cent. of all cases. Flexner and Barker found this organism during the Maryland epidemic of 1892.

The streptococcus has been isolated, and in other cases the staphylococcus pyogenes also. Among some bacteriologists (as Bordoni-Uffreduzzi) the opinion prevails that all of these different cocci are varieties of the same organism—the pneumococcus of Fraenkel.

The pathology of cerebro-spinal meningitis is that of an extensive purulent inflammation, with infiltration of the subarachnoid space. The cerebro-spinal fluid is increased and usually turbid with floccules of fibrin in the early stages; later on, it becomes purulent. This increase in the fluid causes bulging of the dura, especially posteriorly, perhaps because of the patient's recumbent position. The fluid, according to Councilman, contains many leucocytes, but not abundant fibrin except in the cases caused by the pneumococcus. Flexner found numerous large phagocytic cells in the fluid from one of his cases. The small pial vessels are enormously distended, the leucocytes being collected along their walls and in the perivascular lymph spaces. The inner surface of the dura is reddened, and the inflammation may extend along the sheaths of the nerves and into the substance of the cord, although there are cases in which, with extensive involvement of the pia-arachnoid, the cord escapes completely. Usually there is a perivascular infiltration with leucocytes and phagocytic cells, and a swelling and proliferation of the cells of the neuroglia. Klebs, Zenker, Strümpell, and Barker all describe accumulations of leucocytes in the cord, forming in some cases focal abscesses. The changes in the nerve cells, shown by the Nissl stain, are peripheral chromatolysis—characteristic of all toxic conditions—and central chromatolysis—characteristic of injury to the axone of the cell. Sections treated by Marchi's method may show degenerated fibres, especially in cases of long duration.

Congestion and œdema of the lungs is a frequent complication. Pneumonia, either primary or secondary, and usually lobular, is also frequently present. Councilman found in one case that the process in the lung was due to a purulent embolus from the meninges lodging in a small branch of the pulmonary artery. The liver and kidneys usually show only acute parenchymatous degeneration, the intestinal tract is usually not affected, but may show swelling of the follicles, and the spleen is only exceptionally enlarged. Endocarditis and pericarditis may be complications.

Symptoms.—There is seldom any real prodromal stage, though there may be one or two days of languor, headache, and slight chills preceding the onset of the disease. Usually this is sudden, ushered in by a severe chill followed by fever, vomiting, and headache. The course of the disease is so irregular that it is hard to give a description of a typical form, harder still to divide it into definite stages or definite varieties. Hirsch's classification into three forms, the malignant ("foudroyante"), the abortive, and the acute and subacute, is perhaps the simplest. The malignant form is characterized by its sudden onset, usually in a healthy person, and rapid development. Within a few hours vomiting, delirium, convulsions, rigidity of the neck, unconsciousness, and collapse may follow each other in rapid succession, and death has been known to take place in less than twelve hours. Several cases of less than twenty-four hours' duration are on record. These cases belong not to the sporadic but to the epidemic form, and are more apt to occur among the early than the later cases. A purpuric rash is often seen, which has led to the clinical names applied to this disease: "spotted fever," "malignant purpuric fever," etc. The second, abortive, form would be recognized with difficulty in the absence of an epidemic. More or less pronounced cervical rigidity with pain on motion, and severe, remitting headache may be the only symptoms present. It is apt to last only a few days, but there may be recurrences of rigidity and headache for some time afterward.

The third is the ordinary form, which usually begins more or less suddenly with headache, generally frontal and very severe. Vomiting is often an early symptom and a valuable aid in diagnosis. A more or less pronounced chill is followed by a rise of temperature to 101° or 102° F. The headache often increases in intensity, rendering the patient delirious, not from the meningitis but from the extreme pain. This is not, however, a gauge for the severity of the disease, for it may be very severe in patients who make a good recovery. It is subject to remissions and is apt to come on suddenly during sleep, making the patient waken with a sudden cry ("cri hydrocephalique"). The vomiting may return with the exacerbations of pain; usually it lessens as the disease progresses, but may be so persistent as to endanger the patient's life through excessive weakness. Dizziness, restlessness, sensitiveness to light and sound accompany the headache.

Rigidity of the neck is an early and important symptom, perhaps the most constantly present symptom of this disease. It consists of a tonic contraction, reflex, of the deep muscles of the neck, especially the splenius, is increased on active or passive attempts at movement, and is accompanied with pain. In some cases the rigidity is so pronounced that by putting the hand under the patient's head his body may be raised from the bed without making the neck bend. Often the head is bent back, sometimes so far that the occiput lies between the shoulder blades. The rigidity does not, however, affect the side movements of the head. The pain may be constant, even more severe than the headache, or may be absent when the patient is perfectly quiet and there is no pressure on the neck.

There are also pain and sometimes rigidity all along the spine, increased on motion and pressure, and there may be lightning pains in the limbs due to irritation of the peripheral nerves. Flattening or retraction of the abdomen is not so frequent as in tuberculous meningitis. Traube has pointed out that it is due to a drawing together of the intestines from irritation of the vagus—which is also responsible for the vomiting—and not, as many suppose, to a contraction of the abdominal muscles. Constipation from tonic contraction of the bowels may persist throughout the attack; diarrhœa is rare.

Hyperæsthetic areas alternating with areas of normal sensation are most frequent over the lower extremities and involve both skin and muscles. In some cases this symptom is very pronounced, and even in deep stupor a reaction may be obtained by pressing the muscles of the legs. Anæsthesia is more apt to be a sequela.

The motor disturbances consist in the rigidity of neck and back already described, in tremors or even spasms of the muscles of arms or legs, occasionally of the face, in strabismus, difficulty in swallowing, and sometimes even trismus. Kernig's symptom is often present—a strong flexion of the knee caused by passive flexion of the thigh upon the abdomen. The patellar reflex may be increased or completely lost. Later on, these irritative symptoms may be succeeded by symptoms of paresis, though the latter more often appear as sequelæ. The most common forms are ptosis, dilated pupils, strabismus divergens, and paralysis of the facial muscles; much less common is hemi- or paraplegia.

The cerebral symptoms begin as delirium, passing into stupor or even coma. In less severe cases without delirium there are insomnia, restlessness, and irritability, confusion, dulness or excitability, perhaps hallucinations. Stupor is regarded as a serious symptom, being present almost always in the fulminating cases. The temperature curve is very irregular. In the very rapid cases it soon reaches a high point, 105°–106° F., and remains there for several days, either rising to hyperpyrexia (108°) just before death, or falling suddenly. In the more usual forms the temperature begins to sink after a few days and is then irregularly remitting, showing a great range within twenty-four hours, high fever, and entire absence of fever. Usually the febrile exacerbations tend to be less severe as the disease progresses, but this is not invariably true, and every rise of temperature must be regarded as serious. In atypical cases a regularly remitting fever with chills may simulate malaria; in others there may be a crisis on any day between the sixth and the tenth.

The pulse is usually rapid, especially in children. A very slow pulse is rare. In collapse the pulse is small and extremely rapid from involvement of the vagus, a serious symptom in adults. Heart complications are rare. The respirations may be increased in frequency, but are regular in ordinary cases. Irregular respiration is a graver symptom in adults than in children. In some instances there may be typical Cheyne-Stokes breathing.

The skin symptoms are very variable. Petechiæ seem to have been common enough, in the early epidemics, to give the disease the name of spotted fever, but in many of the later ones this symptom has been insignificant or absent. Roseolæ, like those of typhoid, scarlatinal eruptions, erysipelatous eruptions, urticaria, erythema nodosum, even gangrene, have been observed. Herpes is present in the majority of cases, and is an important diagnostic symptom. It appears most commonly between the third and sixth days, on lips, nose, and cheeks; more rarely on the neck and body.

The urine is apt to be increased, often contains albumin, sometimes sugar. The diazo reaction is usually present.

Involvement of the special senses constitutes a grave complication. There may be complete loss of smell and taste. In the case of the ear the deafness resulting from inflammation of the labyrinth or from otitis media is apt to be persistent, and in young children results in deaf mutism. Moos found thirty-five cases of deafness out of sixty-four cases of recovery from meningitis. There may be keratitis or even panophthalmitis from an extension of the inflammation along the sheath of the optic nerve, which may itself show an acute neuritis. Randolph examined forty cases in the Maryland epidemic of 1892, and found the fundus normal in only seven. Most of these thirty-three showed a venous congestion of the disc with remarkable tortuosity of the vessels, which sometimes looked quite black as if from complete stasis. Six cases had neuritis optica, one an acute retinitis. The right eye was by far the most frequently affected. The pupils are usually small at first, then there is often a unilateral dilatation, which is a valuable aid in diagnosis. As a rule, just before death there is extreme dilatation of both pupils.

Complications in the form of joint affections have appeared in certain epidemics: serous effusion into knees, ankles, and wrists. More rarely the exudation is purulent.

There is a question as to whether the pneumonia so often accompanying meningitis is to be regarded as a cause, a complication, or a sequela. Many observers have considered the meningitis as secondary to the pneumonia. In some cases this is indubitably true, the inflammation being caused by an invasion of the meninges by the pneumococcus; in other cases there has seemed to be a double infection, and finally Councilman declares the pneumonia, in the epidemic forms at least, to be secondary to the meningitis and caused by the entry of the diplococcus intracellularis into the lungs. He succeeded in isolating the organism from eight cases of pneumonia complicating epidemic meningitis.

Excessive anæmia and emaciation, even in robust young patients, forms a very serious complication in the more protracted cases. When the vomiting has been obstinate or the pain persistent and exhausting, it may reach as extreme a form as that of carcinoma or phthisis (Klebs). Undoubtedly many patients die of inanition in the later weeks of the disease.

There is usually a leucocytosis which may be very pronounced, and which is an aid in the diagnosis between this disease and typhoid fever.

Sequelæ.—Headache may persist for years, caused probably by areas of thickening in the pia mater. Deafness and blindness have already been referred to as deplorably frequent sequelæ. Loss of speech, independent of loss of hearing, mental feebleness, aphasia, and loss of memory are not so persistent, but tend to pass away slowly. Hemiplegic or paraplegic symptoms, paralysis of cranial nerves, also tend to clear up.

Diagnosis.—In the absence of an epidemic this may not be easy. Any acute infectious disease in which the cerebro-spinal symptoms are pronounced may be, undoubtedly often is, mistaken for cerebro-spinal meningitis. The diagnosis between the epidemic form and the other forms of acute meningitis also presents difficulties, and is of special importance from the point of view of prognosis, for the epidemic form has the most favorable outlook. Tuberculous meningitis has a longer prodromal period, the symptoms are usually less acute, the fever not so high, and there are usually evidences of tuberculous lesions elsewhere in the body. The purulent forms due to infection by streptococcus or pneumococcus are said to be characterized by greater severity of the cerebral symptoms—delirium and coma—and by a less extreme rigidity of the neck (Leichtenstern). Quincke's lumbar puncture is a most valuable diagnostic aid. Councilman says that the bacteriological examination of the fluid withdrawn is as important a clinical procedure as examination of sputum. His results have already been quoted. Lichtheim states that he has never failed to find tubercle bacilli in all the cases of tuberculous meningitis thus examined in his clinic. The presence of streptococci has been demonstrated in many cases, and according to Councilman and to Leyden and Goldscheider, these cases invariably prove fatal. The naked eye appearance of the fluid withdrawn by puncture is also important. A large amount of fibrin indicates infection with the pneumococcus. Fluid withdrawn early in the disease is usually almost clear and contains only polymorphonuclear leucocytes; later on, epithelioid and large phagocytic cells are found (Flexner). In very rapid cases the fluid is not so abundant, and may be distinctly purulent. Lichtheim records a case in which the puncture yielded no pus, yet the patient died of secondary purulent meningitis, the pus being found in localized pockets. The puncture is best made between the second and third or third and fourth lumbar vertebræ, the needle passing in for a depth of 4 cm. in children and 7 or 8 cm. in adults. The great increase of pressure in the cerebro-spinal fluid makes aspiration usually unnecessary. It is a procedure often attended with beneficial results to the patient and seldom at all harmful. Lichtheim has, however, recorded two cases in which an exacerbation of the symptoms followed so immediately upon the puncture as to leave little room for doubt that they were caused by the puncture. Only one of the cases, however, ended fatally.

The differential diagnosis of this disease from typhoid fever depends, in cases in which the nervous symptoms are prominent, upon the great irregularity of the temperature chart in cerebro-spinal fever, the presence of herpes, the leucocytosis, and the detection of micro-organisms in the cerebro-spinal fluid.

Tetanus has symptoms of rigidity and muscular spasm much like those of the initial stages of cerebro-spinal fever, but tetanus begins without fever, trismus is an early and prominent symptom, the muscular spasms are more easily excited, the sensorium is intact, and there is absence of vomiting and headache.

Acute muscular or acute articular rheumatism, and especially rhuematism of the cervical muscles in childhood, may be hard to distinguish from meningitis, but there are no radiating pains, and the swelling of the joints in meningitis, if present, is a late symptom.

Prognosis.—The mortality from this disease is usually high, although different epidemics vary greatly in this respect. According to Hirsch, the average mortality is thirty-seven per cent. for European, forty-five per cent. for American epidemics. It is said to be higher in the small epidemics. Councilman's figures for Boston were sixty-eight per cent., Flexner's and Barker's for Maryland only forty-eight per cent. Early childhood is bad; healthy young persons have the best chance. In all cases it is extremely difficult to give a prognosis, for the disease is liable to sudden fatal exacerbations at any time; while, on the other hand, the most serious cases, even the fulminating ones, may recover. Symptoms of depression, as coma or stupor, convulsions especially in adults, obstinate vomiting, very high fever, are all grave, while a long protracted case is apt to die from inanition.

Treatment.—In the early stages cold to the head and spine by means of ice bags and the ice coil, free diaphoresis and evacuation of the bowels, and perfect quiet, are all that is indicated in uncomplicated cases. Severe pain in the head or back often requires morphine, sometimes in large doses. Chloral seems to be well borne and is preferred by some clinicians. Local blood letting by wet-cupping or leeches is said to afford relief in delirium with great congestion of the head. Bathing or cold packing or sponging is recommended by Osler, but strongly objected to by Leyden and Goldscheider, on the ground that the necessary moving increases pain and may cause unconsciousness. Counter irritation is more valuable, in the later stages, for persistent headache, and may be produced by a light application of the Paquelin cautery; blisters are no longer in favor. The same may be said for mercury, formerly so much employed. Iodide of potassium is still recommended by many writers. Landon Carter Gray advises combining it with ergot and quinine. Persistent vomiting is best treated by hypodermic injections of morphine, in cases which cannot be controlled by simpler remedies, such as iced champagne, sinapisms, etc. Surgical treatment (the removal of the arch of a vertebra, incision into the dura, and drainage) has not given encouraging results. The nutrition is of the greatest importance, especially in protracted cases. While there is still much fever, milk and broths are indicated; in the later stages and in the intervals between the exacerbations any light nutritious food may be given. Unfortunately there is often great difficulty in inducing the patient to take nourishment, and forced feeding may have to be used. As general tonics quinine in large doses, iron, the iodides, and belladonna have been recommended.

II. *Acute Secondary Leptomeningitis.*—This is distinguished from the form just described by the fact that it is secondary, not primary; according to many observers it is distinguished by the fact that it is caused by micro-organisms other than the diplococcus intracellularis Weichselbaum. These cases are very hard to distinguish from sporadic cases of cerebro spinal fever proper, cases occurring in the absence of an epidemic. Councilman makes a sharp distinction between those sporadic cases which are proven to be due to infection by Weichselbaum's meningococcus, and the secondary cases which are caused by the pneumococcus, streptococcus, etc. Osler divides the meningitides into four classes: (1) Those due to the diplococcus intracellularis; (2) those due to the pneumococcus, which are usually secondary to pneumonia; (3) those due to the tubercle bacillus; and (4) those due to the streptococcus. Under this last head would come most of the cases which are secondary to otitis media, to mastoiditis, to erysipelas, to periostitis following trauma, to septicæmia, to ulcerative endocarditis, to extension from neighboring foci of suppuration, as pelvic cellulitis, suppurative pleuritis, etc., also the cases of meningitis complicating the acute infectious diseases. Exceptionally other micro-organisms are found in these secondary cases, as the typhoid bacillus, the colon bacillus, the staphylococcus pyogenes, and the gonococcus.

The extent of the disease is very variable. The suppuration may be limited to small foci or may form a general infiltration. The pathology is that of purulent inflammation, and does not need recapitulation. An extension of the process to the dura seldom occurs; the inflammation remains limited to the pia-arachnoid.

The symptoms are those of acute cerebro-spinal meningitis, complicated by the pre-existing disease. Headache, delirium, rigidity of the neck with or without retraction, high fever, vomiting, and convulsions, when developing in the course of an acute infectious disease, as a sequence of trauma or in a general septicæmia, would indicate an extension of the infection to the cerebro-spinal membranes. There may be trismus, epileptiform attacks, hyperæsthesia of the muscles and skin, twitchings or muscular spasms. As in the epidemic form, herpes is common. The temperature varies, but is rarely as high as in the epidemic form, and the pulse is apt to be slow. The pupils are at first contracted or unequal, later they are widely dilated.

The treatment is properly directed to the primary disease. For the cerebro-spinal symptoms the methods described above are to be tried, but the prognosis is very bad, such cases being almost invariably fatal.

III. *Acute External Meningitis, Acute Pachymeningitis, Acute Peripachymeningitis ("Periméningite Aiguë").*—By some authors these are considered two different affections, the latter involving the peridural connective tissue only, the former the dura itself.

"Perimeningitis" was first described and named by Albers in 1833 as a primary acute affection of the connective tissue surrounding the dura mater. He reported two cases. In 1879 Leyden proposed the name peripachymeningitis, a name which has been generally accepted by the Germans, while the French have adhered to the original name. The disease is a rare one. Deléarde in 1900 reviewed the literature and collected sixteen cases, adding one of his own. Of these, fourteen were men, the larger number being between the ages of twenty and thirty, the exciting cause apparently exposure and overexertion. Autopsy revealed the presence of inflammation in the peridural tissue only, which sometimes extended to the tissues around the vertebral column, but was essentially primary in the connective tissue surrounding the dura.

The port of entry for the infection is unknown. The organisms isolated are the staphylococcus aureus in two cases (Antony and Netter), the streptococcus in one (Deléarde). As the dura is free from the vertebral column laterally and posteriorly, the inflammatory exudate tends to collect on these surfaces and may travel out through the intervertebral foramina along the spinal nerves, as in Meslier's case. The effusion may be serous and abundant, or fibrinous, forming a false membrane over the outer surface of the dura; or, especially in the very rapid cases, it may consist of a small amount of bloody pus. The extent of the exudate varies much. Usually the cord is softened at the point of greatest inflammation, but is normal above and below.

There are no pathognomonic symptoms. The onset is usually sudden, with pain in the limbs and paraplegia, but without spasm and with normal or diminished reflexes. Anæsthesia appears early, preceded by lightning pains, and usually there is a zone of hyperæsthesia just above the anæsthetic area. Pressure on the spine over the inflamed region is very painful. The general symptoms are fever with morning remissions and a typhoid condition. Death is preceded by a fall of temperature (89.6°, F. in the rectum was noted in Lemoine and Lannon's case). Symptoms of internal meningitis, muscular spasm, rigidity of the neck, etc., appear late, if at all, and are evidences of an extension of the process to the pia-arachnoid. The rapid paralysis and anæsthesia without spasm or contraction are the chief diagnostic symptoms.

The prognosis is extremely bad. One case, that of Antony, operated on by Chipault, who performed laminectomy of the seventh to the eleventh dorsal vertebræ, recovered temporarily, but soon succumbed to suppurative endocarditis. Usually death occurs early. Meslier's case, lasting eight days, is the longest in Deléarde's series. Asphyxia from paralysis of the muscles of the thorax is the most common cause of death.

Pachymeningitis or peripachymeningitis secondary to some inflammatory process in the body is, according to the authors quoted above, to be strictly distinguished from the primary form, but the usual text-books make no such distinction, nor do they lay much stress on the limitation of the process to the dural or to the peridural tissue. Caries of the vertebræ is, naturally, the commonest cause of this condition; then follow suppurative processes near the vertebral canal, as psoas abscess, abscess of the muscles of the back, retropharyngeal abscess, deep sacral bedsores. Gowers believes that most of these cases of so-called secondary pachymeningitis are in reality cases of primary meningitis with secondary abscess formation. The inflammation almost never passes through the dura to the pia-arachnoid. Usually the inflammatory exudate is semipurulent and forms a layer over the outer surface of the dura, especially in the space between the posterior surface of this membrane and the arches of the vertebræ. In those cases which follow caries of the spine the vertical extent of the process is limited to the extent of bone disease. In any case gravity seems to affect the distribution of the exudate, for it rarely rises above the upper cervical region. In acute cases the symptoms are similar to those of the primary form, but not so rapid in development, and they are apt to be somewhat masked by the accompanying disease. Bedsores develop rapidly if the disease lasts long enough.

The only form which affords opportunity for treatment is that in which there is an accessible focus of inflammation which can be treated surgically. Trephining and free drainage of the vertebral canal is indicated. The general treatment follows that outlined for cerebro-spinal fever.

IV. *Tuberculous Meningitis.*—This form properly occupies a place between acute and chronic meningitis, for it may be acute, subacute, or chronic. It is divided by some authors into primary and secondary, but the primary cases rest on a very infirm base. Councilman has never seen a primary case, and Osler considers such cases very doubtful. A careful search will in almost all cases reveal an old tuberculous focus, if not in the lungs then in lymphatic glands, bone, or even in the middle ear. Jacobäus attributed a case of tuberculous meningitis of the cauda equina to extension from a tuberculous endometritis.

The process is more marked in the cerebral than in the spinal membranes, and the symptoms of spinal meningitis may be masked entirely, yet it is probable that in all cases the spinal meninges are also involved. Lichtheim found tubercle bacilli in the fluid obtained by lumbar puncture in all the cases of tuberculous meningitis examined in his clinic (figures not given); Fürbringer in twenty-seven out of thirty-seven cases. Oppenheim, Heubner, and Leyden and Goldscheider consider extension to the spinal meninges almost invariable. Osler reports a case of pure spinal meningitis (tuberculous). The localization of the process in the membranes at the base of the brain has led to the name "basilar meningitis," the large amount of fluid exudate to the name "acute hydrocephalus" or "water on the brain." It is much more common in children than in adults, but is rare during the first year of life; more common from the second to the fifth years.

The membranes at the base of the brain are cloudy, and covered with an exudate which is serous or gelatinous, or semipurulent, and causes matting of the membranes. There may be numerous tiny white tubercles scattered throughout, or they may be very few and revealed only after a careful search. They tend to form along the small pial arteries, and examination of the choroid plexus may reveal them, or it may be necessary to make a careful dissection of the branches of the middle cerebral arteries, when they will be found along the sheaths of the smaller vessels. Though more fully developed in the basilar region, the tuberculous process spreads to the vertex and to the vertebral canal. The abundant exudate—which is no measure of the extent of the tuberculous process—may cause flattening of the convolutions of the brain and enormous distention of the ventricles. Lichtheim says that the fluid is generally clear, but a delicate veil of fibrin often appears on standing, and is apt to contain in its meshes tubercle bacilli.

The tubercles are miliary, but have a tendency to early caseation, which is found even in the rapid cases—those of nine or ten days. In the slower cases there is an extensive confluence of the tubercles with formation of large caseous masses, in which the bacilli are found in great numbers. Giant cells are not common. Hektoen has described a peculiar tuberculous endarteritis which is not an extension from without, but due to an implantation of bacilli from the blood. The dura may escape entirely, or may show simply congestion. Ophüls describes tubercles of the ependyma either deep, from infection through the lymphatics, or superficial, from infection through the cerebro-spinal fluid.

The prodromal stage is protracted as compared with that of purulent meningitis, and the disease follows well-marked stages. The symptoms of the prodromal stage are headache, listlessness, irritability, constipation, loss of appetite, more or less insomnia. These may pass gradually or suddenly into the stage of irritation: severe headache, vomiting, fever, often convulsions. Headache is apt to be intense and agonizing, requiring powerful sedatives and being sometimes uncontrollable. The temperature rises rather gradually and is not high, 100–103 F., the pulse increasingly irregular. In this stage the pupils are contracted, and there are muscular twitchings or spasms. The next stage is marked by a subsidence of the irritative symptoms, the headache is less severe, the head retracted, the patient is dull and stupid, the eyes half closed, the eyeballs moving slowly from side to side, or there may be strabismus, the pupils dilated. Sudden flushes may appear over limited areas and redness follows rubbing or passing the nail quickly over the skin (the tache cérébrale). Convulsions may occur in this stage, which passes over into the stage of paralysis, characterized by a low delirium or coma, with dilated pupils, a weak, rapid pulse, a subnormal temperature, and sometimes paralysis of face or limbs. Death occurs in two to three weeks, sometimes preceded by a sudden rise of temperature.

The type described is that usually seen in childhood. In adults the process is extremely variable. Chantemesse, Boix, and Jaccoud all emphasize the great difference between the form in childhood and that in adult life, Jaccoud, indeed, asserting that the fatal outcome is the only common symptom. Jacobäus, however, explains this partly on the ground that it is the unusual cases only which find their way into the literature. The onset may be very sudden and the disease fatal within a few days. A case of Heubner's—adult—was at work up to thirty hours before death. He was seized with convulsions, delirium, and finally lethal coma. In other cases the disease may apparently begin in the spinal membranes and affect the cerebral secondarily. In a case of Jacobäus', a pulmonary consumptive, the symptoms began in the legs and travelled up. Boix reports a case which simulated tetanus, being ushered in by trismus.

The diagnosis of tuberculous meningitis depends upon the discovery of a tuberculous focus elsewhere in the body, the long prodromal stage, the comparatively low temperature, the marked irregularity and slowness of the pulse, and the more gradual development of the distinctive symptoms of meningitis than occurs in the purulent form. Ophthalmoscopic examination may reveal tubercles of the choroid. The value of Quincke's lumbar puncture has already been emphasized.

The disease is almost invariably fatal. Von Leube reports one recovery. A young phthisical adult had symptoms of tuberculous meningitis, recovered, suffered an exacerbation of the symptoms in the lungs, and succumbed to a second acute attack of meningitis. Examination of the spinal membranes showed evidence of healing tubercles. Reinhold had a case which followed a similar course. In the fluid obtained from a case of supposed epidemic meningitis Freyhan found tubercle bacilli, but the patient recovered. Osler has never seen a case diagnosed as tuberculous recover, nor has he found evidence of past disease at autopsy. *Alice Hamilton.*

SPINAL-CORD DISEASES: CERVICAL HYPERTROPHIC PACHYMENINGITIS.—The first adequate description of this rare disease was given by Charcot in a communication to the Société de Biologie in 1871. Two years later it was made the subject of a thesis by Joffroy, and since that time all writers on nervous diseases have associated the names of these two observers with classical descriptions of this form of meningitis.

Pathologically the disease is characterized by a chronic inflammation beginning on the inner aspect of the dura, and resulting in an exuberant stratiform overgrowth of fibrous tissue. As a result the dura may attain to a thickness five to ten times greater than the normal. The spinal roots traversing the thickened meninges are at first irritated and finally more or less completely strangled by the fibrous overgrowth. Later on, the cord itself shares in the morbid process, either by mechanical compression or by actual invasion, in the latter case the inflammation creeping in along the pial septa and blood-vessels. The ultimate result is a welding together of membranes, roots, and cord in a dense, stratified mass of fibrous tissue which may undergo partial ossification. Vacuolation of the cord has been said to occur as an end result in certain cases, and is probably due to the retraction of the fibrous tissue.

The disease usually begins in the dura surrounding the lower portion of the cervical cord, and produces a fairly constant clinical expression of its presence; it may, however, invade the pons and medulla or involve the upper dorsal region.

From an etiological standpoint nothing definite is known about the disease. Charcot speaks of it as accidental, having nothing to do with the family or hereditary types of nervous affections. Exposure to cold and damp seems to be the chief causative factor, although traumatism is accorded its usual place in the list, probably for the sake of uniformity. Oppenheim thinks that syphilis is a very common if not a prime cause; in the opinion of the writer the disease is much too rare to warrant this view.

The symptomatology has been somewhat arbitrarily divided by Charcot into three periods corresponding to the three stages of pathologic development. In the first—neuralgic or pseudo-neuralgic period—there is very severe pain in the neck, in the back of the head and between the shoulders, and sometimes in the top of the chest. With this there is a feeling of tension or stiffness, and the cervical spine may be tender to percussion. In addition, paræsthesiæ and neuralgic pains appear in the regions supplied by the ulnar and median nerves—the radial practically escapes—and are accompanied or followed by tremor and a certain degree of muscular tension. This stage of the disease may last for from four to six months, and is usually followed by the second or paralytic period.

At the beginning of this second period the pain has practically subsided. Paralysis of neuritic origin has, however, succeeded. This paralysis corresponds chiefly to the distribution of the ulnar and median nerves, the radial practically escaping. The muscles mainly involved are the small muscles of the hand and the flexors of the hand and fingers. As a result the unantagonized action of the extensor group brings about a peculiar attitude of the hands—hyperextension at the wrist-joint, with extension of the basal and flexion of the middle and end phalanges. This is known as the preacher hand (*main de prédicateur; Prediger hand*) and is practically pathognomonic. The reason for the exemption of the radial nerve from participation in the morbid process is not obvious, since its roots certainly lie within the diseased dural territory. It is curious also that mention is not oftener made of an implication of the cilio-spinal fibres of Klumpke-Dejerine arising from the first dorsal segment of the cord, with consequent changes in the pupil and in the palpebral fissure.

The third symptomatologic period is not always clearly to be separated from the others. In it appear the signs of a break in the conductivity of the cord, the result of strangulation or infiltration. This is evidenced by spastic paraplegia, anæsthesia, and loss of control of the vesical and rectal sphincters. These symptoms are produced in part by the local compression or asphyxiation of the cord, as has been stated, and in part by the secondary degenerations which naturally result therefrom.

As a rule, the disease extends over a period of years. It may, however, come to a standstill at any stage, leaving permanent damage which corresponds in degree with the amount of cord or nerve destruction that has taken place, or allowing complete restitution to the normal. Fatal cases are recorded.

When the disease process occurs in the classical situation, the lower portion of the cervical enlargement, its clinical features are sufficiently characteristic to determine the diagnosis. Obscurity comes when there is bulbar or pontine involvement or when the upper dorsal cord and roots are mainly implicated. An early cervical Pott's disease may be mistaken for cervical hypertrophic pachymeningitis; in such a case the obvious implication of the vertebræ themselves, which occurs sooner or later in the course of Pott's disease, should serve to differentiate. From tumors starting in the meninges or from the cord itself and growing vertically, differentiation is very difficult if not impossible; here the rarity of the disease under consideration should influence the decision.

The therapeutic measures most indicated are hot baths, the local application of the actual cautery over the lower cervical vertebræ, and the internal administration of potassium iodide and mercury, the last two being of value even in cases which are not specific in origin. In a case of Remak's galvanism rendered good service. Surgical measures are to be avoided. *Joseph W. Courtney.*

SPINAL-CORD DISEASES: CHRONIC SPINAL MENINGITIS.—Localized areas of chronic meningitis accompany chronic disease of the bones of the spinal column, tumors, chronic inflammatory diseases of the cord, etc. It is practically impossible to separate chronic pachymeningitis from chronic leptomeningitis. The process may predominate in one membrane and the symptoms may vary accordingly, but the other is invariably involved to a greater or less extent. Chronic productive inflammation of the pia-arachnoid and dura mater is very common, especially in old age; it is associated with trauma, atrophy of the cord and brain, chronic alcoholism, and general paralysis. It is usually accompanied by hemorrhage into the newly formed tissue and is therefore denominated pachymeningitis interna hæmorrhagica. In the early stages the inner surface of the dura mater is covered with a fine, easily removable, veil-like membrane consisting of a fibrinous network with spindle-shaped connective-tissue cells and leucocytes. Gradual organization of this membrane takes place by the formation of connective-tissue fibres, and the outgrowth of vascular buds which form a rich vascular network. These thin-walled vessels are very prone to rupture, so that the membrane becomes studded, at first with hemorrhages, later with masses of blood pigment from the disintegrated corpuscles. The outer part, next the dura, grows sclerotic, and is inseparable from the dura itself. Large hemorrhages may occur—hæmatoma of the dura—with symptoms of compression. The early stages may be found at autopsy, in acute infectious diseases, without having caused symptoms during life.

Undoubtedly many cases of so-called "chronic meningitis," especially those of the earlier literature, were really diseases of the cord, for chronic spinal meningitis is rare as a primary malady, and our knowledge of it is as yet slight and defective. The clinical picture differs widely from that of the acute, for the symptoms of irritation are replaced by those of pressure. The nerve roots seldom escape in this form. Usually they are red and swollen or compressed and atrophied. The cord suffers to a variable degree, most extensively where the process is pronounced in the pia-arachnoid, and the newly formed tissue not only compresses the nerve roots, but passes in along the sheaths of the vessels, causing a marginal sclerosis and a general infiltration of round cells and epithelioid cells. Degenerations following this sclerosis cause the symptoms of a mixed lesion, a meningomyelitis. Usually the changes are localized, especially in the cervical cord; very rarely they are general, as in a case reported by Mitchell Clarke, in which the pathological changes and new formation of connective tissue rich in blood vessels involved the inner surface of the dura and the pia-arachnoid throughout the whole extent of the cord.

The symptoms of chronic meningitis are due, as in the acute form, to irritation and compression, but in the former there are not such severe paroxysms or spasms, and the symptoms increase gradually, at times with long remissions. Pain or stiffness in the back and neck, with radiating pains in the limbs, simulate rheumatism. This is succeeded after a long period by anæsthesia, with hyperæsthetic patches. The muscular symptoms are tremors, gradual loss of power, and wasting. The reflexes are lost. The symptoms vary naturally with the localization of the lesions. Those of the cervical cord are muscular atrophy and paresis of the upper extremities with spastic laming of the lower, and are very similar to those of amyotrophic lateral sclerosis or syringomyelia, except for the more pronounced pain and stiffness.

The form known as pachymeningitis cervicalis hypertrophica was first differentiated by Charcot and Joffroy, who claimed for it a special symptomatology. The thickening of the dura is most pronounced in the cervical cord, where it forms a ring of dense fibrous tissue, with adhesions to the bony canal and to the pia-arachnoid. The outgoing nerve roots are compressed and show degeneration with proliferation of interstitial tissue. Pressure on the periphery of the cord causes a marginal sclerosis which is followed by ascending and descending degenerations. The proliferation of new tissue may be so extensive as to flatten the cord antero-posteriorly.

Charcot divides the symptoms into a first period lasting two or three months, with severe pains in the back of the neck passing up to the occiput and down to the arms, persistent, with exacerbations. There are rigidity of the neck and back, simulating Pott's disease, paræsthesia in the arms, perhaps paresis. This corresponds to the stage of compression of the nerve roots, while in the second stage there are the symptoms of degeneration, the pains cease, there are laming and atrophy, especially of the muscles supplied by the ulnar and median nerves. There are laming and contraction of the muscles of the legs, also general cutaneous anæsthesia, decubitus, and there may be paralysis of the sphincters.

The prognosis is grave, for the disease is usually regularly progressive, and a recovery probably speaks for a wrong diagnosis. Rest is essential; warm baths and counter-irritation, by stimulating liniments or sinapisms, may be employed. Joffroy recommends the use of the thermo-cautery for the hypertrophic form. Mercury and iodide of potassium are recommended, the former by inunction over the spine, and combined with cantharides for counter-irritation. In using anodynes it is important to bear in mind the long course of the disease and the importance of frequently changing the drug and of trying to reduce the dose occasionally. Galvanism, massage, and passive movements are indicated for the muscular wasting.

Syphilitic Meningitis.—It is very probable that many of the cases which are diagnosed as chronic meningitis are syphilitic in origin. The most common change found in the spinal cord in syphilis is meningomyelitis, which generally affects the membranes of the brain as well. Williamson states that in thirty-two cases of spinal syphilis examined by him, sixteen were meningomyelitis, three were chronic meningitis. The syphilitic process shows itself in the vessel walls especially, although the weight of opinion is against a specific syphilitic arteritis. A general arteritis, however, in young individuals is apt to be syphilitic. The dura is diffusely infiltrated and thickened, there may be typical gummata with caseous centres, but more frequently there are only local accumulations of new connective tissue. The pia may in some places exhibit five to ten times its normal thickness, being gelatinous or densely fibrous, and adherent to the dura. The changes in the membranes extend to the cord in the form of proliferation of the connective tissue along the sheaths of the vessels and of the neuroglia. The changes in the vessels are proliferation, sometimes most marked in the intima, sometimes in the adventitia, with thrombosis and obliteration of the smaller vessels. Japha, Schwarz, and Wullenweber report cases of syphilitic meningitis accompanied by cavity-formation in the cord, the cavities being caused probably by necrosis of anæmic infarcts from the blocking of the sclerotic vessels. This condition is not to be confused with syringomyelia, for there is no trace of gliosis around the cavities.

Chronic syphilitic meningitis can cause any of the symptoms outlined under chronic meningitis in general, depending on the localization of the fibrous proliferation. Typically, it is focal in character and associated with focal lesions in the cord itself, so that the pains are usually irregular, unsymmetrical, followed soon by impairment of sensibility and muscular weakness. The pain is said to be worse at night. The rise of temperature is not great—100°–101° F.—and may be subnormal at the end. In Shoyer's case the symptoms began in the left foot and moved gradually upward, the disease lasting over four years.

The prognosis is more favorable than that of any other form of chronic meningitis; the treatment follows the same lines as that for syphilis in general.

Alice Hamilton.

SPINAL-CORD DISEASES: COMBINED DEGENERATIONS OF THE CORD.—INTRODUCTION.—The attitude toward the so-called combined scleroses of the spinal cord has changed with increasing post-mortem study and with the general acceptance of the neurone doctrine as applied to pathological processes. The term "system or systemic disease," as formerly applied by Charcot and others, should be modified to include only degenerations of neurones, "systemic neurone disease," whereas the various degenerations, involving chiefly the white matter of the cord, irrespective of neurones, should be differently classified. A failure to recognize this fact, even on the part of recent writers, has led to a very considerable degree of confusion in the nomenclature, especially since lesions of varying extent and character may give rise to very similar clinical symptoms. With the more accurate study which the new conception of the anatomy of the nerve cell has rendered possible, and with a large number of post-mortem investigations, it is apparent that the "combined scleroses" are more frequently diffuse in distribution than limited to fibre tracts of functional identity. If, then, the term "combined sclerosis," or "combined disease of the dorsal and lateral tracts," be used, it should be understood that there is no implication that the neurones as such are primarily involved, although the lesions may lie, in great part, in the lateral and dorsal portions of the cord. Doubt has been thrown upon the existence of a true systemic degeneration of the peripheral sensory neurones (dorsal tracts), and the central motor neurones (pyramidal tracts) in the form of a combined disease (Goldscheider), except in certain hereditary affections (Friedreich's ataxia, cerebellar ataxia) and in dementia paralytica. It is certainly far less frequent than formerly believed. In the following discussion, therefore, I shall place chief stress upon diffuse lesions of the cord, predominantly located in the dorsal and lateral tracts, and giving rise to the symptoms of ataxic paraplegia. This in no way denies the possibility of the existence of combined disease which is actually systemic in character.

The following provisional groups may be made:

I. Diffuse (combined) degeneration of the cord; combined sclerosis.

II. True combined dorsal and lateral systemic (neurone) disease.

III. Combined systemic disease. (*a*) Result of congenital defect (Friedreich's ataxia, cerebellar ataxia). (*b*) In dementia paralytica.

I. *Diffuse (Combined) Degeneration of the Cord; Combined Sclerosis; Subacute Spinal Ataxia; Subacute Combined Degeneration of the Spinal Cord; Combined System Disease.*—Under these varied titles has been included a type of affection which is sufficiently characteristic to have a definite place among the diseases of the spinal cord. Attention has been drawn to the combination of sclerosis of the dorsal and lateral tracts by Kahler and Pick, Westphal, Strümpell, and Oppenheim; the association of such alterations with pernicious anæmia and cachectic states has become familiar through the work of Lichtheim, Putnam, Dana, Minnich, Nonne, Burr, Bastianelli, Russell, Batten, Collier, very recently by Billings, and many others. The identity of the lesions in these various conditions is still in dispute; that they vary in detail is of course natural and inevitable; that they represent a general group of alterations which may later be subdivided is, however, at present a supposition, justified by the facts at our disposal. No attempt at subdivision—as, for example, lesions due to anæmia or lesions dependent upon general cachexia or toxæmia—will be attempted in what follows. Anæmia has undoubtedly been given a place of undue importance in relation to these lesions. The insistence upon other and more general causes is due primarily to Putnam's work, published in 1891.

PATHOLOGICAL ANATOMY.—The alterations in the cord in this type of disease consist macroscopically in degenerations of the white matter, chiefly in the dorsal and lateral tracts, irregular in distribution, and either not involving whole groups of fibres or extending beyond the confines of such tracts. The dorsal tracts, for example, are affected irregularly, groups of fibres in the immediate neighborhood of much degenerated areas are spared, and the root zones are rarely involved, in striking contrast to the systemic degeneration of tabes. The region of the pyramidal tracts is often much involved, but the alterations always extend beyond the confines of these tracts, chiefly along the peripheral portions of the cord, and on either side of the ventral fissure. The alterations are least marked in the lumbar region, and increase markedly in extent in the upper thoracic and cervical regions. Even to the naked eye the stained section often presents a peculiar, vacuolated appearance. Microscopic examination of the lesions shows the alterations to be essentially limited to the cord, with exceedingly slight alterations of the oblongata or hemispheres. The lesions are characterized by disintegration of myelinated fibres, overgrowth of neuroglia, in part sufficient to form a dense sclerosis and in part slight, vacuolation being due apparently to dilating and degenerating myeline sheaths, many fat granule cells, irregularity of distribution, often with very small foci of degeneration, scattered irregularly through the white matter, and at times focal softening. The gray matter is very slightly involved, and frequently not at all; the nerve roots are not involved; there is no evidence of meningeal thickening, and the blood-vessel walls rarely show changes. The pathological features common to the general group may, therefore, be summarized as follows:

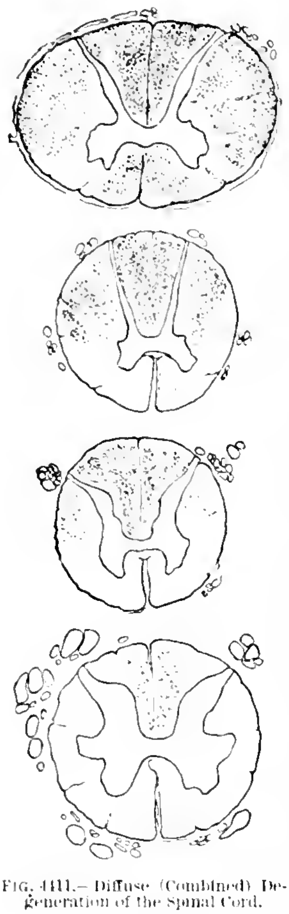


FIG. 4411.—Diffuse (Combined) Degeneration of the Spinal Cord.

1. A diffuse degeneration for the most part limited to the cord, often in more or less discrete patches.
2. A constant involvement of the dorsal and lateral columns, without strict regard to neurone systems.
3. A predominance of the lesion in the cervical and thoracic regions.
4. The common freedom from degeneration of nerve roots, both motor and sensory, and peripheral nerves.
5. The essential non-involvement of gray matter.
6. Insignificant vessel changes.

The reason for the peculiarly constant location of the lesions is probably to be sought in the distribution of the blood supply to the cord, a theory first advanced by Marie. Those who cling to the systemic character of the affection are inclined to search for a more subtle explanation, but the involvement of the cord alone, the tendency toward a peripheral distribution of the lesions, the non-involvement of gray matter, and the frequent occurrence of the disease in impoverished blood states, all indicate the rôle of the blood-vessels and their contained blood. Certain writers have maintained a double lesion, one of diffuse character and the other systemic, with possible secondary degenerations.

ETIOLOGY.—The persons in whom the disease occurs in typical form are usually of middle age, weak constitution, often with neurotic personal or family antecedents, of poor nutrition, cachectic in appearance, and of reduced bodily vigor. It is considerably more frequent in women than in men, according to Putnam's statistics. Syphilis may be disregarded as an etiological factor. A frequent though by no means universal accompaniment or possible cause of the disease is anæmia of the pernicious type. This association has led to the popular but wholly erroneous assumption that the alterations of the spinal cord described above are peculiar to anæmia. Lead poisoning, malaria, grave secondary anæmia, and other debilitating influences have also been given as causes, and the disease has at times occurred in otherwise healthy individuals. Overwork, excessive anxiety, gastro-intestinal disorders, may have a predisposing influence. Further than this our accurate knowledge does not go. Whether or not a subtle toxæmia, of a character as yet not understood, may ultimately be found responsible is possible, but far from being proved. It may be said with assurance at the present time that a well-characterized affection of the cord occurs in cachectic individuals toward middle life, leading to diffuse, quasi-systemic degenerations, dependent, in part at least, upon the distribution of the vascular supply.

SYMPTOMATOLOGY.—In general, during the early stages, the symptoms are somewhat vague in character and may simulate functional disorders. The most conspicuous early symptom is paræsthesia of the extremities, noticed earlier in the feet. Disordered sensations may occur in other portions of the body—genitals, distributions of cranial nerves—but are much less usual. This paræsthesia is frequently very distressing. Slight disorders of micturition and rarely of defecation may occur. Objective disorders of sensation are not conspicuous, though they certainly occur, and in a well-reported group of cases (Russell, Batten, Collier) take an important place in the later stages of the clinical picture. Disorders of motion are of the character of a slight spastic paraplegia, with exaggerated deep reflexes, and the Babinski phenomenon. As the disease progresses, the symptom-complex assumes the general character of an ataxic paraplegia, with a predominance of ataxia or paraplegia depending upon the greater involvement of the dorsal or lateral columns. In later stages, as the lumbar portion of the cord is invaded, the knee-jerk may be abolished, and the patient be reduced to a helpless paraplegic condition, with loss of sphincter control. The mind is rarely affected, and the cranial nerves show no noteworthy involvement. Pigmentation of the skin, epileptic attacks, excessive diarrhœa or constipation, atrophy of the optic nerve, mental instability, dissociation of sensation, pain in the back and limbs, transient œdema, muscular atrophy, altered electrical reactions, have all been described as occasional symptoms.

Certain writers, notably Bastianelli and Russell, Batten and Collier, have attempted to classify cases either by etiology (Bastianelli) or by symptomatic course (Russell, etc.). The latter divide the disease sharply into three stages: first, slight ataxic paraplegia, constituting one-half to three-quarters of the duration of the illness; second, sudden loss of sensation, with increasing motor paresis, leading to inability to walk or stand, marked spastic paraplegia; third, stage of flaccidity, flaccid paraplegia, complete flaccid motor paralysis, complete anæsthesia, with loss of deep reflexes, incontinence, wasting of muscles, and loss of faradic reaction. In the experience of others these sharp divisions cannot be maintained; such a course evidently marks a variety of the general affection, which is highly important, but cannot be regarded as characteristic of the entire group. In general, it must be said that on the symptomatic side attempts to deduce a perfectly characteristic clinical picture have as yet failed, although the grouping of the symptoms of primary paræsthesia, ataxic paraplegia increasing rather rapidly in intensity, followed by a stage of more or less complete motor and sensory paralysis, in the absence of lancinating pains and Argyll-Robertson pupil, point strongly toward combined lesions of the character under consideration.

Diagnosis, Course, and Prognosis.—The diagnosis in the later stages should not be difficult, and in the early stages should be assumed as probable in cases in which an otherwise unexplained and persistent paræsthesia, especially of the legs, is associated with slight ataxia and a tendency toward spasticity with exaggerated deep reflexes, particularly if the patient be of middle age, with evidences of cachexia. Multiple sclerosis may simulate this affection at various stages, but in general it may be distinguished by the youth of its victims, the characteristic speech defect and tremor, with a marked preponderance of motor over sensory involvements. Myelitis should also receive consideration in the differential diagnosis. Uncomplicated tabes should give rise to no confusion.

The course of the disease is from six months to two years, with occasional instances of much longer duration. As a rule, the patients are already in a debilitated condition when the symptoms manifest themselves, a fact which evidently must have a more or less direct bearing upon the outcome.

The prognosis is always bad, both from the point of view of the general condition of the patient and also because of the usually rapidly advancing cord degenerations.

Treatment.—Attention should first be directed toward the discovery and amelioration of the underlying condition causative of or associated with the alterations in the cord. Anæmia, whether of the so-called pernicious variety or secondary, general debility, and disordered bodily functions in general, should be treated by the recognized means at our disposal. It is possible that much might be done in the earliest stages to avoid or modify the serious and ultimately irremediable cord degenerations. If they have developed, however, and the patient is ataxic, or ataxic paraplegic, recourse should certainly be had to the Frenkel exercises, modified to meet the indications in individual cases. The usual drugs—iron, strychnine, arsenic, the iodides, etc.—may be given, but with small hope of permanent benefit.

II. *Combined Dorsal and Lateral Systemic (Neurone) Disease.*—In spite of the doubt which has been thrown upon the existence of a true neurone degeneration involving dorsal and lateral tracts, cases have been reported clinically, and in a few instances anatomically verified, of the existence of such a combined lesion (Oppenheim). Degenerations of the columns of Goll and Burdach, the pyramidal tract, the direct cerebellar tract, and less frequently of Gowers, and the uncrossed pyramidal tracts, have been described, with the assumption that these tracts were degenerated as systems and not as a part of a more general process.

Such cases of primary degeneration of lateral and dorsal neurone systems give rise to the symptoms of tabes and lateral sclerosis, the one or other type of symptom predominating in direct relation to the extent of the dorsal or lateral pathological change. Symptoms of tabes, with lancinating pains and Argyll-Robertson pupil, but with exaggerated knee-jerk, should always give rise to a strong suspicion of a combined systemic degeneration, giving the general clinical picture of ataxic paraplegia. Should the definite signs of tabes, including loss of knee-jerk, be associated with muscular weakness, a similar diagnosis of combined lesion is justified. The signs of tabes, on the other hand, may be in great measure subordinated to those of lateral degeneration—spastic paraplegia. In this case slight disorders of sensation, sharp pains, condition of the pupils, bladder weakness, should be carefully investigated to determine the possible involvement of sensory neurones. Ataxic paraplegia, as commonly observed, is no doubt usually due to the more diffuse process described above. The important differential point is the existence of a true tabes, which does not occur in the diffuse combined lesions.

The treatment is as indicated for the foregoing disease, and for Friedreich's ataxia.

III. *Combined Systemic Disease.—(a) Result of congenital defect (Friedreich's ataxia); cerebellar ataxia; hereditary cerebellar ataxia; (b) in dementia paralytica.*

(*a*) *Friedreich's Ataxia.*—See article on this subject.

Cerebellar Ataxia.—Hereditary cerebellar ataxia, type Nonne-Marie, bears a close resemblance to Friedreich's ataxia, except for the facts that the knee-jerks are increased, the pupils are immobile, there is atrophy of the optic nerve, there are marked disorders of sensibility, and club-foot and kyphosis do not develop. Lesions of the cerebellum and other portions of the brain have been found, and in one case (Menzel) a combined system disease of the cord.

(*b*) *Combined Systemic Disease in Dementia Paralytica.*—Alterations of the spinal cord (Westphal), in the form of degeneration of the pyramidal tracts or of the dorsal, sensory tracts, or of both, are frequent in dementia paralytica. Whether the alterations in the pyramidal tracts are to be regarded as primary neurone degenerations or as secondary to changes in the cortex remains in doubt.

Gowers' Ataxic Paraplegia.—In 1886 Gowers drew attention to a condition presenting the symptoms of degeneration in the dorsal and lateral tracts, to which the clinical name ataxic paraplegia was given. The classification of this condition is difficult, but from the description of the pathological alterations it should rather be included among the diffuse combined degenerations than among the true systemic diseases. After what has been said it does not require separate description.

E. W. Taylor.

Partial Bibliography.

Kahler and Pick: Arch. f. Psych., 1877, viii., p. 251.
Westphal: Arch. f. Psych., 1879, ix., p. 413.
Strümpell: Arch. f. Psych., 1880, xi., p. 27; 1886, xvii., p. 217.
Ballet and Minor: Arch. d. Neurol., 1884, vii., p. 44.
Gowers: Lancet, 1886, July 3, 10, pp. 1, 61.
Lichtheim: Cong. f. Inn. Med., 1887, p. 84.
Putnam: Journ. Nerv. and Ment. Dis., February, 1891.
Dana: Journ. Nerv. and Ment. Dis., February, 1891: April, 1891; January, 1899.
Nonne: Arch. f. Psych., 1893, xxv., p. 421.
Burr: Univ. Med. Mag., April, 1895, and Journ. Nerv. and Ment. Dis., 1903, xxx., p. 14.
Bastianelli: Bul. d. R. Acad. Med. d. Roma, 1895-96.
Russell, Batten, and Collier: Brain, 1900, lxxxix., p. 39.
Putnam and Taylor: Journ. Nerv. and Ment. Dis., January and February, 1901.
Billings: Bost. Med. and Surg. Journ., 1902, cxlvii., p. 225.
Kattwinkel: Deut. Arch. f. klin. Med., 1902, lxxv., p. 37.

SPINAL-CORD DISEASES: CONGESTION OF THE CORD.—Our actual knowledge regarding spinal congestion is very limited, and hypothetical statements that it is the basis of many nervous symptoms are unwarranted. The diseases in which it is uniformly found after death are those in which the patient has died in convulsions complicated by asphyxia, or in the early stages of myelitis. The only positive evidence that a spinal congestion has existed during life is the discovery of distended capillaries, accompanied by small capillary hemorrhages. Without the latter the congestion found may have been a post-mortem occurrence, due to the position of the body on the back.

The *causes of active congestion* are excessive muscular exertion, violent sexual excesses, poisoning by strychnine, alcohol, and carbonic oxide, the sudden arrest of menstruation or the stoppage of hemorrhage from piles, and possibly exposure to cold. Traumatism of the vertebræ, especially general concussion of the spine, such as occurs in railway injuries, probably causes active spinal hyperæmia, in a few cases examined capillary hemorrhages having been found after death in the cord. It is probable that spinal congestion is usually localized in the lower half of the cord, though the entire organ may be affected. An active hyperæmia of the anterior cornua is the first occurrence in poliomyelitis anterior, and this is usually quite extensive, while the actual process of inflammatory degeneration is subsequently limited to a small area. The latter produces the permanent atrophic paralysis of infants; to the former must be ascribed the temporary paresis of the first stage of the disease, which is always more extensive than the permanent paralysis.

The causes of passive congestion are the same as those producing this effect in the brain or other organs (*q.v.*).

The *symptoms of spinal congestion* are a sensation of weight and fatigue in the legs and back, increased by any effort, so that continued exertion is impossible; pains, numbness, formication, and sensations of heat and cold, with increased susceptibility to changes of temperature and to pain and touch in the extremities; weakness, but not paralysis, in the entire muscular system, attended by an increase of reflex excitability; a diminution of sexual power, and a diminution of control over the bladder and rectum not sufficient to be termed incontinence. Any symptoms more serious than these, such as severe tearing pains in the back and general hyperæsthesia, or such as girdle sensations, incontinence, and actual paralysis, must be ascribed to congestion of the spinal meninges as well as of the cord, or to disturbances of a grave nutritive kind initial to an actual myelitis. These symptoms are always bilateral and usually more marked in the lower half of the body, although the arms may become involved. They usually come on suddenly after some known cause; but occasionally a chronic congestion is suspected, which lasts for months, and is attended by symptoms of neurasthenia.

The *diagnosis of spinal congestion* is an uncertain one. When symptoms such as those described appear, and do not go on to more serious conditions, but gradually pass off, and no adequate cause can be found, the diagnosis can be made. If, however, serious symptoms of myelitis ensue, it must be admitted that the disease was myelitis from the outset, and not a simple hyperæmia. A long duration of symptoms of spinal congestion points rather to the existence of capillary hemorrhages, attended by small foci of inflammatory degeneration, or to nutritive changes in the spinal cord.

The *prognosis* should always be reserved, in view of the uncertainty of diagnosis and the possibility of myelitis.

The *treatment* should consist of absolute rest in bed, in a prone position; the application of cool cloths, wet with an evaporating lotion, to the spine, or an ice bag or the ether spray; saline purgatives; and full doses of ergot with small doses of belladonna. *M. Allen Starr.*

SPINAL-CORD DISEASES: DIAGNOSIS OF LOCAL LESIONS IN THE CORD.—The spinal cord is a long, cylindrical organ, made up of numerous segments, each of which not only has a function of its own, but also bears an important part in relation to the functions of other segments. Each segment of the cord consists of a mass of gray matter, surrounded by a series of white tracts, from which passes out a pair of spinal nerves. In some of the lowest order of vertebrata the comparative independence of each segment is indicated by the fact that the spinal cord consists of a series of bulbous enlargements joined together by only a few connecting fibres. And even in man there are some evidences that the functions of each segment of the cord are independent of all others. But in the higher vertebrata the various segments are closely united to one another, and are also connected with the brain, which controls them all by means of the white tracts surrounding the gray matter. Hence, in addition to its own special function as a nervous centre, each segment has functions of transmission of impulses to adjacent segments and to distant parts of the nervous system. Therefore, in dealing with local lesions in the spinal cord, the first point to determine is whether the lesion involves the nerve centres of a single segment, or the tracts which pass through that segment to other centres. In the first case, when the gray matter of a single segment is affected, the symptoms are limited in extent and in number, consisting of localized paralysis, limited anæsthesia, loss of certain reflexes, disturbance of certain automatic actions, and local vaso-motor and trophic disturbances. In the second case, when the white matter of a single segment is affected, the symptoms are widespread and numerous, consisting of partial or complete paraplegia, anæsthesia of the lower half or even of the entire body, loss of control over reflex and automatic activity, and extensive vascular and trophic changes. And when both gray and white matter of a single segment are totally involved, there will be a combination of local and general symptoms, the distribution and extent of which will depend wholly upon the particular level of the segment of the cord which is affected. It is therefore evident that the first step in the diagnosis of local lesions of the spinal cord is the determination of the functions of the various segments, and of the various tracts which pass through them.

I. THE FUNCTIONS OF THE SEGMENTS OF THE SPINAL CORD.—Each segment of the spinal cord consists of that portion of the entire organ which gives origin to one pair of spinal nerves. There are, therefore, thirty-one segments in the human cord. There is no natural division between adjacent segments, but if a cord with its nerves be carefully removed, there will be no difficulty in cutting it up into segments, each of which will receive two afferent and give off two efferent nerves. Each segment is made up of two symmetrical halves, naturally separated by the anterior fissure and posterior septum, but joined by a commissure.

The afferent or sensory nerves enter the posterior surface of the segment, and, passing through the white matter, end in the gray. The efferent or motor nerves pass out from the anterior surface of the segment, having their origin in the anterior gray horn, and traversing the white matter bordering these horns. The figure (Fig. 4412) shows four such segments at different levels of the cord with their afferent (*s*) and efferent (*m*) nerves as well as the motor tracts and association tracts to the various segments.

A. The Gray Matter.—The size and shape of the area of gray matter, seen in horizontal section of the cord, differ in almost every segment, the difference between adjacent segments being more marked in the cervical and lumbar enlargements than in the dorsal region. The shape of the area of gray matter in the dorsal region resembles that of the letter **H**, and, accordingly, anatomists describe two lateral halves with a central gray commissure between them, and in each half an anterior and a posterior horn. In the enlargements of the cord the mass of the horns is much larger than in the dorsal region, and the shape varies in each segment. The amount of gray matter in any segment depends upon the number of cells in the anterior and posterior horns. These cells are not scattered irregularly through the gray matter, but are collected into groups. These groups are quite distinct in the anterior horns, in some cases being small, and found only in a single segment; in others being long, and extending through several segments. This varying arrangement of the anterior groups at different levels is seen in the figure (Fig. 4413). The function of the cells in the anterior horn is to govern the motion and nutrition of the muscles.

The more exact localization of motor functions in the groups of cells in the cervical and lumbar enlargements has been attempted by various writers. Fig. 4413 shows the groups found at three different segments of the cord. There are some of these groups—viz., the inner antero-lateral and postero-lateral groups—which develop early in fœtal life, and are common to man and the less highly developed vertebrates. These are thought to govern the fundamental movements common to man and animals, and earliest acquired in children, viz., flexion and extension, abduction and adduction of the limbs. Other groups, viz., anterior and median groups, are found only in monkeys and man, and the central groups in man alone. These are also found to develop later than the others. They are therefore thought to govern the accessory movements, which are more specialized and depend on finer adjustment, such as the act of walking upright, pronation and supination, and the finer motions of the hands and fingers, actions which are learned some months later than those of a fundamental kind. In some cases of disease, limited to these groups of cells—*e.g.*, poliomyelitis anterior—the symptoms have been found to justify this distinction, loss of power and atrophy of certain muscles being produced by a lesion in certain groups of cells. The connection of the different groups, in various segments, with individual muscles, as far as at present known, is shown in the table accompanying this article.[1] (See p. 340.)

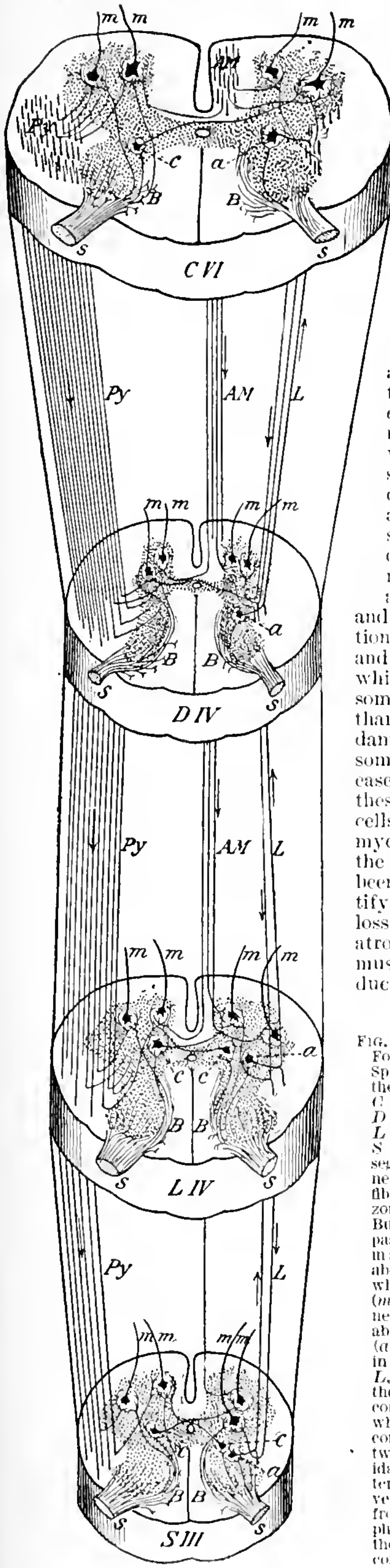


FIG. 4412.—Diagram of Four Segments of the Spinal Cord to Show the Motor Mechanism. *C VI*, Sixth cervical, *D IV*, fourth dorsal, *L IV*, fourth lumbar, *S III*, third sacral segments: *s*, sensory nerve root whose fibres enter the root zone of the column of Burdach, *B*, and then pass into the gray matter terminating about (1) motor cells whence motor fibres (*m*) issue as motor nerve roots; or, (2) about association cells (*a*) whose fibres pass in the lateral column *L*, to other levels of the cord, or (3) about commissural cells (*c*), whose fibres cross the cord associating the two sides. *Py*, Pyramidal tract; *AM*, antero-median tract conveying motor impulses from the right hemisphere of the brain to the motor cells of the cord.

The arrangement of cells in the posterior horns is different from that in the anterior horns. There is a column

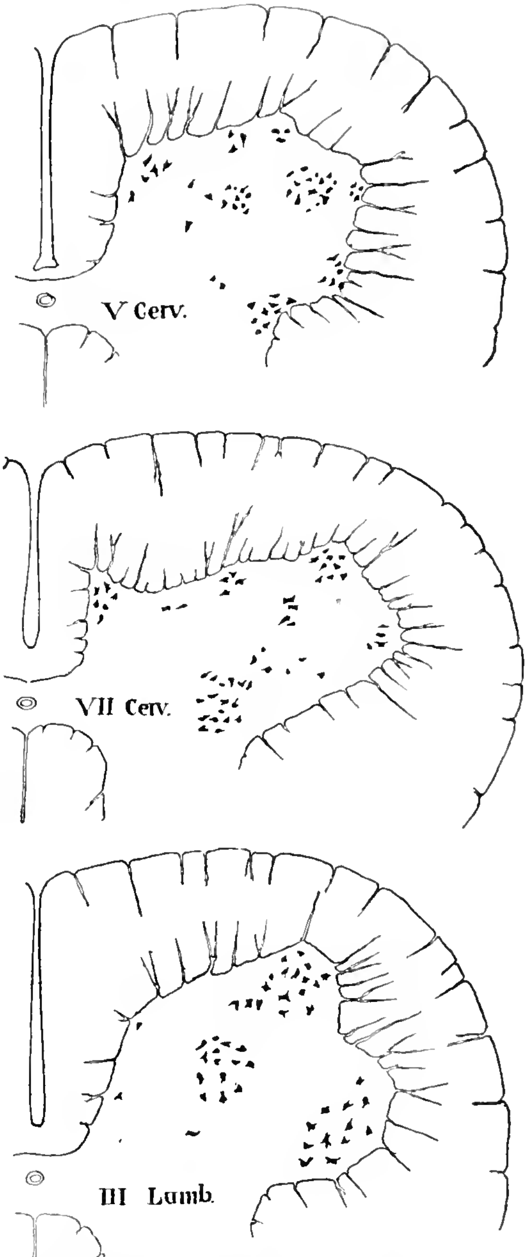


FIG. 4413.—Showing the Different Grouping of the Cells in the Gray Matter of the Spinal Cord at Three Different Levels. (Drawn from photographs.)

of cells extending through the lower dorsal region, known as the vesicular column of Clarke, and situated in the median and inner part of the horn (see Fig. 4412, *c*). The column begins in the third lumbar segment, and extends upward to the seventh dorsal segment. Its probable function is to regulate the vaso-motor and sympathetic nervous mechanisms.[2] There is a continuous column of cells in the middle of the posterior horn, not collected together into groups, but scattered through the neuroglia and gelatinous substance of the posterior horn. These cells are very small in size, and thus contrast markedly with those already described. It is probable that the gelatinous mass in the posterior horn has something to do with the sensory function, for it is present in the nervous system wherever a sensory nerve ends. The sensations of touch, temperature, and pain are carried into the posterior horns by the posterior nerve roots, which terminate in the gelatinous substance and in cells which lie about the central canal of the cord in the gray matter at the junction of the posterior and anterior horns (Fig. 4414, *X*).

All the cells of the gray matter give off branching processes which interlace, forming a dense network of nerve fibrillæ around the group of cells. This interlacing mass of fibres is composed partly of the dendrites of cells which collect impulses, and partly of the axones of cells which send out impulses. These axones in their pas-

LOCALIZATION OF THE FUNCTIONS OF THE SEGMENTS OF THE SPINAL CORD.

Segment.	Muscles.	Reflex.	Sensation.
Second and third cervical.	Sterno-mastoid, trapezius. Scaleni and neck Diaphragm.	Hypochondrium (?) Sudden inspiration, produced by sudden pressure beneath the lower border of the ribs.	Back of head to vertex. Neck.
Fourth cervical......	Diaphragm. Deltoid. Biceps, coracobrachialis. Supinator longus. Rhomboid. Supra- and infraspinatus. Levator anguli scapulæ.	Pupil, fourth to seventh cervical. Dilatation of the pupil produced by irritation of neck.	Outer part of shoulder.
Fifth cervical...........	Deltoid. Biceps, coracobrachialis. Supinator longus. Supinator brevis. Deep muscles and shoulder blade. Rhomboid, teres minor. Pectoralis (clavicular part). Serratus magnus.	Scapular. Fifth cervical to first dorsal. Irritation of skin over the scapula produces contraction of the scapular muscles. Supinator longus. Tapping its tendon in wrist produces flexion of forearm.	Back of shoulder and arm. Outer side of arm and forearm.
Sixth cervical...........	Biceps, brachialis anticus. Pectoralis (clavicular part). Serratus magnus. Triceps. Extensors of wrist and fingers. Pronators.	Triceps. Fifth to sixth cervical. Tapping elbow tendon produces extension of forearm. Posterior wrist. Sixth to eighth cervical. Tapping tendons causes extension of hand.	Outer side of arm and forearm. Outer half of hand.
Seventh cervical.........	Triceps (long head). Extensors of wrist and fingers. Pronators of wrist. Flexors of wrist. Subscapular. Pectoralis (costal part). Latissimus dorsi. Teres major.	Anterior wrist. Seventh to eighth cervical. Tapping anterior tendon causes flexion of wrist. Palmar, seventh cervical to first dorsal. Stroking palm causes closure of fingers.	Front, back of arm and forearm. Middle and ring fingers.
Eighth cervical......	Flexors of wrist and fingers. Intrinsic muscles of hand.	....	Forearm and hand; ulnar area.
First dorsal............	Extensors of thumb. Intrinsic hand muscles. Thenar and hypothenar eminences.	....	Inner side of forearm.
Second and twelfth dorsal	Muscles of back and abdomen. Erectores spinæ.	Epigastric, fourth to seventh dorsal. Tickling mammary region causes retraction of the epigastrium. Abdominal, seventh to eleventh dorsal. Stroking side of abdomen causes retraction of belly.	Skin of chest and abdomen, in bands running around and downward, corresponding to spinal nerves.
First lumbar..........	Quadratus lumborum. Transversalis obliqui. Ilio-psoas. Sartorius.	Cremasteric, first to third lumbar. Stroking inner thigh causes retraction of scrotum.	Skin over groin and in front of scrotum.
Second lumbar.........	Ilio-psoas, sartorius. Flexors of knee (Remak). Quadriceps femoris.	Patella tendon. Striking tendon causes extension of leg.	Outer side of hip. Front of thigh.
Third lumbar.........	Quadriceps femoris. Inner rotators of thigh. Obturator. Adductors of thigh.	Bladder centre. Second to fourth lumbar.	Front of thigh. Inner side of leg.
Fourth lumbar	Abductors of thigh. Abductors of thigh. Flexors of knee (Ferrier).	Rectal centre. Fourth lumbar to second sacral. Gluteal. Fourth to fifth lumbar. Stroking buttock causes dimpling in fold of buttock.	Outer and back side of thigh and front of leg to ankle. Dorsum of foot.
Fifth lumbar......	Glutei. Biceps femoris. Semitendinosus. Popliteus. Outward rotators of thigh. Flexors of knee (Ferrier).	Achilles tendon. Over-extension causes rapid flexion of ankle, called ankle clonus. Babinski reflex. Scratching sole of foot causes extension of great toe. Fifth lumbar to first sacral.	Leg and foot, outer part.
First and second sacral...	Biceps femoris. Semimembranosus. Extensor longus digitorum. Gastric. Tibialis posticus. Tibialis anticus.	Plantar. Tickling sole of foot causes flexion of toes and retraction of leg.	Back of thigh and leg in saddle-shaped area. Inner side of foot.
Third sacral.......	Peronei. Intrinsic muscles of foot.	....	Back of buttock, seat.
Fourth and fifth sacral...	Sphincter ani et vesicæ. Perineal muscles.	....	Perineum, anus. Back of scrotum.

sage through the gray matter send off little fibrillary branches termed collaterals, which terminate in end-tassels about other cell bodies. Through this gray matter impulses pass in all directions, uniting the functions of the various cell groups, and of the sensory and motor areas of the cord. It is probable that impulses coming to the segment, either from the periphery or from the brain, are conveyed directly to the cells of the segment, and are distributed through the medium of the branches of the cells to several groups of cells.

Furthermore, each segment controls in some degree the processes of nutrition in the part of the body with which its sensory nerves are connected. It regulates the vasomotor tone in the organs and limbs, and it influences processes of growth and repair in the skin and mucous membranes. But the existence of trophic cells in the cord has not been proven. Nor can the automatic mechanisms of the cord be assigned to definite cells. They can only be referred to the gray matter of certain segments.

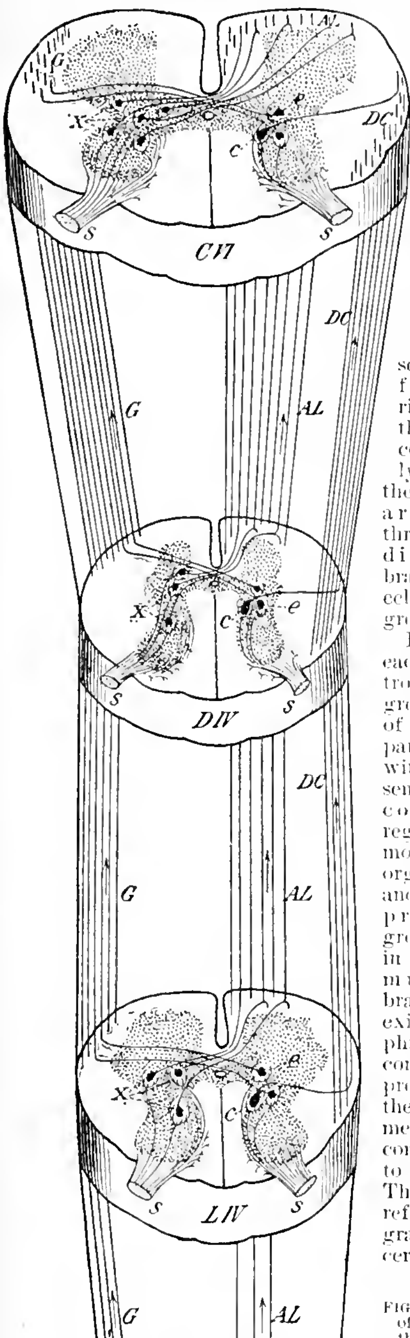


FIG. 4414. — Diagram of Four Segments of the Spinal Cord to Show Sensory Mechanism and Conduction. *S*, Sensory nerve root; *G*, column of Gowers; *AL*, antero-lateral column; *DC*, direct cerebellar column; *C*, cells of the column of Clarke sending fibres to *DC*; *X*, cells of the sensory gray matter sending fibres to *AL*; *e*, cells of the sensory gray matter sending fibres to *G*.

The function of the gray matter of the individual segments is shown in the preceding table. The facts upon which this table has been prepared are gathered from comparative anatomy, from physiological experiment, and from pathological observation. The level of the segment is given; the muscles governed by the groups of cells in it are mentioned so far as they are at present known; the reflex and automatic mechanisms governed by each segment are recorded, and the manner of producing the reflex acts; and the area of skin which sends its sensory nerves to the individual segments is described.

B. The White Tracts. — The gray matter of the spinal segment is surrounded by white nerve tracts, whose function is the transmission of impulses between adjacent and distant segments, and between the various segments and the brain. These tracts are quite numerous, and although in the normal adult cord they cannot be distinguished from one another, there are several means by which their lim-

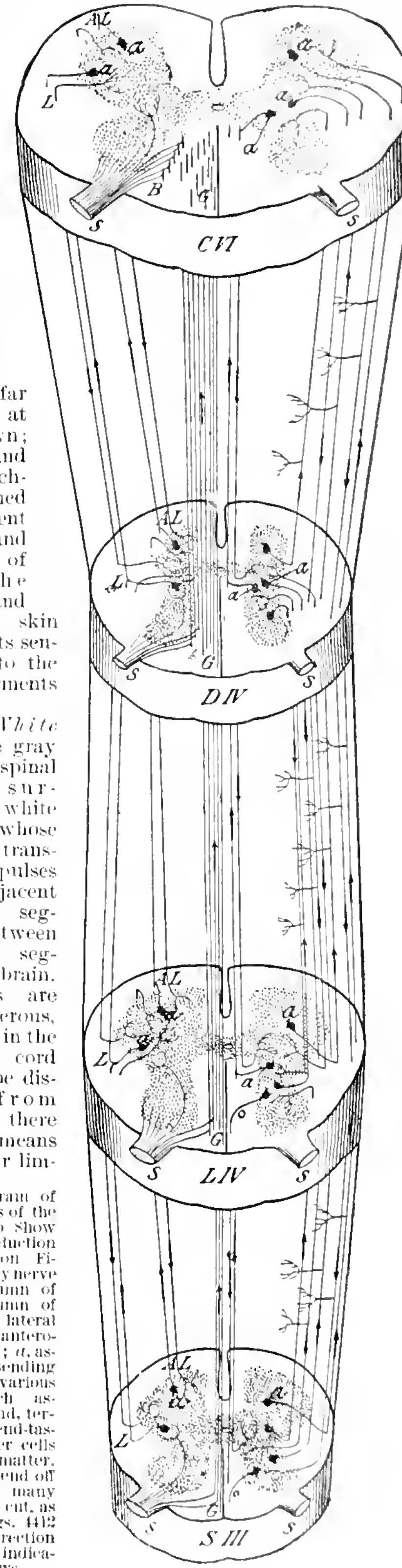


FIG. 4415. Diagram of Four Segments of the Spinal Cord to Show Sensory Conduction and Association Fibres. *S*, Sensory nerve root; *G*, column of Goll; *B*, column of Burdach; *L*, lateral column; *AL*, antero-lateral column; *a*, association cells sending axones into various columns which ascend or descend, terminating in end-tassels about other cells in the gray matter. These axones send off collaterals at many levels. In this cut, as well as in Figs. 4412 and 4414, the direction of impulses is indicated by the arrows.

its are determined. Thus in fœtal cords of various ages different tracts can be distinguished by the fact that they develop at different times. And in diseased cords pathological processes are often strictly confined to certain tracts. This is especially true of the processes known as secondary degenerations, by means of which the exact boundaries, the length, and the function of the various tracts have been ascertained. The older division of the columns of the cord into anterior, lateral, and posterior must be set aside in favor of the late divisions founded on these facts.

In a cross-section of the cord at the cervical region the following tracts are seen in each half of the segment:

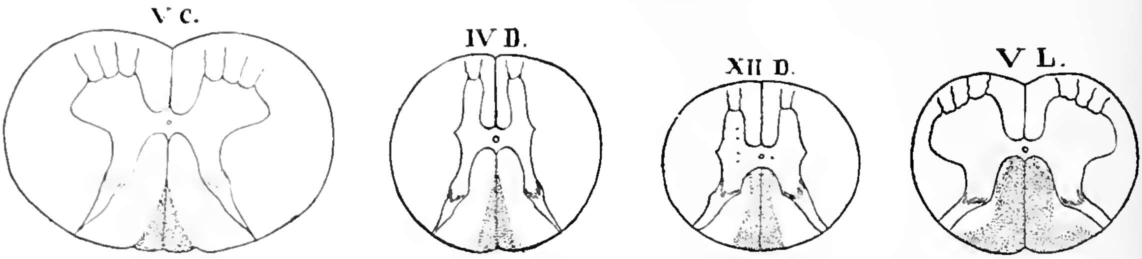
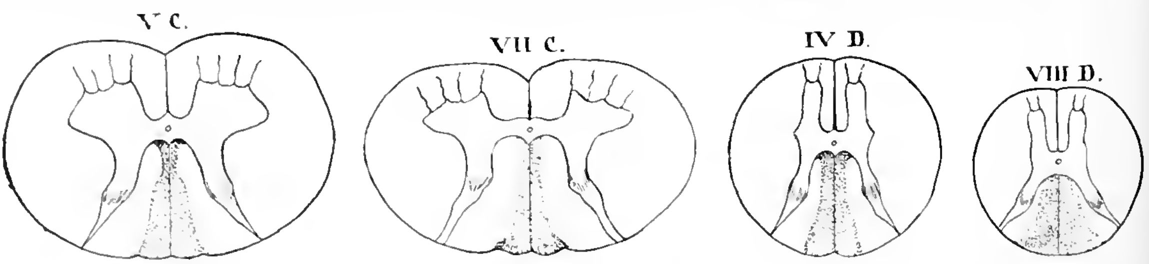


FIG. 4416.—Area of Ascending Degeneration in the Posterior Columns after Compression of Cauda Equina, Involving the Sciatic Nerve Roots only.

1. *The Motor Tracts* (Fig. 4412, *Py*, *AM*), two in number, which come through the anterior pyramids of the medulla, from the motor region of the cerebral cortex on either side of the fissure of Rolando. It will be remembered that the pyramids of the medulla decussate partially just at the upper limit of the spinal cord.[3] The majority of the fibres of each pyramid cross the median line to the lateral column of the spinal cord. The remainder pass directly onward into the anterior column. Those that cross over are called the crossed pyramidal tract. Those that do not cross are called the direct or anterior pyramidal tract, or column of Türck. The latter lies along the side of the anterior fissure of the cord, and is called the anterior median column (Fig. 4412, *AM*). The former lies in a triangular space in the posterior part of the lateral column, bounded by other tracts on all sides (Fig. 4412, *Py*). These motor tracts differ somewhat in size in different cords. When only a few fibres from the medulla cross over, the anterior median column is large and the opposite lateral pyramidal tract is small; but this is the exception. As a rule the lateral tract is three times the size of the anterior one. They differ also in length; for the anterior median column only extends to the upper sacral region, but the crossed pyramidal tract extends to the very lowest segment of the cord. They both send in their fibres to the anterior gray horns of the cord at all levels, and therefore decrease in size as they pass downward. They both transmit voluntary impulses from the brain to the anterior motor cells of the cord (Fig. 4412, *m*), a single nerve fibre in the motor tract carrying an impulse which reaches several groups of cells. They both degenerate downward after any lesion which cuts them off from their nutrient cells in the cerebral cortex. If that lesion is in the brain on one side, the anterior median column on that side, and the crossed pyramidal tract on the opposite side, will be degenerated in the cord. If the lesion is in the cord on one side, both motor tracts on that side will degenerate downward. If the lesion divides the entire cord, the degeneration will be bilateral in both columns. These motor tracts transmit not only voluntary impulses, but also inhibitory impulses, which hold in check the reflex activity of the spinal centres. Hence a lesion in their course produces not only paralysis, but also a loss of control over the bladder and rectum, and an increase in the spinal reflex activity.

2. *The Association Tracts* (Fig. 4415).—Each spinal segment has been shown to have functions of its own. But the different segments always act in harmony, and in hardly any act, either motor or sensory, is any segment independent of the rest. Hence a large part of the white matter of the cord contains fibres, shorter or longer, joining the various segments with one another, and associating their actions. The cell bodies which give origin to these fibres lie in the various parts of the gray matter, and send fibres both up and down in all the columns. These fibres give off collaterals in their course. The fibres lie about the anterior horns of the cord, on their different sides, making up together a large antero-lateral column which has been divided into an anterior column (Fig. 4415, *AL*), and a general lateral column, the latter having a portion between the crossed pyramidal tract and the outer surface of the gray matter which has been called the lateral limiting layer (Fig. 4415, *L*). Some association fibres also pass in the posterior columns adjacent to the posterior commissure. All these tracts are about the same size at all levels of the cord, thus differing from the motor tracts, which decrease in size from above downward, and from the sensory tracts, which increase in size from below



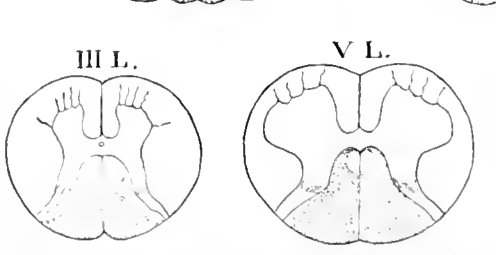


FIG. 4417. Area of Ascending Degeneration in the Posterior Columns after Compression of Cauda Equina, Involving all the Sacral and Lumbar Nerves.

upward. They degenerate but a short distance in any transverse lesion of the cord. They degenerate both upward and downward. It should not be forgotten that the anterior nerve roots pass out of the cord through the anterior column, and that many of these roots pass upward or downward for some distance before making their exit. Hence the antero-lateral column is not wholly made up of association tracts. There is no form of disease limited to the association tracts exclusively, hence it is impossible to bring any known symptoms into connection with the lesion when they are affected in a general myelitis.

3. *The Sensory Tracts.*—These occupy the posterior columns of the cord, of which there are two on each side of the posterior median septum, viz., the postero-external column, or column of Burdach, and the postero-median column, or column of Goll. They also pass in the lateral columns of the cord, in the antero-lateral ascending tract or column of Gowers, and in the direct cerebellar column. When all the nerve roots of the cauda equina, including both sacral and lumbar nerves, are compressed and destroyed, the ascending degeneration occupies a somewhat larger area than in the first case, involving both posterior columns as high as the middle of the dorsal region and a large part of the column of Goll in the cervical region (see Fig. 4417). When a transverse lesion of the cord in the dorsal region cuts off all sensory conduction from below the level of the mid-dorsal region, the area of ascending degeneration is still larger than in the first two cases, and in the cervical region involves the entire column of Goll (see Fig. 4418). When the cord is divided in the lower part of the cervical enlargement, the ascending degeneration involves a very large area, including both the entire column of Goll and a part of the column of Burdach in the upper cervical region (see Fig. 4419).

From these facts it becomes evident that the posterior nerve roots contain a number of fibres which, after entering the cord, turn upward and pass on to the medulla oblongata, each successive set from below upward lying a little in front of, and outside of, the preceding set, and gradually filling out the entire column of Goll and a portion of the column of Burdach. This is shown in Fig. 4415, *G*, *B*, at level *C VI.* In a cross-section in the upper cervical region it can, therefore, be affirmed that the fibres in the posterior median part of the column of Goll transmit sensory impulses from the legs; that the fibres in the median and lateral portion of the column of Goll transmit sensations from the thighs and pelvis; that the fibres in the anterior portion of the column of Goll transmit sensations from the body exclusive of the arms; and that the median part of the column of Burdach transmits sensations from the arms. Experimentation on animals has proven that the nerve fibres entering the cord in the posterior nerve roots, and passing upward in this manner to the medulla, degenerate upward upon the side on which they enter. There is no reason, therefore, to believe that in man there is any decussation, in the spinal cord, of the fibres thus far described. But since all sensations, except those of muscular sense, are known to cross over to, and ascend in, the opposite side of the cord in man, immediately after their entrance, it follows that the fibres thus far considered have for their function to transmit the sensations of muscular sense. And this

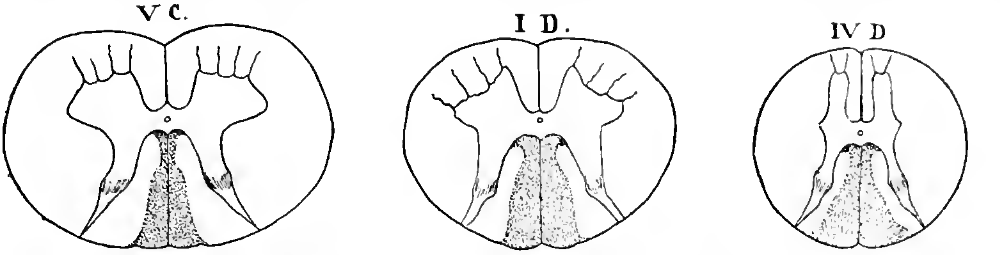


FIG. 4418.—Area of Ascending Degeneration in the Posterior Columns after a Transverse Lesion of the Mid-dorsal Region.

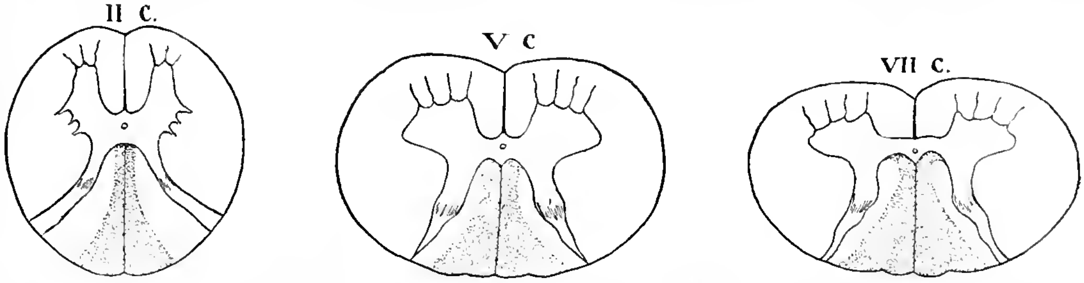


FIG. 4419.—Area of Ascending Degeneration in the Posterior Columns when the Lower Cervical Region of the Cord is Involved by a Transverse Lesion.

The column of Burdach is made up very largely of the posterior nerve roots which enter it and pass upward or downward for some distance before leaving it, to end in the posterior gray horn, or to enter the column of Goll (Fig. 4415, *B*). The column of Goll is made up wholly of long fibres extending from the posterior nerve roots to the medulla (Fig. 4415, *G*). The exact areas taken up respectively by the short posterior roots and the long fibres differ greatly at different levels, and they have only recently been determined by a study of the tracts degenerated after transverse lesions at different levels. These recent investigations deserve a moment's notice.

If the posterior nerve roots are divided between the posterior spinal ganglia and their entrance into the cord, an ascending degeneration occurs in the cord. It is by observing the course of this ascending degeneration that the upward continuation of the sensory nerves has been determined.[4] The area of the posterior columns of the cord which degenerates upward differs in different cases. When the sciatic nerve roots alone are divided, or the sacral portion of the spinal cord is destroyed, the ascending degeneration occupies a large area of the posterior columns in the lumbar region, a smaller area in the dorsal region lying wholly in the column of Goll, and the posterior median portion only of the column of Goll in the upper dorsal and cervical regions (see Fig. 4416).

conclusion is further established from the facts gathered from the pathology of locomotor ataxia. For in this disease, in which the muscular sense is the one most seriously impaired, the same areas of degeneration are found. There is, first, the sclerosis in the root zone of the column of Burdach, involving the nerve roots in it, and secondly, the secondary degeneration in the column of Goll, whose extent is determined by the extent of the primary lesion. The higher the primary lesion advances, the greater the area of the column of Goll involved. Since cases have been observed in which the sensations of touch, of pain, and of temperature, and of the muscular sense, have been affected singly, it follows that the tracts conveying these sensations must be separate from one another. The fibres so far described terminate in the nuclei of Goll and Burdach. But from these nuclei the fibres of the interolivary tract and lemniscus arise, fibres which are known to decussate in the sensory decussation of the medulla, and are known to transmit sensations of muscular sense exclusively. Hence the conclusion seems warranted that the sensory tract for muscular sense lies in the column of Goll for all parts below the arms, and in the median part of the column of Burdach for the arms.

With regard to the sensory tracts for touch, pain, and temperature, our knowledge is much more indefinite. These sensations enter the cord by the posterior nerve roots. But these roots do not send all of their fibres upward in the path already described. And if the area of the cord occupied by the column of Goll in the cervical region be compared with the entire area of the posterior nerve roots, it will be seen that a mere fraction of the fibres entering the cord by these roots ascends to the medulla. The large remainder terminate in the cord. Anatomists describe various manners of termination. Some fibres end directly in the posterior gray horn; others pass through it to reach the anterior gray horn; others, still, cross over through the posterior gray decussation to the other side of the cord. Many fibres enter the column of Burdach and pass directly through it to enter the gray matter in the vicinity of the vesicular column of Clarke; others ascend some distance in the column of Burdach before they enter the gray matter, and a few turn downward in the column of Burdach before ending in the gray matter. The fibres turning downward are collected into a small bundle, named the comma-shaped bundle of Schultze, from the shape of its area in cross section. From the fact that general myelitis involving the posterior gray matter is always attended by sensory symptoms, it is concluded that many sensations are sent to the cells of the posterior horns. From the cells in the posterior gray matter some nerve fibres pass backward into the columns of Goll and Burdach, and mingle with the fibres of those columns, presumably ascending with them to the medulla. It is not improbable that these fibres transmit sensations of touch. Even in the most extreme cases of secondary ascending degeneration in the posterior columns, after division of the nerve roots, many fibres in those columns escape. It is therefore certain that some of the fibres making them up have their origin and nutrient cells in the gray matter of the posterior horns, rather than in the posterior spinal ganglia. Hence the facts do not exclude the possibility of the transmission upward of sensations of touch in the posterior columns of the cord after such sensations have crossed the median line in the gray matter. And that they are transmitted in this region the older physiological experiments established. Other physiological experiments point to a transmission of sensations of touch in the lateral columns of the cord. And Gowers has established the existence of a tract in the periphery of the antero-lateral column, lying anterior to the direct cerebellar tract, which degenerates upward after transverse lesions. This is called the antero-lateral ascending tract. Its fibres arise from cells in the gray matter (Fig. 4414, *c*), cross to the other side, passing through the antero-lateral column, and turn upward in this column. This column ascends through the antero-lateral part of the medulla and pons. Some of its fibres have been traced into the lemniscus and some into the cerebellum. There are other fibres which arise from cells in the posterior gray matter of the cord, and crossing to the opposite side, ascend in the antero-lateral column (Fig. 4414, *X*, *AL*) of the cord.

The sensations of temperature and pain are uniformly preserved or lost together, hence it is concluded that they pass in the same tract. No definite position can be assigned as yet to that tract. In syringomyelitis, in which the lesion is limited to the central gray matter of the spinal cord between the anterior and posterior horns, a loss of temperature and pain sensations in all parts below the level of the lesion has been observed, and it has been concluded that these sensations are transmitted by the gray matter. Gowers believes that they pass in his antero-lateral tract, but the conclusion rests upon too small a number of observations to be hastily adopted. It seems to be likely that the transmission of sensations through the cord is not merely attained by these long tracts, but that they pass chiefly through a series of the association tracts already described, which are scattered through all the columns. A given sensation sets up many reflex and vaso-motor impulses in the cord in addition to being sent to the brain to awaken a perception. Hence it is likely to pass by a broken rather than a continuous tract. But the exact course of sensory impulses is not yet determined with accuracy.

4. *The Direct Cerebellar Column.*—The last column of the cord to be described is one lying upon the outer surface of the lateral column, and extending from the lower dorsal region to the corpus restiforme of the medulla, and thence to the cerebellum. Its termination in that organ has led to its name—the direct cerebellar tract. It is made up of fibres whose origin is in that column of cells which lies in the median part of the posterior horn known as the vesicular column of Clarke (Fig. 4414, *c*, *DC*). The cells are only found in the dorsal region, hence all the fibres in this tract come from the dorsal segments of the cord. They reach the lateral periphery of the cord by passing diagonally through the lateral column. They are supposed to transmit sensations upward from the Clarke column of cells to the cerebellum, because they degenerate upward after a transverse lesion of the cord. The function of both the cells and the tract is uncertain. From recent investigations by Gaskell, however, it seems probable that the vesicular column of Clarke is connected with the vaso-motor and sympathetic nervous systems by means of very small nerve fibres extending from the sympathetic ganglia into the cord. If this is so, the function of the direct cerebellar tract is to transmit those rather indefinite sensations from the viscera, or to act as a tract for unconscious sensations or motor impulses necessary in a central regulation of visceral and vascular action. The hypothesis that they convey muscular-sense sensations from the trunk is hardly warranted, since these must be of little importance in lower animals, who do not walk erect—in which animals, however, this column is well developed.

II. Symptoms Leading to the Diagnosis of Local Lesions in the Spinal Cord.—Such being the functions of the various parts of the spinal cord, it remains to discuss the symptoms arising when various parts are diseased. And it will be as well to approach this subject from the side of the symptoms rather than from that of the lesion, since it is the object to determine the lesion in any case.

1. *Spinal Paralysis.*—The motor tract conveying voluntary impulses from the brain to the muscles consists of two elements: first, the cerebro-spinal element, and, secondly, the spino-muscular element. Each element consists of a set of nerve cells and their outgoing fibres, which not only transmit impulses from the cells, but are nourished by them. The cells of the cerebro-spinal element lie in the cerebral cortex. Their fibres make up the motor tract through the brain and through the direct and crossed pyramidal tracts of the spinal cord.[5] These fibres terminate about the motor cells of the anterior horns of the cord at various levels, some of them reach-

ing its very lowest part. Any lesion in the cells of the cortex, or in the course of the fibres, which cuts them off from those cells, results in the degeneration downward of the cerebro-spinal element to its termination in the motor cells of the spinal cord. The *first form of spinal paralysis* is due to a lesion at the spinal part of this cerebro-spinal element of the motor tract. If the cord is divided by a transverse lesion at any point, the function of this element of the motor tract is thereby suspended. As a result, voluntary motion is arrested in the parts below the lesion. If the lesion involves but one-half of the cord, it is the limbs on the side of the lesion which are paralyzed. If it involves the entire cord, both sides are paralyzed. The extent of the paralysis depends upon the level of the lesion; the higher the lesion the more extensive the paralysis. The degree of the paralysis will depend on the character of the lesion, slight compression of the cord at one point by a tumor, or a pachymeningitis, or a projecting vertebra, being followed by some stiffness of movement and rigidity of the muscles, with weakness, rather than by absolute loss of power in the parts below the level of the pressure. The cerebro-spinal element of the motor tract also transmits the inhibitory impulses which continually keep the spinal reflex and automatic mechanisms in check. A lesion of this tract, therefore, produces not only weakness and paralysis, but also increase of the deep reflexes, and impairment of control over the bladder and rectum. The muscular action of the limbs, being no longer controlled by the brain, is governed wholly by the centres in the spinal cord. These act in response to sensory impulses, or spontaneously, without check, and hence the preponderating strength of flexor over extensor muscles tends to produce a position of adduction and flexion of the limbs which are paralyzed, and a heightened muscular tone, with tendency to rigidity. The nutrition of the paralyzed muscles may suffer somewhat from disuse, and from the attendant vaso-motor paresis, but no rapid atrophy is noted when the cerebro-spinal element of the motor tract is alone involved. And it is also to be noted that the paralysis affects the entire limb or limbs, and not any special group of muscles. In these cases the electric contractility remains normal in the paralyzed limbs.

A typical example of this form of spinal paralysis is seen in compression of the spinal cord, below the lesion, and in lateral sclerosis or spastic paraplegia (*q.v.*).

The *second form of spinal paralysis* is due to a lesion in the spinal part of the second element of the motor tract, viz., the spino-muscular element. This consists of the cells of the anterior gray horns of the cord, and the anterior nerve roots which pass out through the anterior columns of the cord. Destruction of the cells suspends both voluntary and reflex motor impulses to the muscles. The cells not only control the motion, but also the nutrition, of the nerves to which they give origin, and of the muscles to which these nerves go. Therefore destruction of the cells produces atrophy of the muscles with which they are connected. If the destruction is gradual, the atrophy is gradual, as in progressive muscular atrophy. If the destruction is rapid, the atrophy is rapid, as in infantile paralysis. The degree of the atrophy depends upon the degree of destruction of the group of cells which govern the particular muscle affected. If the group is wholly destroyed, the muscle becomes totally atrophied. In addition to paralysis with atrophy there is in the second form of spinal paralysis a change in the electric reaction of the paralyzed muscles. They lose their contractility to the faradic current, and alter their contractility to the galvanic current, responding in a sluggish manner, and to the positive more readily than to the negative pole. This is called the reaction of degeneration (*q.v.*).

The extent of the paralysis depends upon the extent of gray matter affected, and a reference to the table of the localization of functions already given (page 340) will enable one to determine the effect of a lesion at any particular segment, or through a group of segments, of the spinal cord. A typical example of the second form of spinal paralysis is found in infantile paralysis or poliomyelitis anterior. The muscles in this disease are paralyzed, atrophied, exhibit the reaction of degeneration, and lose their reflex excitability. An entire limb is rarely affected, certain groups of muscles being usually paralyzed together, *e.g.*, the deltoid, biceps, brachialis anticus, and supinator longus (upper arm group); or the extensors of the wrist and hand muscles (lower arm group); or the glutei and thigh muscles (thigh group); or the anterior tibial and peroneal groups of the leg (leg group). The muscles affected are not those which are supplied by a single peripheral nerve—a fact which enables a diagnosis between a lesion in the spinal cord and a lesion in a peripheral nerve to be easily made—but those which act together to produce a definite physiological act.

The contrast between these two forms of spinal paralysis can be seen at a glance in the following table:

First Type of Spinal Paralysis.	Second Type of Spinal Paralysis.
Lesion in pyramidal tracts.	Lesion in anterior gray horns.
Paralysis usually on both sides equally, in legs or in legs and arms, never in arms alone.	*Paralysis* may be limited to any single limb, and rarely affects both limbs equally.
All muscles are about equally affected. No muscles are entirely normal.	Certain groups of muscles only are affected. Others escape wholly.
Muscular tone is heightened.	Muscular tone is diminished.
Tendency to rigidity appears.	Muscles are relaxed.
Reflex excitability is increased.	Reflex excitability is lost.
Atrophy is absent or is slight, and merely due to disuse, hence is gradual in progress. It affects the entire limb.	*Atrophy* is always present in the paralyzed muscles. It advances rapidly, and may become extreme.
Electric contractility is unchanged.	*Electric contractility* is changed. Reaction of degeneration is present within two weeks of the onset.
Vascular tone is diminished; cyanosis and œdema may occur.	*Vascular tone* is diminished, but œdema does not occur.
Paralyzed limb is cold, and sweat may be increased.	Paralyzed limb is cool, but sweat is not increased.
Trophic disturbances in the skin are not infrequent.	*Trophic disturbances* in the skin do not occur.
The control over the bladder and rectum may be diminished or lost.	The control over the bladder and rectum is not impaired.
Example: Spastic paraplegia.	Example: Infantile paralysis.

The *third type of spinal paralysis* is a combination of the first and second types. When a transverse lesion of the spinal cord entirely destroys a single segment, it produces paralysis of the first type in the parts below the level of the lesion by cutting off the tracts to those parts, and paralysis of the second type at the level of the lesion by destroying the gray motor cells at that level. The general effect of such a lesion depends entirely upon the level at which it occurs; the higher the lesion, the greater the extent of the first type of paralysis. The distribution of the second type will depend on the level of the segment involved. The greater the extent of the lesion at the level affected, the greater the extent of the second type of paralysis. An example of this is also found in amyotrophic lateral sclerosis. When a longitudinal lesion of great extent occurs—such as the general destruction of the cord in general myelitis—the second type of paralysis is the form which is found, but all the muscles are affected, not merely a few groups. The bladder and rectum are also affected, and bedsores are frequent.

In any case of spinal paralysis, if the electric condition of the muscles paralyzed be ascertained by the aid of a faradic battery, and the diagnostic points here brought together be applied, reference to the table of the localization of functions will enable the exact level of the lesion to be determined.

Spinal Anæsthesia.—The course of the sensory tract in the spinal cord is still somewhat imperfectly understood. It is known that all sensory impulses reach the spinal cord through the posterior nerve roots, which partly enter the apex of the posterior horn, and partly enter the column of Burdach, and pass upward as already described. The sensations of muscular sense ascend on the same side as that on which they enter. Those of touch, temperature, and pain cross over, as soon as they

EXPLANATION OF PLATE LII.

The segments of the spinal cord are numbered: C_{I} to C_{VII}, D_{I} to D_{XII}, L_{I} to L_{V}, S_{I} to S_{V}; and these numbers are placed, in the plate, on the region of the skin supplied by the sensory nerves of the corresponding segment. In order to determine, in any given case of spinal-cord disease, the level of the cord affected, it is necessary to test the sensations and to compare the area of anæsthesia with the diagram here given. It is to be remembered, however, that the skin of the body is plentifully supplied with sensory nerves which anastomose freely at their terminations, and the researches of Sherrington have demonstrated that each part of the skin is supplied with sensory nerves from two adjacent segments of the cord. Hence a condition of anæsthesia in the skin indicates a suspension of function of two segments of the cord at least, for if one segment alone were affected the segments above and below it would be capable of supplying the skin with sensation.

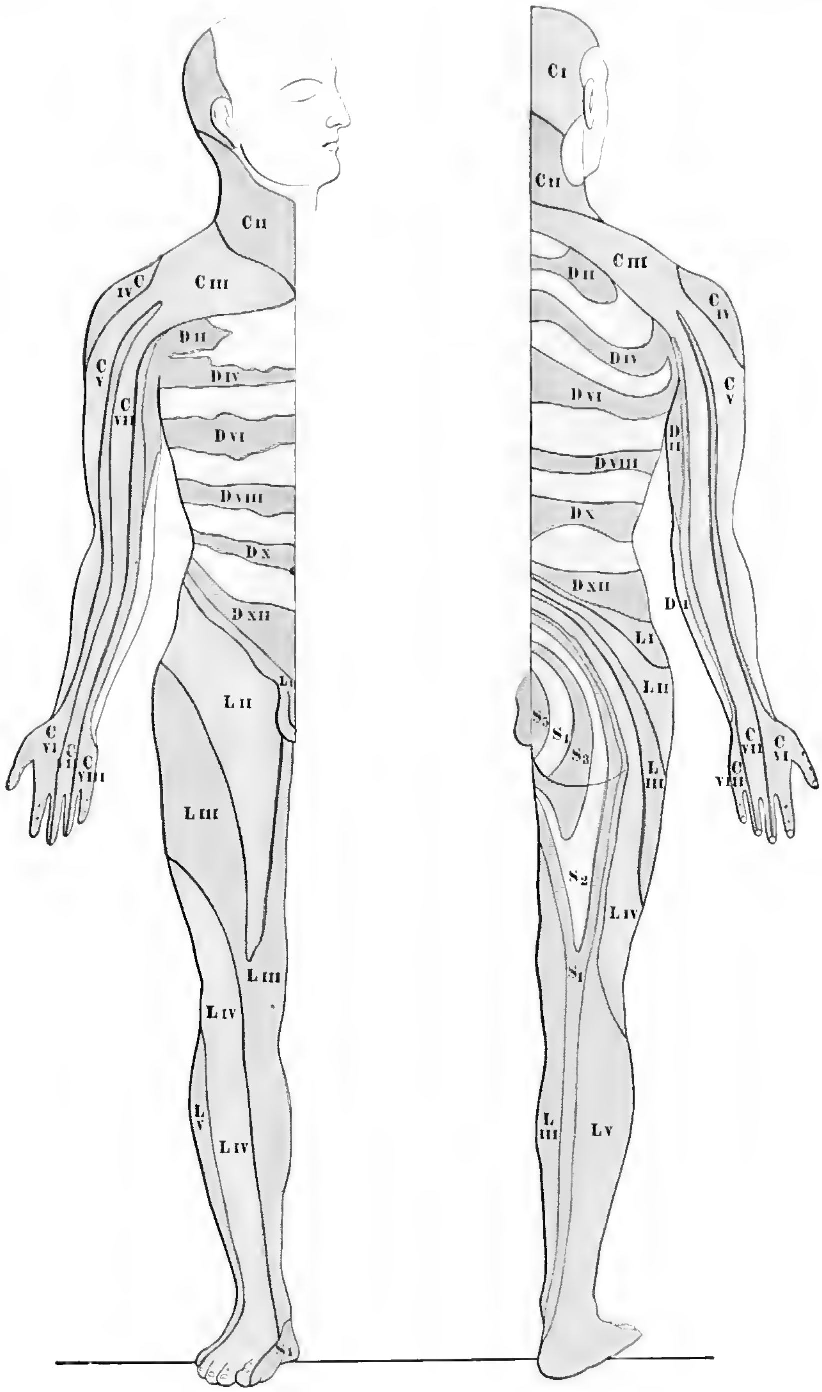


PLATE SHOWING THE AREAS OF THE SURFACE OF THE BODY WHICH ARE RELATED TO THE VARIOUS SEGMENTS OF THE SPINAL CORD

c, cervical: *d*, dorsal: *l*, lumbar: *s*, sacral. When a segment of the cord is destroyed the surface of the body is anæsthetic in the area corresponding to that segment.

(From Dr. M. Allen Starr)

any one of these acts are similar to those underlying the simple spinal reflex, and the same lesions arresting it may arrest these acts. But the result of such arrest is more serious, for, in the case of the bladder or rectum, retention or passive incontinence of urine or fæces may follow. And if the inhibitory impulses from the brain to these centres are cut off, the voluntary control over these mechanisms is impaired, and the acts cannot be initiated voluntarily, and active incontinence may result. The location of the bladder and rectal mechanism is in the lower sacral region. Hence, when this part is the seat of a lesion, or is cut off from the brain by a lesion at a higher level in the motor tract, incontinence, either active or passive, or retention, may result.

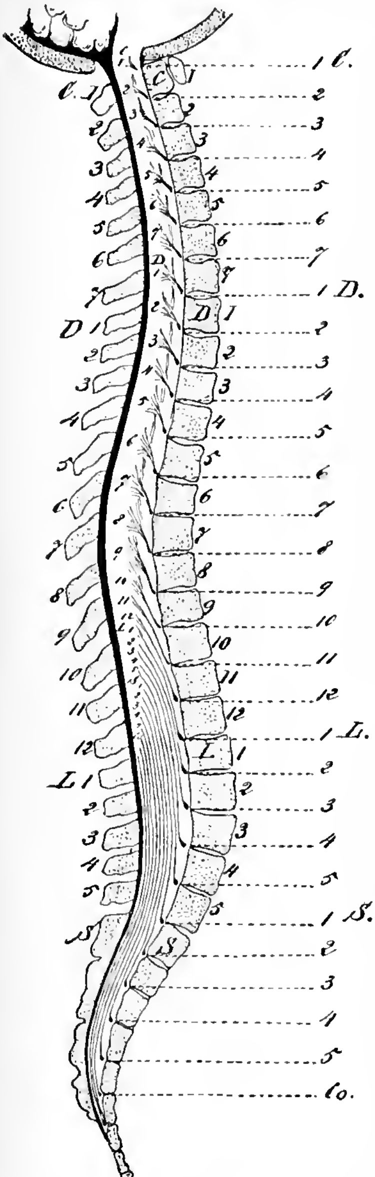


FIG. 4420.—Relations between the Segments of the Spinal Cord and their Nerves and the Bodies of the Vertebræ. (Gowers.)

A part of the automatic mechanism of respiration is governed by the cervical and dorsal regions of the cord, and is interfered with in disease in those regions. Lesions of the upper cervical region paralyze the diaphragm and thus cause death.

DISTURBANCE OF VASO-MOTOR AND TROPHIC FUNCTIONS of the cord may occur from various forms of lesion. Anterior poliomyelitis produces atrophy of the muscles paralyzed, and a sufficient affection of the vaso-motor system to cause objective, as well as subjective, coldness in the limb; and when the lesion lies deep in the anterior horn, an arrest of development of the bones of the limb affected. General myelitis is usually associated with a tendency to bedsores upon the parts exposed to pressure, which cannot be avoided by the most scrupulous cleanliness, and to cystitis, and these are ascribed to a disturbance of trophic impulses to the skin and bladder. Posterior sclerosis is sometimes associated with trophic changes, such as perforating ulcers, joint affections (Charcot's arthropathies), and eruptions on the skin. In a few cases of leprosy serious lesions of the posterior gray horns have been observed. In general myelitis there is a partial vaso-motor paralysis, indicated by cyanosis, sluggish circulation, œdema, and coldness, with abnormal sweating in the paralyzed parts. But any definite statement regarding the exact localization of vaso motor or trophic functions in the spinal cord cannot be made as yet. And recently many vaso-motor and trophic symptoms, formerly supposed to be due to spinal lesions, have been found to be produced by disease in the peripheral nerves. It is, however, established that trophic lesions are most frequently observed when the gray matter of the spinal cord in the vicinity of the central canal, including the vesicular column of Clarke, is the part diseased; or when all sensation is cut off from the paralyzed limbs by a transverse lesion.

The regulation of urinary excretion is presided over by a centre in the medulla, and the nerve tract thence to the liver and kidneys is traced through the cervical region of the spinal cord to the first dorsal segment, where it enters the sympathetic chain of ganglia. A lesion in the lateral column of the cervical cord, by involving this tract, may cause a vaso-motor paralysis of either the liver or the kidneys. In the former case diabetes mellitus is produced; in the latter, diabetes insipidus results. It is therefore necessary, in lesions of the spinal cord, to examine the amount and constituents of the urine.

In any case of spinal disease in which it is desirable to localize accurately the lesion, it is suggested that a written summary of the symptoms be compared with the table of localization of the functions of the cord, when it will become evident, by contrasting the normal with the abnormal conditions, what part of the cord is affected. As Bramwell justly observes, "the essence of the clinical examination of the spinal cord consists in the systematic and separate examination of each spinal segment, by observing the motor, sensory, reflex, vaso-motor, and trophic conditions of its body area." Such an examination will lead to accurate diagnosis of local lesions.

But one point remains to be mentioned, that is, the relation of the various segments of the cord to the bodies and spines of the various vertebræ. As the cord extends only to the level of the second lumbar vertebra, its various segments do not lie opposite to the vertebræ from which they are named. The accompanying diagram of Gowers (Fig. 4420) displays the mutual relation between the segments and their nerves, and the bodies of the vertebræ, and no further description is needed.

M. Allen Starr.

REFERENCES.

[1] For a full account of the grouping of these cells, see Localization of the Functions of the Spinal Cord, by M. A. Starr, American Journal of Neurology and Psychiatry, vol. iii., pp. 443 *et seq.*—Ross: Diseases of the Nervous System, p. 829.
[2] Gaskell: Journal of Physiology, 1886.
[3] See article on *Brain, Diagnosis of Local Lesions in the.*—The Motor Tract, in Vol. II. of this HANDBOOK.
[4] Schultze, F.: Ueber Secondäre Degeneration im Rückenmarke. Arch. f. Psych., xiv., from which article the figures are taken.
[5] For the anatomy of this motor tract, see the article referred to above, in Vol. II. of this HANDBOOK.

AUTHORITIES.

Gowers: Diseases of the Spinal Cord.
Lüderitz; Ueber das Rückenmark-Segment. Arch. f. Anat. u. Phys., 1881.
Ferrier: Brain, vol. iv., p. 223.
Beevor: Med. Chirurg. Transactions, vol. lxxviii.
Starr: Localization of the Functions of the Spinal Cord. Amer. Jour. Neurol. and Psych., August and November, 1884.—Localization of Lesions in the Lumbar Cord. Amer. Jour. Med. Sci., 1893. Localization of Lesions in the Cervical Cord. Brain, 1895.
Thorburn: A Contribution to the Surgery of the Spinal Cord, 1893.
T. Kocher: Die Verletzungen der Wirbelsäule, Jena, 1896.
H. Schlesinger: Beiträge zur Klinik der Rückenmarks- und Wirbeltumoren, Jena, 1898.
R. Wichmann: Die Rückenmarksnerven und ihre Segment-Bezüge, Berlin, 1900.

SPINAL-CORD DISEASES: FRIEDREICH'S (HEREDITARY) ATAXIA.—The condition known as Friedreich's or hereditary ataxia was first described by Friedreich in 1861, and a detailed account published by him in 1863, with three autopsies. In 1876 he published a further paper on the subject, with a description of three new cases. From this time on, through the investigations of Schultze, Rütimeyer, Dejerine and others, the affection came to be clearly recognized as an hereditary disease of childhood, affecting chiefly the spinal cord, and characterized by a type of ataxia hitherto undescribed. W. Everett Smith in 1885 published an important paper on the subject of "hereditary or degenerative ataxia," in which he described six cases in one family, with an autopsy. He was able at that time to collect fifty-seven cases from the literature. In 1890 Ladame made a critical digest of the subject, published in translation in *Brain*, in which he summarized the knowledge up to that year, and gave full bibliographical references. Nine autopsies only had been recorded, and five of these were in Friedreich's own cases. Oscar Richardson has recently described the post-mortem findings in a second case from the family reported in 1885 by W. Everett Smith.

Pathological Anatomy.—The spinal cord has usually been found small and somewhat imperfectly developed, which is in accordance with the apparently hereditary

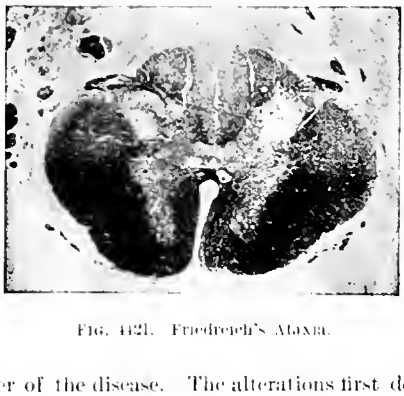


Fig. 4421. Friedreich's Ataxia.

character of the disease. The alterations first described by Friedreich consisted in a degeneration of the dorsal tracts, atrophy of dorsal roots, and certain changes, slight in degree, in several peripheral nerves. Later study has shown that wider areas of the white matter are involved than was at first supposed, and that the gray matter also takes part in the degenerative process, though to a much less marked degree. Degeneration of the dorsal tracts to a very considerable extent is constant, with a probable constant accompaniment of degeneration of dorsal nerve roots, giving an appearance wholly analogous to tabes, and leading to the assumption that the primary sensory neurone, as such, is involved. The direct cerebellar tract is degenerated; Gowers' tract and Lissauer's bundle may be. Various observations have been made regarding the motor pyramidal tracts, and it is still in dispute whether they are in themselves involved as neurone systems in the same way that the dorsal tracts are. Degeneration in the region of the pyramidal tracts decreases from below upward, and disappears (Leyden-Goldscheider) at the lower level of the oblongata. In Richardson's case, the pathological anatomy of which he has described and which he has given me the opportunity of studying, the following lesions of the white matter were definite: degeneration of dorsal columns throughout the cord, and of dorsal nerve roots in the lumbar region; degeneration of pyramidal tracts, of somewhat lessening intensity toward the upper portions of the cord, including the uncrossed tracts in the cervical region; degeneration of direct cerebellar tracts, and in less degree of the region of Gowers' antero lateral ascending tracts (see Fig. 4421).

In the gray matter the cells of Clarke's columns have, in certain cases, shown degenerative changes, along with the myelinated fibres of that nucleus. Alterations in other portions of the gray matter of the cord have been described, but are of somewhat doubtful character. Very few observations on the peripheral nerves have been made, but certain degenerations have been described which would be in accord with the theory of a neurone degeneration. The type of lesion in the cord is similar to that found in other sclerotic processes, an overgrowth of neuroglia following a greater or less degree of destruction of myelinated fibres. The theory of a primary overgrowth of neuroglia has not been generally accepted. Alterations in the blood-vessels in degenerated areas occur, and also have been described in the pia and nerve roots, but no characteristic significance is to be attached to the changes found.

The cause of the foregoing anatomical alterations has, in general, been sought in a defect of development, of hereditary character, leading to early degenerative changes in the spinal cord. The distribution of these changes in the relatively few cases examined post mortem has led certain observers to the assumption of a combined systemic disease, which gains weight from the fact that the disease occurs as a family affection, and does not apparently depend upon faulty blood states or vascular conditions within the cord itself. Certain cases, however, do not show a sharply systematized degeneration, although the lesions are always of a quasi-systemic character. The study of Richardson's case, to which I have already alluded, leads to the conclusion that neurones, as systems, are involved, though it cannot be said with certainty that groups of neurones, of which our knowledge is as yet deficient, may not also be degenerated. In support of this assumption is the distinct degeneration of dorsal nerve roots and of direct pyramidal tracts, as well as the characteristic degenerations of the recognized neurone systems. The most satisfactory conception of the disease, therefore, is that in congenitally defective nervous systems early degenerations of a systemic or quasi-systemic character take place, chiefly limited to the spinal cord, which progress exceedingly slowly, ultimately leading to characteristic motor and sensory disorders.

Symptomatology.—The most conspicuous feature of the disease is a characteristic inco-ordination, which is best described as a combination of a tabetic and a cerebellar ataxia. The gait is uncertain, slow, highly inco-ordinate, and accompanied by a considerable degree of swaying from side to side. Static ataxia is well marked in the extremities and head after the disease has progressed beyond its initial stages. The Romberg sign (swaying with the eyes closed) is much less constant than in tabes, but has been described in certain cases. A further characteristic motor disturbance is peculiar involuntary, chorea-like movements involving the head, which persist during rest, but are increased on intended movement. At times a definite, so-called intention tremor may develop. True paralyses do not occur in the long course of the disease, except in the late, more or less helpless stage, when weakness of muscle groups may develop, and finally paraplegia with contractures, which renders locomotion impossible. Another very constant motor disorder, but not one of the earliest signs, is nystagmus, which is usually not present when the eyes are at rest, but may be elicited by fixation, particularly in a lateral direction. This sign should, however, be interpreted with caution. Disturbance of speech is a further important sign; it is slow, difficult, irregular in utterance, and hard to understand. The tongue is tremulous and is the seat of twitching movements, suggesting, in conjunction with the speech disorder, disturbances of co-ordination similar to those observed in the extremities and possibly bearing some analogy to multiple sclerosis.

For reasons not easy of explanation the sensory sphere suffers in very slight degree, in marked contrast to tabes. With but few trifling exceptions muscle sense and skin sensibility, as well as the special senses, have been found unimpaired. The occasional occurrence of sharp pains and abnormal subjective disorders of sensibility in the extremities are of interest only because of their rarity. In view of the constant extensive degeneration of sensory areas in the cord, and the high degree of inco-ordination early developed in the disease, this lack of objectively demonstrable sensory disorders must be regarded as one of the striking peculiarities of the disease. An appeal to vicarious or certainly added function in neurones remaining intact in an affection of very gradual progression, may be suggested by way of explanation.

The superficial skin reflexes, the pupil, bladder, and rectal reflexes show essentially no alteration, whereas the loss of knee-jerk is constant in all well-developed cases. Trophic and general vaso-motor disturbances have seldom been observed, and the sexual function remains unimpaired. A frequent occurrence, which has not received as yet a satisfactory explanation, is a deformity of the foot of the nature of a talipes equinus, or equino-varus, often with an elevated arch, shortening of the foot as a whole, development of so-called claw-foot, with particularly strong dorsal flexion of the great toe. Scoliosis is also an occasional accompaniment. Cerebral symptoms do not occur, except vertigo, and in the later stages of the disease a general impairment of the mental faculties.

Diagnosis, Prognosis, and Course.—The symptoms,—early ataxia, loss of knee-jerk, choreic movements, clubfoot, disorders of speech, nystagmus, with progressive helplessness, beginning before the sixteenth year—point unmistakably to Friedreich's ataxia. With the possible exception of so-called cerebellar ataxia, tabes, and multiple sclerosis, the differential diagnosis from other organic cord affections should present no difficulties. The grouping of symptoms given above is usually well marked and is unique.

The course of the disease is steadily progressive, beginning in childhood and lasting for from twenty to forty years or even longer, death ultimately being due, in many cases, to intercurrent disease, or to cystitis or decubitus, induced by the cord changes.

Etiology.—The actual cause of the disease remains obscure. The facts that it occurs in children before or at the age of puberty, that cases have frequently been observed in the same family, though by no means constantly, that the cord, post mortem, gives indications of faulty development, have led to the suggestion that it is due to hereditary influences. Further than this nothing of value has been found. An appeal to syphilis, alcohol, or various neuroses or psychoses in ancestors does little to elucidate the matter. Nor is it profitable in a disease of this character to lay stress upon possible exciting causes. As in all disease, there is a predisposition, which is rather the statement of a self-evident fact than an explanation, so long as we remain in complete ignorance of what constitutes predisposition. The fact of importance is that in certain families the affection has appeared in several members. As given by Gowers, sixty-five cases were distributed in nineteen families, and ten occurred in one family. Sporadic cases are probably more frequent than is ordinarily supposed. It has been a frequent observation that many cases occur in one generation in families in which the parents or ancestors were not victims of the disease—so-called indirect inheritance. The affection is, therefore, to be regarded as one of the group of "family diseases."

Treatment.—In the present state of our knowledge, treatment must remain essentially unavailing, except as directed toward the amelioration of symptoms. Systematic exercises (Frenkel), avoidance of overexertion, careful attention to general hygiene, good food, and fresh air, with such drugs as are symptomatically required, must constitute our main reliance. *E. W. Taylor.*

Partial Bibliography.

Friedreich: Virchow's Archiv, 1863, xxvi., xxvii., p. 391.—*Idem*, 1876, lxviii., p. 145, 1877, lxx., p. 140.
Smith: Bost. Med. and Surg. Journ., 1885, cxiii., p. 361.
Ladame: Brain, 1890, xiii., p. 467. Critical Review with bibliography up to that time.
Richardson: Journ. Bost. Soc. Med. Sci., 1898, iii., p. 25.
Vincelet: Monograph, Carré et Naud, Paris, 1900.
Schoenborn: Neurolog. Centbl., 1901, xx., p. 10.
Barker: Transactions Ass'n of American Physicians, 1903.

SPINAL-CORD DISEASES: HEMORRHAGE IN THE CORD.—(Synonyms: Hæmatomyelia; spinal apoplexy.) Hemorrhage in the spinal cord is very rare in comparison with hemorrhage in the brain. When it occurs it is usually of small extent. This is not extraordinary when the size of the organ and the firmness of its connective tissue sheath, and the low pressure in the spinal arteries, are considered. As a rule, the clot in the spinal cord is long and narrow. It destroys a considerable part of the cord at one segment, and extends into the segments above and below, injuring these to a less extent. The clot is usually found in the gray matter of the cord, most frequently in the anterior horns, then in the posterior horns, and rarely in the white columns. Sometimes the surface of the cord is broken and the blood infiltrates the pia mater. Occasionally a large number of small clots are found at different levels. As the patient rarely dies at once of hemorrhage the clot is usually found in a state of decomposition, and the cord around it is infiltrated with blood cells, pigment granules, and hæmatin crystals. If the hemorrhage is capillary—as sometimes occurs—it is detected by the presence of pigment and crystals among the degenerated spinal elements. Around the clot the spinal cord is usually found in a state of softening, which is red in recent cases, and white when the process has been a long one. At a post-mortem examination the question sometimes arises whether the condition found is a myelitis with secondary hemorrhage, or a hemorrhage with secondary myelitis. In the former case the microscopic examination shows a greater preponderance of granular corpuscles and leucocytes, a greater degree of degeneration in the nerve cells, and a greater extent of connective-tissue growth. Secondary degenerations upward and downward from the segment destroyed, and secondary degenerations in the motor nerves from the segment affected to the muscles, are observed after spinal hemorrhage as after myelitis. The meninges are rarely involved.

Etiology.—Spinal hemorrhage is met with in males more frequently than in females, and in youth and middle age most often. The predisposing causes are chronic changes in the general arterial system, hemorrhagic diathesis, purpura, and myelitis of the spinal cord. The exciting causes are injuries to the vertebral column and cord and extreme muscular effort, also the sudden exposure to a marked change of atmospheric pressure. A number of cases of cervical hemorrhage have occurred from sudden bending forward of the neck.

Symptoms.—As a rule, the symptoms begin suddenly, and the patient is seized in a moment with complete paraplegia and intense pain in the back at the level of the hemorrhage, and shooting pains in the body and stiffness of the spine. A spinal apoplexy usually comes without any warning, after a sudden effort. When premonitory symptoms have existed for a few days it is probable that the case is one of acute myelitis. The extent of the paralysis depends upon the level of the lesion. (See article on *Spinal-Cord Diseases: Diagnosis of Local Lesions in the Cord.*) If it is located in the lumbar or dorsal region, the lower half of the body only is involved; if in the cervical region, the arms are affected as well. The hemorrhage is rarely so very limited as to affect one extremity only, but it is not infrequently the case that the symptoms are more marked on one side, and in some cases the symptoms of a Brown-Séquard type have occurred. The paralysis is total, no voluntary motion is possible, the limbs are relaxed and never rigid. The muscles do not atrophy or present any change in the electric reactions, excepting those which are supplied with nerves from the segment which is destroyed by the hemorrhage. The condition of the reflex action depends upon the seat of the lesion: it is suspended at the level of the hemorrhage, and increased in the segments below it. If the hemorrhage is in the cervical region there is an atrophic flaccid paralysis of the arms and a spastic paralysis of the legs. In such a case there may be ventro-pupillary symptoms also.

If the hemorrhage is confined to the central gray matter and the patient survives, the symptoms may resemble those of syringomyelia. The bladder and rectum are uniformly paralyzed, and various forms of incontinence of urine and fæces result, dependent upon the seat of the lesion. If this is situated high up in the cord, the viscus may empty itself occasionally, as the need arises, unconsciously to the patient and independently of his effort or control. If the lesion is low down (below the eleventh dorsal segment), there is usually retention of urine and fæces, or complete relaxation of the sphincters. Cases sometimes occur of hemorrhage into the lower sacral region and conus terminalis from injuries; and in such cases there may be paralysis of the bladder and rectum only, with a small heart-shaped area of anæsthesia about the anus and buttocks. Vasomotor paralysis accompanies the voluntary paralysis, and results in cyanosis and coldness of the paralyzed limbs, and predisposes the parts to the development of bedsores. The latter appear, very soon after the hemorrhage, on the prominent parts of the body which are subjected to pressure; voluntary movements to relieve such pressure, or reflex movements for the same purpose, being impossible on account of the lack of power and of sensation, for complete anæsthesia and analgesia exist in the paralyzed limbs from the outset. Pain in the back, which occurs at the time of hemorrhage, does not usually persist. The danger in these cases is from the occurrence of bedsores, or of cystitis, and consequent infection from these sources, with the development of septic fever. If the hemorrhage involves the respiratory centres in the upper cervical region, sudden death takes place. This is rare.

The symptoms described are those of a severe hemorrhage, sufficient to destroy one or more segments of the cord. As a rule these symptoms gradually subside as the pressure of the clot is removed and the only permanent symptoms are those which are due to the actual destruction of the spinal elements, viz., limited atrophic paralysis and localized anæsthesia. Dissociated anæsthesia, viz., a loss of the senses of pain and temperature with preservation of the sense of touch, is not an uncommon result in the parts below the segment affected. If the clot is a small one, however, the symptoms may be more limited and less serious, partial anæsthesia and localized paralysis, with atrophy, being the result. This, however, is the exception. Capillary hemorrhages give rise to widespread symptoms, which so closely resemble those of diffuse myelitis that differential diagnosis is impossible.

The PROGNOSIS is very bad in spinal apoplexy, for a destruction of the spinal elements cannot be recovered from. The patients either die suddenly, or die of complications, or linger on for months with all the symptoms of chronic myelitis. In the lighter cases they may recover sufficiently to get about, but some evidences of the hemorrhage in the form of local paralysis or areas of anæsthesia always remain.

The DIAGNOSIS is usually easy, the sudden onset of total paraplegia being characteristic. In meningeal hemorrhage the paralysis is less marked than the spasms, and anæsthesia is rare. In poliomyelitis anterior there is marked constitutional disturbance, with fever, before the paralysis begins, and anæsthesia is not present. In acute central myelitis the onset is more gradual, the symptoms develop successively, they extend gradually to other parts, and fever is usual.

TREATMENT cannot reach the disease, but the patient should be kept absolutely quiet in the prone posture in bed, ice should be applied to the spine, and ergot should be given freely. The subsequent treatment resolves itself into care of the patient, and such measures as are used in the management of a case of chronic myelitis.

M. Allen Starr.

SPINAL-CORD DISEASES: LATERAL SCLEROSIS.

—(*a*) PRIMARY LATERAL SCLEROSIS.—(Synonyms: Spastic spinal paralysis; Tabes dorsal spasmodique.)

Definition.—The disease is characterized by a gradually progressing paralysis, which begins in the lower extremities, is accompanied by greatly exaggerated tendon reflexes, muscular rigidity, and contractures, and is not attended by sensory, trophic, or visceral symptoms. The anatomical basis is supposed to be a primary sclerosis of the antero-lateral columns.

Etiology.—We know very little of the causes of the disease. It occurs chiefly in adults, more frequently in men than in women. Exposure, excessive venery, syphilis, trauma, infection, lead poisoning, etc., have been assigned as causes in individual cases. Some cases occurring near Rome, several of which were in one family, seemed to be due to the effects of a leguminous article of diet, *lathyrus cicera*. In quite a number of instances heredity was the chief factor in causation; the disease occurring distinctly as a family disease, having been found in a number of generations, with often a number of cases in the same generation. For instance, in one of Strümpell's cases the grandfather, father, two uncles, and a brother were supposed to have been similarly affected; in one of Spiller's cases fourteen, in five generations, were believed to have had the disease. In some of Strümpell's cases the disease appears to have begun in early, in others in late adult life. In Spiller's and a number of other reported cases it began in early childhood. In most of these cases the disease appears to have been very slow in its progress.

Symptoms.—The disease begins with weakness in one or both lower extremities. There is an undue sense of fatigue on exertion, and an objective examination shows a slight paresis. There is at the same time some difficulty in walking, this being at first most noticeable on rising in the morning. As the paresis increases, motor irritation symptoms are soon manifested. These are at first slight clonic or tonic spasms of the affected muscles. They are most likely to occur when the patient is fatigued, are easily evoked by active or passive movements of the limbs, but often come on in the middle of the night. The tendency to muscular spasm—brought on by either a voluntary or a passive movement, or in a reflex way—increases to such an extent that complete muscular rigidity and contractures of the limbs occur. This condition antagonizes every action of the patient, makes his voluntary efforts altogether futile, and, therefore, causes the paralysis to appear more complete than it really is. The rigidity can usually be overcome, in early stages of the disease, by slow persistent pressure, but when it becomes excessive it resists powerful efforts. The usual position of the rigidly contracted limbs is that of extension at the knees, the feet in the equino-varus position, and the thighs firmly pressing against one another. Their immobility is often interrupted by clonic spasms. Occasionally the limb is drawn for a short time into another position.

A striking and usually an early symptom is the exaggeration of the deep reflexes. The patellar tendon reflex is greatly exaggerated; muscular contractions can be elicited by striking any of the tendons—for instance, the inner or outer hamstrings, where tendon reflexes cannot be elicited, as a rule, in health,—and even tapping over the periosteum will produce like manifestations. But the most striking of these phenomena is the ankle clonus, rapid and rhythmical clonic contractions taking place when the foot is sharply flexed, and continuing as long as the foot is held in a flexed position. When the reflexes are much exaggerated the clonic contractions, on evoking the ankle clonus, may not be limited to the ankle, but may extend to all the muscles of the extremity. The ankle clonus also becomes a disturbing element in walking, as every time the body rests on the toes in progressing forward there is a tendency to its production. The most notable change in the superficial reflexes is the presence of the Babinsky toe phenomenon.

The gait is very characteristic. As the legs are weak and stiff the feet cannot be freely lifted, and, when moving forward, they sweep the floor, making an almost characteristic scraping sound. At the same time, in order that the foot can be brought forward, it makes a wide outward sweep. The gait is sometimes further impaired by clonic spasms of the muscles—those representing the foot clonus, as just described—and these spasms may cause a temporary halt in walking, or may make that act altogether impossible. Walking is more difficult on an up or down grade, and on an uneven surface, than on the level and on an even surface. It usually becomes easier after the patient has walked for a while. The gait just described is that observed when the spastic symptoms are already well marked. At a later period, when there is complete rigidity of the legs, walking is impossible.

The disease slowly extends upward, involving the muscles of the abdomen, back, and upper extremities. The latter are usually affected to a less degree than the lower extremities, though exaggerated reflexes and muscular tension are associated with the paresis. The upper extremities may even be rigidly contracted, in which case the position is usually one of slight flexion and pronation of the fore-arm, and strong flexion of the wrists and fingers, the arm being pressed firmly against the body.

In typical cases there are no further symptoms on the part of the nervous system. The sensibility is intact, the functions of the bladder and rectum are normal, there are no trophic changes in muscles or skin, and no special changes in the electrical reactions.

The progress of the disease is usually very slow. Though the patient be altogether bedridden and without power of motion, the general health need not suffer. Unless there be some complication he may live to old age.

The symptoms of spastic spinal paralysis are found in Little's disease, a congenital paralysis usually due to disease which has developed during fœtal life, or which is the result of injury to the brain in parturition. The brain disease, in these cases, is usually shown by such conditions as strabismus, speech disturbances, idiocy or imbecility, epilepsy, and the like. But in some instances there are no cerebral symptoms; the disease appears to be purely spinal and, therefore, belongs to this category. The pathological state, however, is likely to be due to a developmental defect. A definite determination of this question must await future pathological findings. Improvement in such cases is not uncommon.

The following case, at present under the writer's observation, illustrates this class of cases: I. J——, a boy eleven years of age, did not learn to walk as other children. Prior to that time nothing abnormal was detected. The spastic condition is now very marked. As he stands he rests altogether on his toes—the heels cannot be brought to the ground—and the thighs are pressed firmly together. When he tries to walk, which he can do only if well supported, the thighs rub each other and the legs cross. When the patient sits the feet and lower legs sway in the air. The rigidity of the limbs is such that much force is necessary to make any passive movements. The Babinsky phenomenon is present, and all the deep reflexes are exaggerated The ankle clonus, as well as those of the Achilles and patellar tendons, can be elicited. The intellect, sensation, and the functions of the bladder and rectum are unimpaired, and there is no evidence of the involvement of the upper extremities or of the cranial nerves. The disease, therefore, appears to be limited to the motor tracts of the cord.

Morbid Anatomy and Physiology.—Symptoms like those of spastic paralysis had been observed in connection with various diseases, but Erb was the first to describe this as a separate and distinct disease, whose basis he believed to be a primary sclerosis of the antero-lateral columns, especially the pyramidal tracts. His views have been quite generally accepted, but yet, it must be acknowledged, there has not been much positive evidence to substantiate them. In a number of post-mortem examinations, where this disease was diagnosed during life, lesions in the brain, tumors in the medulla oblongata, diffuse sclerosis, etc., were found. In some instances, nevertheless, the disease appeared to be a primary sclerosis of the lateral columns. But, whether or not a primary disease be usually found, it is probable that the pathological changes in the lateral columns produce the symptoms of this disease, for when spastic symptoms are found with multiple sclerosis, diffuse myelitis, etc., the lateral columns are found to be affected.

The paresis or paralysis is explained by the destruction of nerve fibres in the pyramidal tracts, the tracts conveying voluntary motor impulses. The motor irritation symptoms cannot be so satisfactorily explained. Charcot believed them to be due to dynamic changes in the large ganglion cells, these being placed in a state of irritation by the degenerated nerve fibres of the pyramidal tracts. Hughlings Jackson supposed that in these cases the influence of inhibiting centres in the brain had been removed by the destruction of the pyramidal tracts, and that the excessive motor manifestations were due to the absence of this influence.

Diagnosis.—The symptoms of spastic paralysis may appear with multiple sclerosis, transverse or diffuse myelitis, brain lesions, etc. In order to establish the diagnosis in these cases we must look for the further symptoms of these various diseases, as, for example, the indications of involvement of the gray matter and posterior columns in transverse myelitis; optic atrophy, nystagmus, intention tremor in multiple sclerosis, etc.

Especially in multiple sclerosis there may for a long time be no other symptoms than those of spastic paralysis. For that reason, when the latter symptoms are present, one should always be on the watch for other symptoms, symptoms that may indicate the presence of another disease.

It is to be remembered that this disease is one of long duration, that post-mortem examinatio s have been made only many years after its inception. In those cases, therefore, in which other changes have been found than those in the lateral columns—in Gowers', Goll's, the cerebellar tracts, etc.—the primary disease may have been only in the lateral columns. At present we can only make a diagnosis of spastic spinal paralysis. We cannot be certain, during life, that the disease in the lateral columns is primary, or that it is altogether limited to that part of the cord.

Prognosis.—When uncomplicated the disease does not appear to shorten life. It is sometimes capable of improvement, and even cures have been reported.

Treatment.—The treatment applicable in these cases is that usually adopted in locomotor ataxia and other forms of chronic disease of the cord. Rest in bed for a number of weeks, especially when there seems to be an exacerbation of the disease, may produce amelioration of the symptoms. Hydrotherapy, electricity, massage, applications of the thermo-cautery along the spine, the administration of various drugs, are among the remedial measures that may be used. In the spinal form of Little's disease tenotomy and other orthopedic measures, together with rest, have sometimes produced good results.*

(*b*) Amyotrophic Lateral Sclerosis.—For both the description of the symptoms and knowledge of the anatomical character of this disease we are chiefly indebted to Charcot. Though somewhat akin to the disease just described, it presents striking differences both in its symptomatology and in its morbid anatomy. It occurs chiefly in persons of middle age, but has been observed in children.

Symptoms.—The disease usually begins with slowly progressing paralysis of the upper extremities, which is soon accompanied by atrophy and fibrillary contraction of the paralyzed muscles. Subsequently muscular rigidity and contractures occur, the arms assuming the position found in spastic paralysis, viz., partly flexed at the elbows and pressed against the body, forearms pronated, hands and fingers strongly flexed. These contractures may remain even when the muscles are almost completely atrophied. Usually, after the lapse of a number of months the lower extremities become involved. In them the manifestations are mostly like those of spastic paralysis—paralysis, exaggerated tendon reflexes, muscular rigidity, contractures,—while little or no atrophy of the muscles is observed. The electrical reactions are altered

* Since this article was written Mills and Spiller have reported to the American Neurological Association a case in which there appeared to be a primary sclerosis limited to one pyramidal tract. The pathological findings are also given in the report.

according to the degree of muscular atrophy. In the lower extremities there may be a mere quantitative change—diminution of electrical irritability—while in the upper extremities the alteration is usually more marked, and, when the muscular atrophy advances rapidly, as often occurs in the small muscles of the hand, the typical reaction of degeneration may be found.

At a still later period bulbar symptoms, those of glosso-labio laryngeal paralysis—atrophy of the lips and tongue, difficulty in deglutition, indistinct speech, respiratory disturbances—appear, and finally carry off the patient.

The symptoms do not always appear in the order described. Sometimes the disease begins in the lower extremities, extending thence to the arms, and finally to the cranial nerves. Sometimes the disease begins as a bulbar paralysis, though it need not, therefore, run a rapid course. The writer has at present under observation a case which began with bulbar symptoms two years ago, and now presents a typical picture of the disease. In this case the muscles supporting the head upon the trunk are, also, almost completely paralyzed.

The degree to which spastic symptoms, and to which muscular atrophy appear in both upper and lower extremities, is also quite variable, depending upon the part of the nervous system in which the morbid changes began, and upon the extent to which the gray and white nervous tissues are respectively affected.

The duration of the disease is usually from one to three years. The well-marked cases hitherto recorded terminated fatally. Death is generally caused by the bulbar symptoms.

Morbid Anatomy and Physiology.—The morbid changes are almost, if not altogether, limited to the motor central and peripheral nervous apparatus. There is sclerosis—atrophy of the nerve fibres and increase of the connective tissue—of the direct and crossed pyramidal tracts in the cord, often extending above the crossing of the pyramids in the medulla. In some instances the atrophy has been followed the whole length of the motor pathway to the central convolutions, and atrophied pyramidal cells have been found in the cortex of these convolutions. There is atrophy of the large ganglion cells of the anterior cornua, and of the cells of the nuclei of the affected cranial nerves. Certain of the cranial nerves, of the anterior roots of the spinal nerves, of the mixed nerves and of the muscles, are also found in various stages of atrophy.

As to the explanation of the symptoms, the muscular atrophy is due to the atrophy of the large ganglion cells, the bulbar symptoms to disease of the nuclei of the cranial nerves, the spastic phenomena to sclerosis of the pyramidal tracts. The preponderance of spastic or atrophic manifestations is due to preponderance of the morbid process in the white or gray matter respectively.

Diagnosis.—While the disease is still confined to the upper extremities it may be mistaken for subacute poliomyelitis anterior, or even for progressive muscular atrophy, for the weakness, fibrillary tremor, and other manifestations—atrophied thenar and hypothenar eminences, claw-hand, etc.—are very much like what is observed in the latter disease. But its progress, even when unusually slow, is more rapid than that of progressive muscular atrophy. Furthermore, spastic symptoms, exaggerated tendon reflexes, some muscular rigidity, etc., are likely to be manifest at an early period, thus aiding us to distinguish it from the aforementioned diseases.

When the disease begins in the lower extremities or as a bulbar paralysis, it is as yet impossible to make a diagnosis of amyotrophic lateral sclerosis. At times in the bulbar form, spastic phenomena—the jaw clonus—are found. When the disease has developed in its typical form, with atrophic paralysis in the upper and spastic paralysis in the lower extremities, as well as with bulbar symptoms, no mistake is possible.

Myelitis, multiple sclerosis, gliosis, syphilis, may be so localized as to simulate this disease. But usually other symptoms—sensory and trophic symptoms and symptoms on the part of the bladder and rectum—will appear and thus differentiate these diseases from amyotrophic lateral sclerosis, which has only motor symptoms.

The prognosis is sufficiently indicated in the foregoing description. Such treatment may be resorted to as is employed in other chronic diseases of the cord.

Philip Zenner.

SPINAL-CORD DISEASES: MENINGEAL HEMORRHAGE.—Spinal hemorrhage is of two varieties: extrameningeal, between the dura mater and the bones; and intrameningeal. The last named may occur between the dura and the arachnoid, or between the latter membrane and the pia mater. The extrameningeal variety is the commoner.

Etiology.—Both on this score and on that of symptomatology a good deal of error appears to have been perpetuated by writers of text-books. The explanation of this fact lies in the relative infrequency with which the disease in question occurs. Hence writers are compelled to formulate their opinions on theoretical grounds rather than on actual observation in the clinic and in the pathological laboratory. The causative importance of spinal injuries seems particularly to be overestimated. In the writer's experience traumatic hemorrhage, either within or without the spinal envelopes, of sufficient extent to produce definite symptoms, is almost too rare—even in severe spinal fractures and fracture dislocations—to demand serious consideration. In the minor spinal injuries the symptoms attributed by many writers to meningeal hemorrhage could be attributed more logically to the pinching of nerve roots or to the transitory pressure on the cord resulting from the spinal distortion produced by the injury.

Meningeal hemorrhage occurs at all ages and is more common in men than in women. In early childhood it is never spontaneous; it merely gravitates into the spinal membranes from those of the brain, as in the case of the birth palsies. It is sometimes found post mortem in severe convulsive conditions, epilepsy, chorea, tetanus, puerperal eclampsia, and strychnine poisoning. It is also found in the hemorrhagic forms of certain acute specific diseases, such as smallpox and yellow fever; rarely as an isolated phenomenon in typhoid fever. In most of these cases it is probably an agonal phenomenon and is not recognized at the time of its occurrence. Extradural hemorrhage is a rare result of the bursting of an aortic aneurism, after erosion of the bodies of the vertebræ. Within the dura hemorrhage may result from the rupture of an aneurism of the vertebral artery.

Pathologic Anatomy.—Extradural hemorrhage is usually small in amount; it comes from the venous network which lies between the dura and the bone and is found mainly posteriorly, this situation being favored by gravitation and by the fact that the space between the dura and the bone is greater posteriorly than anteriorly. In very large effusions the blood may make its way out between the intervertebral foramina, along the nerves. The cervical region forms the commonest site for this variety of hemorrhage, and the blood is usually found more or less coagulated.

In making a post-mortem examination care should be taken, as Gowers has pointed out, not to fall into the error of considering as ante-mortem hemorrhage the blood which has gravitated into the meningeal veins and is subsequently released into the retrodural space when the canal is opened.

Intrameningeal hemorrhage varies greatly in amount. In the subarachnoid form it comes usually from the pial vessels and may surround the cord for a short distance, or fill the whole subarachnoid cavity. It has even been known to force its way through the valve of Vieussens into the cerebral ventricles. The cerebro-spinal fluid is often blood stained, a fact which may lead the observer into thinking the hemorrhage larger than it really is. In cases more than a few days old there are usually signs of meningitis, set up by the irritation of the effused blood.

Symptoms.—To produce any symptoms whatsoever the hemorrhage must be extensive. Such symptoms are at first irritative and result mainly from the more or less complete asphyxiation of the nerves which pass through the hemorrhagic area. The first indication is, as a rule, sudden with severe pain in the back. This pain is most intense at a point corresponding to the site of the hemorrhage, but radiates up and down the spine. With this pain in the back are others of a paroxysmal character, due to the irritation of the spinal nerves involved in the hemorrhage. These vary in distribution with the level of the cord implicated. Between the paroxysms of pain all sorts of disagreeable sensations may be experienced in the regions supplied by these nerves, the result of perverted function. More or less muscular spasm usually accompanies the pain; this may affect the vertebral muscles only so far as to cause rigidity of the spine, or it may produce actual opisthotonos; for the rest, it involves in part the muscles supplied by the affected nerves, and in part the muscles supplied by the cord below the hemorrhagic focus. There is usually spasmodic retention of urine. In a short time more or less paralysis follows this stage, but there is rarely if ever a condition of complete paraplegia. As a rule the sensorium remains clear throughout; occasionally unconsciousness may develop as a result of shock, and coma or delirium may come on.

Diagnosis.—Hemorrhage into the membranes, if at all severe, is usually marked by the group of symptoms above mentioned: sudden intense pain in the back, with spasmodic pain and other phenomena indicative of perverted function in the region supplied by nerves implicated in the hemorrhagic focus, muscular spasm followed by partial paralysis, spasmodic retention of urine, etc. In hemorrhage into the substance of the cord the pain is very much less in degree and more distinctly local, the paralysis is immediate, much more extensive and persistent, and the resulting atrophy more pronounced; the sphincteric disturbance is very marked and priapism is often present; the reflexes are abolished if the hemorrhage involves the entire transverse area of the cord, and increased if the lateral columns are mainly implicated. Should the cord hemorrhage make its way into the membranes the symptoms of both lesions will be combined, but even then the chronological order of the symptoms will enable one to follow the course of events. Meningitis has a more gradual onset, and fever is present from the outset; meningitis may, however, be started up by a hemorrhage, a fact that should be borne in mind. In myelitis the pain is very rarely prominent and the irritative phenomena so common to hemorrhage are *nil* or nearly so. Tetanus is differentiated by its more gradual onset, the presence of trismus and the absence of the severe spinal pains.

Prognosis.—In stormy cases the symptoms may reach their maximum in a few hours and death may result. This is particularly true if the cervical region is the one affected, owing to the implication of the phrenic nerves. If the patient survives the shock and exhaustion which accompany the culmination of symptoms, very gradual improvement may take place, with ultimate complete recovery. The danger is that the decline of the hemorrhagic symptoms may be followed, after a few days, by the onset of those of a meningitis which may prove fatal. If, however, the meningitis be of only moderate severity, it will begin to abate at the end of a week or ten days and gradual improvement will follow; complete recovery is a matter of many months.

Treatment.—Absolute rest is a prime requisite. The patient should be laid upon an air or water mattress and made to lie upon the face or side as much as possible, in order to have the spine elevated. The bladder and rectum should receive careful attention. Early scarification beside the spine, with free letting of blood, is a logical procedure, if the anatomical connection between the venous plexuses and the veins in the postvertebral tissues be considered. This may be followed by the application of ice to the spine and the internal administration of some form of ergot. The pain should be controlled by morphine or other sedative. If acute meningitis follows the hemorrhage, the treatment for this condition elsewhere indicated should be followed. The resultant paralyses are best dealt with by electricity and massage.

Surgical interference has been advocated by many in cases in which the early symptoms progress rapidly and the patient's strength remains good. The writer's experience with spinal surgery does not lead him to a warm advocacy of this measure. *Joseph W. Courtney.*

SPINAL-CORD DISEASES: MYELITIS.—Etiology.—Myelitis is one of the rarer forms of disease of the spinal cord. With the exception of certain special varieties, it is usually a disease of early adult life, and grows more infrequent in middle life and old age. The male sex seems to be much more predisposed than the female. Thus, among thirty-three cases under my observation there were twenty males and thirteen females. This discrepancy is probably owing to the greater frequency of the exciting causes among males.

The exciting causes of myelitis are numerous. The most frequent one, in the writer's experience, has been exposure to cold and wet. The disease is observed not infrequently after a debauch, if the patient has been compelled to sleep on the damp ground or lie in the gutter, etc. It may also result from working in ditches, or even from a brief exposure to wet and cold.

Traumatism plays a much less considerable part in the etiology of this disease. The inj y may be inflicted directly upon the spinal cord, as the result of gunshot and stab wounds, direct blows on the back, or even blows on the head. Injury to adjacent parts may also lead to myelitis. For example, in one of the writer's cases an injury to the back gave rise to a myositis in the erector spinæ muscle, attended with suppuration. After a long interval the pus made its way along the roots of the spinal nerves, through the intervertebral foramina, to the pia mater, where it set up an acute meningitis, and then extended to the substance of the cord, setting up myelitis. A certain amount of myelitis always attends spinal meningitis, but it is usually confined to the outer segment of the cord, and does not produce any notable symptoms.

Myelitis is also a frequent result of injuries to the spine (fractures, dislocations, etc.) which are attended with direct pressure on the cord; or it may occur in spinal concussion, when there is no evidence of injury to the external parts. In the latter form, however, the myelitis is more apt to be subacute or chronic.

Crocq reports a case of acute myelitis resulting from forced extension of the cord. So-called compression myelitis is also observed quite often, usually as the result of Pott's disease, more rarely of cancer or other tumors of the vertebræ. In the majority of cases, however, evidences of inflammation of the cord are wanting in this condition and the post-mortem appearances indicate degeneration due to interference with circulation. In some cases, however, evidences of myelitis are manifest.

In a considerable proportion of cases myelitis follows an infectious disease, being due either to the presence of bacteria in the cord or more frequently to the action of toxins circulating in the blood. Thus, cases have been reported after diphtheria, dysentery, typhoid fever, influenza, gonorrhœa, smallpox, measles. Schiff reports a case of acute hemorrhagic myelitis during the course of typhoid fever in which a fatal termination occurred eighteen hours after the onset of the spinal symptoms.

Among the rarer infectious sources of myelitis may be mentioned erysipelas, malaria, pneumonia, whooping-cough, scarlatina, puerperal sepsis, and streptococcus infection. Quite a number of cases have been reported in which a bronchiectatic cavity has been the starting-point of infection. Flatau reports a case which began several weeks after a suppuration of the antrum of Highmore.

Marinesco believes that the poison acts indirectly through the blood-vessels or directly upon the nerve tissues.

Moltschanoff found, upon injecting guinea pigs and white mice with gonococci toxins, that symptoms developed on the part of the nervous system, and marked changes in the cord were discovered on microscopic examination (colossal vacuolization of all the cells of the anterior and posterior horns).

It has also been claimed that myelitis may be due to tuberculosis or syphilis independently of local specific lesions.

Not a few cases have been reported as the result of acute or chronic poisoning with lead, arsenic, alcohol, or coal gas.

Formerly it was supposed that myelitis was not infrequently secondary to a cystitis or to inflammation of other parts of the urinary tract, the intervening link consisting of an ascending neuritis. At the present time we are inclined to believe that such cases are due to infection with the toxins of gonococci or streptococci.

In this connection we may mention an interesting case, reported by Dupré and Delamare, of a man, aged twenty years, with scoliosis of the dorsal spine since childhood. For ten years he had had a tuberculous process in the left upper maxilla and this was finally curetted. Two months later an apoplectiform paraplegia developed, with pronounced disturbances of tactile and thermal sensation in the legs. Atrophy of the muscles set in, with extensive bedsores and interference with micturition. After a short illness the patient died in a delirious condition. The diagnosis was tuberculous spondylitis and compression of the lumbo-dorsal cord. At the autopsy the spine was found to be intact, but there was extensive hemorrhagic pachymeningitis which encircled the lower dorsal cord like a thick ring. There were also secondary myelitic changes in various segments of the dorsal and lumbar cord. The microscope showed various stages of tuberculous inflammation of the dura. In the cord were found scattered islets in which the parenchyma and glia exhibited extensive degeneration, and there were irregular hypertrophy, with deformity of the posterior horns, and proliferation of the epithelial cells of the ependyma of the central canal.

Finally, in a considerable proportion of cases, we are unable to discover any adequate cause for the development of the disease.

Myelitis may be divided into several varieties, viz.: (1) *Transverse myelitis*, in which the entire thickness of the cord is affected, while the longitudinal involvement is slight, compared to the entire length of the cord; (2) *disseminated myelitis*, in which numerous small foci are scattered irregularly through the cord (this form is very apt to be complicated with a similar condition of the brain, really constituting an encephalo-myelitis); (3) *compression myelitis*; (4) *poliomyelitis*, in which the gray matter is the chief site of the lesion (this will be discussed in a separate article); (5) *purulent myelitis*, in which the disease terminates in the production of abscesses; (6) *chronic myelitis*.

Clinical History.—*Acute transverse myelitis* is rarely preceded by prodromal manifestations, unless this term be applied to the first symptoms of the beginning inflammation. In rare cases there is a feeling of general malaise, slight shivering sensations, or a distinct chill, and there may even be a certain degree of mild delirium; even general convulsions have been observed at the onset of acute dorsal myelitis, and still more often in cervical myelitis. Marked febrile movement is not often noticeable, however acute the inflammation may be.

The onset varies considerably in its degree of suddenness. In rare cases the disease begins as quickly as an attack of cerebral apoplexy. The patient suddenly feels a sense of weight in his lower limbs, this increases, and at the end of a few minutes the limbs are paralyzed. Or the onset extends over a week or more. At first a feeling of numbness, or of pins and needles, is noticed in the soles of the feet; this gradually spreads up the limbs, accompanied by increasing weakness of the parts, perhaps by severe pains in the muscles, particularly the calves of the legs, or by painful spasms of the muscles. Then the anæsthesia and motor paralysis continue to increase, sometimes uninterruptedly, sometimes by fits and starts, until they have attained their greatest intensity. The paralysis may be so complete that the patient is unable to move even the toes to the slightest extent.

Pain in the spinal column is not a pronounced symptom, nor do the patients, as a rule, complain much of tenderness in this region. The pains in the paralyzed muscles, sometimes in the joints, are extremely violent in certain cases, so that I have even known this condition to be mistaken for acute articular rheumatism. These pains may continue during the entire acute stage of the disease. A more constant symptom is the cincture feeling, a term applied to a painful sense of constriction around the abdomen, or thorax, varying according to the site of the disease in the spinal cord; this is usually attended with circumscribed tenderness over the corresponding portion of the spine. The cincture feeling is sometimes described by the patients as confined within very narrow limits, like those of a cord or thin ribbon; sometimes it is as broad as the hand.

In the majority of cases the pains in the limbs disappear as the paralysis becomes more pronounced, but in some instances they persist, even despite complete motor and sensory paralysis (anæsthesia dolorosa). When the pains in the limbs are severe they are usually attended with spasm or contracture of the affected muscles.

The bladder and bowels, especially the former, are usually implicated at an early period. The patient first experiences difficulty in passing water and must strain a good deal to start the flow. Finally, the inability to urinate may become complete, and the use of the catheter is necessary. Or the sphincter also becomes paralyzed, and incontinence results from overflow. The bowels are affected in a similar way, though less frequently. At first there is constipation, sometimes attended with extreme tympanites, from paralysis of the muscular coat of the bowels. Or the stools may pass away involuntarily, and, if anæsthesia is profound, this occurs without the patient's knowledge. In many cases, however, the functions of the bowels are quite undisturbed throughout the entire course of the disease. Even when voluntary evacuations are completely lost, the action of the bowels may sometimes be stimulated by reflex means, as by the passage of a catheter into the bladder, the irritation of the perineum, etc.

The cutaneous and tendon reflexes vary according to the exact site of the disease. Trophic symptoms are not an important feature in myelitis, apart from the atrophy of muscles seen in inflammation of the anterior horns of the cervical and lumbar enlargements. They are observed most frequently in the integument. Vesicular eruptions sometimes appear upon the paralyzed parts, and there may also be excessive desquamation of the outer layers of the skin. The formation of bedsores, which sometimes occur at such an early period as to indicate their trophic origin, will be considered later. We may also call attention to the fact that the changes in the urine, which are so common in this disease, are regarded by some writers as the result of trophic changes in the secreting structures of the kidneys.

Enlargement and tenderness of the knee-joints, sometimes attended with distinct effusion, occur rarely, and their interpretation is obscure. I have also found a similar "rheumatoid" condition in the ankle-joints in a few cases of myelitis.

Gowers reports a remarkable case of trophic disturbance in a patient suffering from subacute myelitis, in which the myelitic symptoms were complicated by cellulitis of the lower part of the abdomen. At the autopsy no local cause of the cellulitis could be discovered.

Vaso-motor symptoms are more frequent than the trophic changes, but possess little clinical importance. The temperature of the paralyzed parts is often changed. At first it is sometimes increased, but later, as a rule, it is decidedly lower than that of other parts of the body. Pitting of the limbs from slight subcutaneous œdema is also not infrequent.

The disease may be arrested at any period during its course, and may then terminate slowly in complete recovery. This is possible even after all the limbs are completely paralyzed, and after extreme wasting of muscles has taken place. As a general thing, however, recovery is incomplete. In the majority of cases the disease advances to a certain point, at which point it remains at a standstill, in some instances for a period of several years. In some of these cases further improvement is possible even after a long interval, during which the patient has remained *in statu quo*. Usually, however, the non-fatal cases terminate in the condition known as spastic paraplegia. The lower limbs gradually become more and more rigid, until finally each limb is moved as if it were one solid body. The feet cannot be flexed, the toes are shuffled across the floor, and the pelvis must be raised farther from the ground, in order to prevent the toes from catching in the floor. The limbs offer a decided resistance to passive motion. The tendon reflexes are often enormously increased. Ankle clonus often develops involuntarily if the patient, while sitting down, happens to bear his weight on the front part of the foot.

In much rarer cases the limbs become contractured in flexion, the thighs upon the abdomen, the legs on the thighs, the feet on the legs. At the same time the thighs are usually adducted strongly upon one another, so that one thigh is drawn forcibly across the other. In these cases bedsores are very apt to develop at the points at which the limbs come constantly in contact with one another. The patients very often suffer from intense pains in the contractured limbs, especially when an attempt is made to overcome the contracture. At other times the pains come on spontaneously in violent paroxysms, which are usually very difficult to control.

Death occurs generally from extension of the inflammation upward, and implication of the muscles of respiration; from gradual exhaustion, resulting usually from the formation of bedsores; or from disease of the kidneys consequent upon cystitis following paralysis of the bladder.

Bedsores develop over the sacrum, and are caused not alone by the protracted pressure on this part of the body, but also by soiling from urine and fæces, which is prevented with difficulty in many cases. In certain severe cases of inflammation of the lumbar enlargement bedsores may occur at a very early period, and then seem to be due directly to trophic changes in the skin.

With proper care and treatment the bedsores may remain confined to the integument, but not infrequently they extend more deeply, spread to the bones, and give rise to pyæmia; or, as I have also seen, the inflammation extends through the sacral foramina and sets up a rapidly fatal meningitis.

The occurrence of cystitis is also an important symptom. Perhaps in the majority of cases it results from the introduction of foul catheters, but it may also develop when such a cause cannot be discovered. The danger, in this condition, consists in the secondary development of acute interstitial nephritis, as the result of the introduction of bacteria along the ureter from the decomposing urine in the bladder. This complication usually proves rapidly fatal, but the writer has seen a few cases in which the post-mortem appearances warranted the belief that this morbid condition in the kidneys may subside. In such cases, however, death was the result of another attack of the same kind. But, on the whole, the renal affection seems to be a rare cause of death, even if the cystitis remains unchanged for a long time.

Close study of the symptoms enables us to localize the lesion very accurately in cases of transverse myelitis.

In myelitis of the lower part of the lumbar enlargement the motor paralysis is confined to the muscles supplied by the sciatics (gluteal region, posterior thigh group, and all the leg muscles, with the exception of the tibialis anticus). The sensory disturbances (complete or incomplete anæsthesia) extend over the entire lower limbs, with the exception of the parts supplied by the obturator and crural nerves (anterior and inner portion of thigh). Reflex movements in the paralyzed parts are abolished. The sphincter ani is paralyzed. When the lesion is a severe one the paralyzed muscles undergo atrophy, and the reaction of degeneration is observed.

In a lesion of the upper part of the lumbar enlargement the motor and sensory paralysis involves the lower limbs completely.

In a lesion of the dorsal cord more or less complete motor and sensory paralysis is observed in the lower limbs throughout, the anæsthesia extending upward to the intercostal nerves given off at the site of the lesion. The bladder and rectum are paralyzed. The muscles undergo very little or no atrophy, and the electrical reactions are unchanged. The cutaneous and tendon reflexes are increased on account of the abolition of the inhibitory influence from the brain.

In a complete transverse lesion of the cervical cord the paralysis affects all the limbs; when the transverse lesion does not cut across the entire cord the paralysis may be confined to the upper limbs (cervical paraplegia). The muscles of the trunk are also involved in these cases, and this process is a great source of danger to life on account of the resulting interference with respiration. In lesions of the lower part of the cervical enlargement the intercostals are paralyzed. If the lesion extends higher the diaphragm also becomes paralyzed, from implication of the nucleus of the phrenic nerves. As a general thing the muscles do not undergo atrophy, because the disease usually proves rapidly fatal. When the cilio-spinal centre is involved we may observe dilatation or contraction of the pupil, according as the centre in question is irritated or paralyzed.

Optic neuritis has also been observed in rare cases of myelitis of other parts of the cord (usually of the disseminated variety), but its relation to the spinal inflammation is not clear. The neuritis and myelitis probably are effects of the same underlying cause.

In lesions of the upper cervical cord the symptoms are similar to those just described; but in these cases the disease is apt to spread into the medulla oblongata, and to involve certain of the cerebral nerves. The following brief abstract will illustrate the history of acute myelitis of the upper cervical cord, extending into the medulla oblongata.

A. B—— contracted syphilis two months ago. At the present time he exhibits a roseola, and is suffering from slight sore throat. On November 12th he had sexual intercourse while standing. During the same night he complained of an uneasy feeling in the legs, and of slight numbness in the tips of both middle fingers and in the feet. On the next day he walked up five flights of stairs twice; then the legs began to feel heavy. He managed to get about his room on the following day (Saturday), but on Sunday morning was unable to rise from bed. At my first visit (November 16th, 6 P.M.) I found the patient in the following condition: Almost complete paralysis of the lower limbs; slight motion of the thighs; a little reflex action from the soles; numbness of the entire limbs. He could hold his water, but after it began to flow he was unable to check it. There was very marked paralysis of the upper limbs, especially the right limb, but most movements could be performed slowly; partial anæsthesia of the upper limbs and trunk, none of the face; voice a trifle hoarse; temperature, normal; respirations, 16; pulse, 84 and of good quality. The patient does not use the diaphragm in breathing, but can do so quite well voluntarily. He says that he sometimes has difficulty in breathing, and cannot cough as well as yesterday.

November 17th, 9 A.M.—Passed a bad night, unable to sleep at all; whenever he was about to doze off he had to struggle for breath; had one bad attack of dyspnœa which lasted three hours. No reflex from the soles of the feet; power absolutely lost in lower limbs; also worse in upper limbs, particularly the right; sensation more blunted; passed a large quantity of urine at 5 A.M.

Respiration, 20; pulse, 90; respirations interrupted occasionally by a long breath; more difficulty in breathing; still moves the diaphragm voluntarily, but not so vigorously as last night. Speech is more hoarse, the vowels are not enunciated very clearly. Slight anæsthesia of the left side of the face, paresis of the left internal rectus, also of the right side of the face. He has double vision over a small area a little to the left of the median line on the horizontal. All the right facial muscles are paretic; he is unable to close the right eye entirely.

November 17th, 8 P.M.—Condition unchanged, has slept at intervals, once for half an hour at a stretch.

November 18th, 10 A.M.—Left pupil slightly dilated, but reacts to light; left side of face not so numb; paresis of internal rectus improved; no double vision; enunciates vowels more distinctly. Paralysis of the limbs is a little more marked; no reflex from soles; urine passed freely. During the night had severe pain between the shoulders; respiration, 22; pulse, 86; diaphragm not so active, but respiration easy.

November 18th, 9 P.M.—Respiration, 33 and more labored; diaphragm weaker; pulse, 84 and weaker. Skin cool and covered with cold sweat; looks a little bluish; face flushed; patient seems excited and talks a good deal—says "he is off his nut because he has taken too much brandy"; pupils normal; speech more difficult, vowels less distinct; does not swallow so well. The patient died at five o'clock the following morning, after increasing difficulty in breathing.

Disseminated myelitis is almost always an infectious or toxic affection. In comparatively rare cases the lesions are confined to the cord, but in the majority of cases they are also found in the medulla, pons, and other parts of the brain. If the lesions in the cord are grouped in such a manner that the transverse section is involved in great part, the symptoms closely resemble those of transverse myelitis. In a considerable proportion of cases, however, an acute ataxia develops, frequently in all the limbs at the same time. The patellar reflexes, instead of being lost as they are in tabes dorsalis, may be exaggerated. The muscles exhibit loss of power, varying in degree from slight paresis to complete paralysis. The lightning pains of tabes are absent and the sphincters may be unaffected. Optic neuritis is not uncommon. When the medulla and pons Varolii are affected, as is generally the case, we may observe scanning speech, nystagmus, tremor, occasionally attacks of mental excitement, as in multiple sclerosis.

So-called *compression myelitis* is usually, as we have intimated in the section on etiology, not a real inflammation. But as this point can be decided only upon autopsy, and not by the clinical history, we will here give a brief description of this condition.

In the majority of cases compression myelitis is the result of Pott's disease and the lesion is situated in the dorsal region. The malady is often preceded by symptoms of irritation of the roots of the nerves by the diseased bone or the secondary pachymeningitis. These irritative symptoms consist of a cincture feeling around the abdomen or chest (according to the location of the vertebral lesion), or of pains in the legs; sometimes there is an eruption of herpes zoster upon the trunk or the lower limbs.

Weakness of the limbs generally begins slowly and finally advances, as a rule, to profound paralysis. This may be preceded for quite a while by marked exaggeration of the knee-jerk and ankle clonus. In the same way these symptoms may persist for a long time after the restoration of motor power.

After the motor paralysis has developed the symptoms differ in no respect from those of ordinary transverse myelitis, except that there is usually a much greater discrepancy between motor and sensory paralysis, the latter being very often entirely absent. The paralysis exhibits very little tendency to extend beyond the parts originally involved. In a certain proportion of cases the lower limbs become contractured—the thighs flexed on the abdomen, the legs on the thighs—or shooting pains in the lower limbs become a prominent feature of the disease. To judge from his own experience, the writer is inclined to believe that this condition is particularly apt to develop when the myelitis is the result of irritation of the cord rather than of compression by morbid products.

When the compression myelitis is the result of cancer of the vertebræ, pains in the lower limbs and trunk are extremely distressing, and, if cutaneous sensation is abolished at the same time, the condition is known as anæsthesia dolorosa. Apart from the excessive violence of the pains, this paraplegia dolorosa cannot be distinguished from other forms of compression myelitis.

Purulent Myelitis.—Purulent inflammation of the spinal cord is much rarer than the similar process in the brain. On account of the protected location of the cord, injuries to the latter and hence surgical infection are uncommon. On the other hand, purulent myelitis has been observed after injuries to the vertebræ without direct lesion of the cord. In such cases the infectious bacteria must have been conveyed through the lymph channels. The disease occurs most frequently as a sequel to suppurative meningitis. It is also possible that the pus-producing germs are conveyed to the cord and meninges at the same time. A few cases have been reported as the result of metastases in remote parts of the body: for example, after abscess of the lung, putrid bronchitis, suppurative processes in the genito-urinary tract, etc.

The symptoms of the disease are generally those of a transverse myelitis, associated perhaps with unusually pronounced meningitic symptoms and evidences of profound general infection. As a rule, the diagnosis of the suppurative character of the inflammation is not very difficult after recognition of the etiological factors in the case.

Chronic myelitis is a much rarer affection than the acute or subacute form of the disease. The causes of chronic myelitis are similar to those of the acute form. It is generally held that the difference in the mode of beginning is the result of differences in the intensity of the etiological factors—for example, sudden and violent exposure will produce acute myelitis, long-continued and less severe exposure will produce chronic myelitis;—but it seems to me that this view is based on theory rather than on well-established clinical facts. In traumatic cases a single traumatism may set up an acute myelitis or an inflammation of the cord which does not make its appearance until long after the symptoms of the original injury have subsided. Perhaps there has been some spinal pain for a few days or weeks after the injury, then the patient feels entirely well; but, a few months later, the signs of slowly advancing myelitis make their appearance.

Syphilis seems to exert a considerable influence as a predisposing cause, but it is questionable whether it acts simply by making the spinal tissues more vulnerable or by the production of gross lesions in the vessels or membranes of the cord. It seems probable, however, that in a large proportion of such cases the former theory is correct, the syphilitic virus appearing to act as a potent predisposing factor, as it does in the production of locomotor ataxia.

Alcoholism also appears to exercise great influence in the production of chronic myelitis; but we must bear in mind that this vice is often connected with repeated exposure to cold and wet, and to violence, and that it is difficult to decide between the parts played by each of these factors.

The *symptoms* of chronic myelitis are very similar to those of the acute form, except that they develop very slowly and insidiously. In some instances this gradual course may be interrupted occasionally by more or less acute exacerbations. In the majority of cases the disease affects the dorsal region, and hence the symptoms are those of slowly developing paraplegia. As in the acute form, the sensory symptoms are generally much less marked than the motor phenomena. The patient complains of formication and tingling in the feet, or of a sense of numbness in the soles, so that the floor does not feel natural in walking. This condition may last a very long time, although no change in sensation can be noticed objectively after the most careful examination. Pain is not a prominent feature, although there is often complaint of a slight girdle feeling around the abdomen. In a few cases, however, the pains are remarkable for their violence. Slight, dull pains are often felt in the back and limbs, particularly after walking for some length of time. These symptoms may last a long time before any motor weakness becomes apparent. The patient notices that he becomes more tired than usual after walking, and finally begins to drag the legs. Rigidity of the lower limbs is an early and almost constant accompaniment of the loss of power (spastic paraplegia). In many cases, indeed, I have noticed a marked development of this spastic condition before any real loss of power could be detected. At the same time the tendon reflexes are notably increased. In some cases disturbances of sensation, which can be determined by objective examination, may be entirely absent, and subjective sensory disturbances may also be extremely slight, or wanting. The symptoms are then exactly similar to those of so-called primary lateral sclerosis, and may remain in this stage for several years before the advent of other symptoms attests the spread of the disease.

In a very small proportion of cases, particularly in those which are due to syphilis, the lesion is confined to a small section of the cord, and, if limited to one-half, may give rise to the symptoms of spinal hemiplegia (paralysis of motion on one side, paralysis of sensation on the opposite side). As a general thing, however, the lesion is not confined exactly to one half of the cord, but extends somewhat into the other side, and motor and sensory symptoms are therefore observed in each limb, although the paralysis of motion is more marked in one limb, that of sensation in the other limb. In this form of the disease, sensory symptoms (anæsthesia, pains in the back and limbs) usually form an important feature.

As a general thing, the lesion spreads slowly along the cord in an upward or downward direction (usually the former), and other parts of the body become involved. The spread of the disease may be exceedingly slow, and even twenty or thirty years may elapse before the final termination. In other cases the chronic course may be interrupted by acute exacerbations. I have also seen several cases in which the symptoms of chronic myelitis appeared to merge later into those of posterior sclerosis or multiple spinal sclerosis.

Spastic symptoms are apt to be extremely severe in this form of myelitis. In the most aggravated cases the muscles are contractured to such an extent that the thighs may be flexed sharply on the abdomen and the legs flexed firmly against the thighs. The rigidity may be so pronounced that the entire body is moved as a whole when the force is applied to the feet. We then find not infrequently that the pressure of one knee upon the other gives rise to the formation of bedsores, and these are also apt to develop upon the sacral and gluteal regions. With proper care and nursing the bedsores may often be prevented, but the absolute helplessness of the patient always entails great suffering. It is a surprising fact, however, that the patient often exhibits a cheerful frame of mind during the entire course of the disease.

In a considerable proportion of cases the functions of the bladder and bowels are notably impaired, but it is found not infrequently, even in the most spastic cases, that the patients still retain considerable power over these organs.

When the sensory disturbances (paræsthesiæ and pains) are severe, the condition of the patient is truly pitiable. Unfortunately, he may remain in this state for many years until finally an intercurrent affection brings relief in death.

In concluding the clinical history of myelitis I will refer briefly to a mode of termination which has been unnoticed by the majority of writers. In a number of cases which have come under my observation the disease appeared to begin as a transverse myelitis; but the symptoms cleared up, in great part, and then merged into those of locomotor ataxia. In the following case I was fortunate enough to obtain a post-mortem examination:

J. D——, thirty-five years of age, married; entered Randall's Island Hospital on September 4th, 1883. The patient gives no evidence of syphilis; habits regular.

The present illness has lasted nine months; it began with ptosis of the right eye; shortly afterward he began to have shooting pains in the legs and arms. In a few weeks he had to quit work on account of the pains and weakness in the lower limbs. About five months ago the patient became so weak that he was unable to walk, and had trouble in holding his water.

Present condition (October 4th, 1883).—Patient walks with assistance, but has a characteristic heel gait, and must watch the movements of his feet; he reels to and fro when standing with the eyes closed.

Anæsthesia and analgesia are present, below Scarpa's triangle, in both thighs and legs; patellar reflexes are absent. Slight inco-ordination of upper limbs, and some numbness of the fingers. Partial ptosis of right eye; both pupils very much dilated, and react poorly to light; optic papillæ unchanged; special senses normal. The dynamometer is forced to forty by the right hand, to thirty-six by the left hand.

October 24th.—Had a pulmonary hemorrhage; dulness and a few moist râles over the upper lobe of left lung.

The motor power of the lower limbs improved considerably, but the inco-ordination rapidly grew worse, the limbs jerking in every direction when any voluntary movement was attempted. There was very marked emaciation, but the muscular power finally appeared to be normal compared with the amount of muscular tissue retained. The ptosis disappeared almost entirely; sight remained normal. The phthisis continued to advance, and the patient died January 7th, 1885, without the development of any fresh symptoms on the part of the nervous system.

Microscopic examination of the spinal cord showed exquisite sclerosis of the posterior columns (enormous increase of the neuroglia and of nuclei), together with a general increase of connective-tissue elements in the remaining portions of the cord, with the exception of the gray matter, which seemed to be perfectly normal. In addition, the blood-vessels of the posterior columns were very much dilated, and their walls were exceedingly thickened, particularly the adventitia, in which the nuclei were enormously increased. The nuclei around the central canal were increased in number, and there seemed to be, also, an increase of fibrous tissue in this locality. Here and there in the other columns of the cord were seen blood-vessels which also presented a considerable increase of nuclei.

Pathological Anatomy.—In a good many cases of acute myelitis no change in the structure of the cord is visible to the naked eye. Sometimes the diseased parts are softened, and their color is changed. The cord cuts less firmly than in the normal state, the cut surface projects as if the cord were too large for the enveloping pia mater, and the normal differentiation between the white and the gray matter becomes less distinct or is completely lost. The entire surface has a reddish tinge; sharply defined reddish streaks (distended blood-vessels) are often seen, particularly in the white matter; and here and there we occasionally notice minute red specks (capillary hemorrhages). In some cases these hemorrhages form the most marked change recognizable by the naked eye, and the cut surface has a bright red, or, at a later stage, chocolate color (hemorrhagic myelitis). The degree of softening varies between very wide limits. In some cases it is entirely absent, in others it is so pronounced that the diseased part of the cord, but particularly the gray matter, is diffluent and flows out like cream.

Schmaus and Sacki give the following description of the pathological anatomy of the various forms of myelitis:

Transverse Myelitis.—In this form of the disease we may find one large focus or several smaller ones. These foci exhibit the appearance of parenchymatous degeneration with swelling, or pronounced vascular changes, or there may be softening, with or without hemorrhage.

In some places the white substance shows marked swelling of the axis cylinders and medullary sheaths; the latter may have a vesicular appearance and stain poorly with Weigert's solution. The swollen axis cylinders, on transverse section, form partly homogeneous, dark-stained bodies, or pale, finely granular bodies. Marchi's method of staining may show black coloration of the swollen fibres, indicating beginning fatty changes. Longitudinal sections show that the axis cylinders break up into smaller segments, and these pieces are often enclosed in swollen medullary substance; if the latter has undergone fatty degeneration, an appearance of granular corpuscles may be simulated. The neuroglia is also involved; the fine fibrillæ, which separate the individual nerve fibres, are swollen into thick, homogeneous bands, which often take a deeper stain; the glia cells are often swollen and enlarged. In addition, we find arterial hyperæmia, dilatation of the small arteries and veins, homogeneous or slightly granular masses of exudation in the interstitial tissue, masses of leucocytes in the walls of the vessels or free in the tissues, and more or less numerous granular corpuscles. When the gray matter is involved, the ganglion cells exhibit interesting changes. These begin with swelling of the granules capable of staining, or with a finely granular distribution of the tigroid substance. Next come changes in the cell body as a whole, viz., homogeneous swelling or degeneration of the cell and its processes, shrivelling of the cell, changes in pigmentation, vacuolar degeneration, finally complete disappearance of certain cells or groups of cells. The nuclei also exhibit signs of degeneration; they stain more deeply, grow smaller and darker, are irregular or fissured, and finally coalesce completely with the body of the cell.

In a second group of cases, the vascular changes are most prominent. The microscope shows that the chief change is a small-cell infiltration, most marked around the vessels and following them along their course. The cellular infiltration occurs chiefly in the lymph sheaths of the blood-vessels, but it also extends into surrounding parts and into the meshes of the neuroglia; sometimes even the pericellular spaces around the ganglion cells are filled with such small-cells. We also find hyperæmia and serous infiltration of the tissues, with secondary conditions of swelling. Not infrequently the evidences of degeneration of the nerve cells and fibres are found to extend diffusely over large areas, while the infiltration occurs only in scattered foci. In other cases, however, the swelling and degeneration are not alone less widespread than the cellular infiltration, but may even be confined to the foci of infiltration, while the remaining tissues are almost unchanged. Sometimes the nerve fibres and ganglion cells are well preserved, even within the zone of infiltration, and evidently are only affected at a late period of the disease. This indicates that the inflammatory process is first manifested in the walls of the vessels. More or less extensive hemorrhages not infrequently accompany the infiltrations. Granular corpuscles in the meshes of the neuroglia become more numerous the longer the process lasts. Even in cases which have lasted only a few weeks we sometimes find the walls of the blood-vessels thickened by cellular proliferations and the lumen diminished by thickening of the intima (endarteritis obliterans).

In a third group of cases the chief feature is a condition of softening, due to infiltration with granular corpuscles. The foci may have the consistence of porridge, or they may even be diffluent on section, leaving vacuolæ. The softening spots consist almost entirely of granular corpuscles, together with detritus of the nerve tissues. In sections which have been stained with Weigert's "medullary-sheath stain," the softened spots appear as brownish-yellow or colorless patches. The vessels show even more pronounced changes than in the previous group. Thrombi are found in some of the vessels, and these may be responsible for a part of the softening. There are also hemorrhagic forms of inflammatory softening; in the slightest grades capillary hemorrhages are found in the softened spots and surrounding parts, and give rise to a speckled appearance.

As a matter of course there are numerous transitions between the three forms just described. A transverse lesion is followed regularly by ascending and descending degenerations.

Acute Disseminated Myelitis.—In this form of disease the various foci exhibit a pronounced vascular character; small vessels form the centre, around which are grouped the swelling and degeneration of the tissues, as well as the infiltration with round cells and granular corpuscles. Larger foci involve several vessels, but even here we find distinct signs of vasculitis, viz., distention of the vessels with blood, small-cell infiltration of the walls of the perivascular and adventitial lymph sheaths, and deposit of granular corpuscles. In older cases there are not infrequently thickenings of the walls of the vessels, especially of the tunica intima. The infiltration with granular corpuscles may be so dense and the degeneration of the tissues so pronounced that the appearances of softening are produced; in other cases hemorrhages are present.

Purulent Myelitis.—Abscess of the cord is of rare occurrence. Infection-producers may enter the cord in three ways: after injury to the cord with direct infection from the outside, through the lymphatics, or through the blood-vessels. If the bacteria enter through the blood-vessels, they may be simply carried along by the current of blood or they may be conveyed in emboli. The latter give rise, in the nervous tissues, to suppurative softening. Apart from traumatic purulent myelitis, the disease is most frequent after suppurative spinal meningitis.

Chronic Myelitis.—Histologically the diseased parts of the cord exhibit either degeneration and sclerosis or a condition of softening, with or without degeneration and proliferation of the glia.

In the former event we find swelling and segmentation of the axis cylinders, fatty degeneration of the medullary sheaths, the formation of hyaline bodies and corpora amylacea. The disappearing parenchyma is replaced by proliferating neuroglia tissue. The blood-vessels present cellular infiltration of their walls (especially of the adventitia, but sometimes of the media and intima), thickening of the walls, adhesion and obliteration of their lymph sheaths, and often dilatation of the perivascular lymph spaces. In some cases there are no decided changes in the vascular apparatus, but the myelitic foci have peculiar relations to the vessels, inasmuch as we often find more or less changed vessels at the centre of the diseased foci, or tracts of degeneration follow the course of the vessels.

The second form of chronic myelitis is that of softening. It is difficult to decide whether the spots of softening are the result of an inflammatory process or of a simple disturbance of circulation. If the softening is owing to infectious or toxic causes, the process may continue as long as these causes are active. It must also be remembered that softening often causes disturbance of circulation in its vicinity, and that the neighboring parts are in a condition of more or less marked œdematous swelling. Hence the softening may continue even after the toxic or infectious agent has ceased action.

With regard to the secondary degenerations of the cord, which are found after myelitis, we refer to other articles in the present series.

Diagnosis.—Acute myelitis must be distinguished from meningitis. The latter affection is very much rarer than acute myelitis, apart from those cases in which it is associated with inflammation of the cerebral pia matter. In meningitis the pains in the back and limbs, the cramps in the muscles, and the hyperæsthesia, are much more marked than in myelitis, and usually persist for a much longer time. Paralytic symptoms are not pronounced, and the bladder and rectum, as a rule, are unaffected. In myelitis, on the other hand, the initial irritative symptoms are often entirely absent, or, in the very large majority of cases, soon give place to anæsthesia and motor paralysis. With the exception of certain cases of inflammation of the cervical cord, fever is usually absent or slight in myelitis; in meningitis there may be decided febrile movement.

In two cases I have seen acute myelitis mistaken for acute articular rheumatism—once in a child suffering from compression-myelitis dependent upon Pott's disease, another time in an adult with extremely acute dorsal myelitis. In both patients the joints of the lower limbs were very tender on pressure, and in the adult there was high fever. In the former, however, examination of the spine revealed a well-marked kyphosis, the loss of power was disproportionate to the apparent severity of the pain, and the tendon reflexes were greatly exaggerated. In the latter the patient also suffered from rapid pulmonary phthisis, which explained the high fever; the pains were not confined to the joints, but were also marked in the muscles, and the lower limbs were anæsthetic (anæsthesia dolorosa).

Hysteria is sometimes mistaken for myelitis, especially when it occurs in young females; or, *vice versa*, myelitis is sometimes, though less frequently, regarded as hysterical paraplegia. The occurrence of other undoubted evidences of hysteria is an important point in diagnosis; but too much stress should not be laid upon this feature, since it must be remembered that hysterical individuals are also liable to be attacked by myelitis. The etiology should also be taken into consideration, and, in the absence of any of the causes previously mentioned, the diagnosis of myelitis in a young female should be looked upon with suspicion. In hysterical cases, however, the evidences of serious organic lesions of the cord are always wanting. There is no pronounced wasting of muscles, no change in their electrical excitability, no loss of power of the bladder and rectum. On careful observation, moreover, it is often found that the apparent paralysis varies in different positions of the body, and that there are sudden changes in motility which remain inexplicable on the theory of an organic disease of the cord.

The diagnosis from hemorrhage of the cord is usually easy, except in cases of hemorrhagic or apoplectiform myelitis, when the symptoms have come on with extreme rapidity. Hemorrhage into the spinal cord is extremely rare, except as the result of injury. The symptoms of motor paralysis attain their utmost severity at once, and then, unless the hemorrhage is situated high in the cervical region, begin to improve slowly up to a certain point. With the exception of the suddenness of the onset, and the previous occurrence of traumatism, there is really no means of differentiating spinal hemorrhage from acute myelitis. In the majority of cases, indeed, the hemorrhage is followed by myelitis, either as the result of the injury to the elements of the cord from the traumatism, or as the outcome of the irritation excited by the clot.

The diagnosis of acute disseminated myelitis is extremely difficult and often impossible. Great importance attaches to the etiology of the disease, as almost all the reported cases have followed traumatism or an infectious or toxic condition. When the process results in paraplegia a probable diagnosis can be made if ocular symptoms are marked, or if there is an early development of bulbar or cerebral symptoms (scanning speech, tremor, hallucinations, mental obtuseness, etc.). When the disease is manifested by an acute ataxia, an important diagnostic feature is the preservation or even exaggeration of the tendon reflexes. Like the paraplegic variety, the ataxic form is also attended by bulbar and cerebral symptoms.

In the majority of cases of compression myelitis the primary lesion is caries of the vertebræ, and, as a general thing, the deformity of the spine is so pronounced that there can be very little doubt with regard to the diagnosis. In Pott's paraplegia, moreover, the exaggeration of the cutaneous and tendon reflexes may precede other symptoms for a considerable period, and may persist after other evidences of myelitis have disappeared. In addition, the sensory symptoms are usually much less pronounced than those in the motor sphere, and may even be entirely absent, despite complete paralysis of the limbs. In a few cases, however, particularly when the patient has been confined to bed on account of some other disease, spinal deformity may not be noticed, and the myelitis is then apt to be regarded as primary.

When compression myelitis is secondary to cancer of the vertebræ, the recognition of the nature of the primary disease usually depends on the presence of a primary cancer in some other part of the body, on the violence of the pains in the paralyzed parts (especially if associated with anæsthesia), and on the presence of a deformity of the spine which seems to be due to an irregular enlargement of the vertebral arches or lateral masses. It must not be forgotten, however, that cancer of other parts of the body may be associated with ordinary vertebral caries. In a case of this kind recently under my observation, I made the diagnosis of compression myelitis from vertebral cancer, but the autopsy proved that the disease had been an ordinary Pott's paraplegia.

Diagnosis.—Railway spine, when due to chronic myelitis or meningomyelitis, may prove a source of great difficulty in diagnosis, especially because the element of malingering so often comes into play in this condition. When this factor can be excluded, the diagnosis is based on the slow development, at a variable period after the injury, of symptoms which point to disseminated focal lesions of the cord, viz., irregularly distributed paralyses, various paræsthesiæ, pain in the spine and limbs, disturbances of micturition, localized atrophies of muscles. A depressed and irritable condition of the mental faculties, with loss of memory, is quite common in this condition.

The diagnosis of chronic compression-myelitis is made in the same way as that of the acute form, except that the symptoms develop much more slowly. Acute exacerbations are particularly apt to develop in this form of the disease.

Chronic myelitis can be distinguished from the persistent paraplegia left over after an acute attack only by the history of the onset of the illness. When, for any reason, the patient is unable to furnish the previous history, the diagnosis is impossible.

Tumors of the spinal cord or its membranes are rare, and their differential diagnosis from chronic myelitis is extremely difficult. The clinical history of the former consists essentially of symptoms of irritation of the nerve roots, followed by those of compression of the cord. In some cases, however, the latter precede the former. The compression of the nerve roots sometimes lasts a long time before the evidences of compression of the cord make their appearance. Probably the most important point in the differential diagnosis is the great variation which is sometimes noticed in the severity of the symptoms. In addition, it is found not infrequently that the first evidences of compression of the cord occur in the form of spinal hemiplegia, owing to the fact that the tumor often develops first in one lateral half of the cord.

Chronic myelitis is not apt to be mistaken for hysterical paraplegia, because the latter disease begins much more abruptly than the former.

The diagnosis of the localization of the inflammation in the cord depends upon the grouping of symptoms, for which we refer the reader to the section on clinical history.

Prognosis.—Complete recovery from acute myelitis, with the exception of the compression-myelitis of Pott's disease, is a comparatively rare result. Incomplete recovery is by far the most frequent termination, although a fatal issue is by no means uncommon. Other things being equal, the disease is more apt to end fatally the higher the location of the lesion in the cord. If the centre for the phrenic nerve has been attacked, as shown by paralysis of the diaphragm, recovery is extremely rare. The occurrence of bedsores is likewise of grave import, particularly if they develop at an early period.

When they occur after the disease has lasted a long time, they often heal quite rapidly under suitable treatment. Mild cystitis is so common in myelitis that it can hardly be regarded as aggravating the prognosis; but in severe cases, especially if the bladder is completely paralyzed, there is always danger of the production of acute interstitial nephritis. The latter affection is almost inevitably fatal at an early period, though in some cases it seems to pass into a stage of quiescence.

The prognosis as regards recovery is also so much less favorable the greater the degree of implication of the gray matter, as evidenced by rapid atrophy of the paralyzed muscles and by the presence of the reaction of degeneration in these parts. But it must also be remembered that even the most marked atrophy of the muscles and complete abolition of their electrical irritability do not entirely preclude the possibility of a very satisfactory degree of recovery. I have had under observation a patient in whom the limbs were completely paralyzed and wasted to the extreme, and the reaction of degeneration was present except in those muscles in which no reaction could be obtained (even the intercostals were partly paralyzed); and yet this patient, at the end of a year and a half, was able to walk about and to perform her duties in such a satisfactory manner that she requested her discharge from the hospital.

The occurrence of a spastic condition of the lower limbs constitutes an almost insuperable obstacle to any further improvement. The degree of motor power which is acquired in these cases, however, is usually quite considerable, and the patients are often able to move about quite freely, unless the rigidity of the limbs is excessive.

Pott's paraplegia generally offers a favorable prognosis, unless the vertebral caries itself, or its sequelæ, constitute a serious menace to life. Improvement in apparently hopeless cases sometimes comes on quite suddenly, and the patient may recover even from a number of severe attacks. In these cases there is always danger of a relapse so long as the tendon reflexes remain exaggerated.

The prognosis of chronic myelitis is always grave. Even chronic compression myelitis, which, of the different forms of the disease, presents the most favorable outlook, rarely terminates in recovery. Unless the slow course of the spinal inflammation is interrupted by acute exacerbations, the patient may linger for years. The longest lease of life is enjoyed in those cases of transverse myelitis in which the disease does not extend up the cord. The greatest danger in these cases arises from the development of cystitis and secondary interstitial nephritis.

In the syphilitic forms of chronic myelitis we are sometimes able to secure a fair degree of recovery, especially if treatment is begun before the disease has extended across the entire section of the cord. But even here it will be found that complete recovery rarely takes place.

It is held by many writers that cases of railway spine, which is probably due to chronic myelitis and meningomyelitis, usually recover; but this statement does not agree with the experience of the majority of unbiassed observers.

Treatment.—The most important indication is to secure as absolute rest in bed as is possible under the circumstances. As soon as any symptoms which suggest the onset of myelitis make their appearance, the patient should take to bed and remain in the recumbent position. The wants of nature should be attended to with the aid of the bedpan, in order to avoid, as much as possible, movement during the acts of urination and defecation. Rest is, in my opinion, by far the most important remedial agent at our command. It is often difficult to determine at what period it is best to allow the patient to begin to exercise the paralyzed limbs, but it is always better to err on the safe side. I have seen very marked improvement in a number of apparently hopeless cases in which this plan had been faithfully carried out for a period of a year to a year and a half.

Contracture of the tendo Achillis is a very common sequel of all forms of myelitis, and it has been suggested that the pressure of the bedclothes upon the feet may exercise some influence in the production of this unfortunate symptom. In order to obviate this, the bedclothes may be suspended on a barrel hoop placed across the lower part of the bed. In a considerable number of cases, however, the contracture will develop despite this precaution.

Next to rest, cleanliness is all-important, because the neglect of cleanliness is very apt to result in the production of bedsores. This usually necessitates the most careful nursing. The external genitalia and gluteal regions must be frequently washed, and thoroughly but gently dried. At the slightest indication of the development of a bedsore, an air-ring should be placed under the buttocks, care being taken that the joints of the ring are not sharp. If the evidences of dermatitis are not relieved speedily in this way, the patient should be placed on a water-bed.

The bladder must be carefully looked after. Catheterization must be resorted to at once, as soon as the bladder is no longer thoroughly emptied. The greatest precautions must be taken to keep the catheter thoroughly aseptic in order to prevent the introduction of germs. Even a soft-rubber catheter must be introduced very gently, because the mucous membrane of the bladder is very apt to be congested, and bleeds readily under such conditions.

Counter-irritation is useful in very many cases. During the first stages of an acute myelitis the application of dry cups along the spinal column may be attended with some benefit. Vigorous counter-irritation with fly blisters is indicated at a later period, but these do not promise much improvement after the disease has become stationary. In this connection I may mention that in a case of chronic myelitis in which all hope of recovery had long been abandoned, I noticed that a remarkable degree of permanent improvement followed the development of a large carbuncle on the back.

The actual cautery is also recommended. I have never seen any benefit from its use, except in rare cases of compression-myelitis. In such cases, however, it sometimes acts with remarkable rapidity.

Among other non-medicinal agents may be mentioned baths and electricity.

As a rule, the patient cannot tolerate extremes of temperature. I usually recommend a sitz bath at a temperature of 100° to 110° F., in which the patient remains for from fifteen minutes to half an hour. If spastic phenomena are well marked, the bath may be as hot as can be borne by the patient. When the spastic phenomena are not prominent, the patient may receive a full bath at a somewhat lower temperature. It is well in such cases to follow the bath with rubbing and massage.

Electricity, when faithfully and persistently applied, is often productive of excellent results. It is employed either as a spinal current or directly to the paralyzed or contractured parts. When applied to the spine one large electrode should be placed over the site of disease, the other on some indifferent part of the body or spine, and they should be held constantly in position for from three to five minutes. The direction of the current seems to be immaterial. Much better results are obtained from applying the current directly to the paralyzed parts. In the majority of cases the galvanic current is preferable, but the faradic current may be used when the muscular contractility remains normal. The current should be merely strong enough to produce visible contraction of the paralyzed parts. The constant stabile galvanic current is used in the treatment of contractures, the electrodes being applied directly over the nerves supplying the contracted muscles. At the same time the interrupted galvanic or faradic current may be applied to the antagonists. In my own experience very little, if any, benefit has been derived from spinal galvanization; but, on the other hand, I have obtained most excellent results from the patient, persistent use of local electrization.

This even holds true of cases of marked contractures of the lower limbs, but a good deal will then be gained by the electrical treatment combined with tenotomy of the contractured parts.

Medicinal treatment does not play a great part in the management of this disease. Ergot has been highly recommended in the acute stages, and hypodermic injections of ergotine have been employed at the onset of hemorrhagic myelitis. I have never seen the slightest advantage from its use, and have abandoned it altogether. Iodide of potassium has also been recommended very highly, and Dr. Gibney speaks in the most favorable terms of its administration in large doses (even ʒ i–ij, t.i.d., in children), in the compression myelitis of Pott's disease. It is very difficult to form an opinion upon the value of this agent in myelitis, though it has seemed to me to exercise a certain amount of beneficial effect. But I have employed it so faithfully, and with such little effect, in Pott's paraplegia, that I am compelled to deny any special influence in this form of the disease. Weir Mitchell has recommended suspension in this disease, but further experience has not shown that this measure possesses much value.

Strychnine is the only medicinal agent which has seemed in my hands to have a decided influence on the course of the disease. This drug may be administered as soon as the acute symptoms have ceased to advance, and it is by no means contraindicated by the occurrence of spastic symptoms. The dose may be raised gradually from gr. $\frac{1}{48}$ to gr. $\frac{1}{12}$, t.i.d., and may be given continuously for months.

So long as any improvement is observed, the patient should be kept as quiet as possible. Later, gentle exercise may be allowed, but the patient must not be permitted to tire himself. Sexual intercourse is particularly to be avoided. Even after the condition of the patient has been stationary for a long time, benefit is sometimes derived from another course of treatment with electricity, counter-irritation, and strychnine.

Leopold Putzel.

SPINAL-CORD DISEASES: POLIOMYELITIS ANTERIOR, ACUTE AND SUBACUTE.—Under this name we recognize a form of paralysis which occurs, as the name implies, most frequently in young children, especially during the period of first dentition. It is by far the most common form of paralysis to which children are subject and presents a well-marked clinical picture. A healthy child is suddenly found to have lost the use of one or more extremities, or of some individual muscle of an extremity. This loss of power may or may not have been preceded or accompanied by febrile disturbance; occasionally convulsions have ushered in the paralysis, but never is the latter accompanied by loss of sensibility. Any of the voluntary muscles of the limbs or trunk may be affected, but the functions of the bladder and rectum are left undisturbed. Such is a general description of the onset of the disease. Soon, however, many of the affected muscles begin to recover their power; this recovery may be almost complete, the paralysis being finally limited to a few individual muscles; or, on the other hand, the greater part of the muscles originally affected may remain paralyzed, and later on undergo atrophy and degeneration. In this atrophy and retardation of growth the bones take part, giving rise to shortening of the affected extremity, while other deformities occur as a result of the unopposed action of the healthy antagonists of the disabled muscles.

Synonyms are numerous, and owe their variety to the views held by different observers as to the nature of the disease, before its pathology had been established. They are: Infantile spinal paralysis; Spinale Kinderlähmung (Jacob von Heine); Paralysie spinale; Paralysis infantilis spinalis; Infantile paralysis; Kinderlähmung; Paralysie infantile; Paralysie des petits enfants; Essential idiopathic or functional paralysis of children; Paralysie essentielle de l'enfance (Rilliet and Barthez); Essentielle Kinderlähmung; Dental paralysis (Underwood, 1784); Poliomyelitis anterior acuta; Acute inflammation of the anterior gray horns of the spinal cord (Kussmaul); Téphromyélite antérieure aiguë (Charcot); Acute atrophic spinal paralysis; Paralysie atrophique graisseuse de l'enfance (Duchenne); Regressive paralysis (Barlow); Myelitis of the anterior horns (E. C. Seguin). These various terms were intended by their originators to indicate what appeared to be prominent clinical or pathological characteristics of the disease. Without entering upon the question as to the relative value of a clinical, as compared with a pathological, designation of diseases, there is no doubt that, of all the terms applied to the affection, the best of the first class is that adopted by Heine (Spinale Kinderlähmung, or infantile spinal paralysis). It is true that here even the word spinal would indicate, in a general way, the anatomical location of the lesion which is the cause of the clinical manifestations; but, inasmuch as it serves to distinguish this form of paralysis from other paralyses of cerebral origin, we can pardon this slight offence against unity in terminology in consideration of the completeness with which it serves to distinguish the disease. Of the purely pathological terms we should prefer poliomyelitis anterior acuta, as indicating the seat of the lesion, the term acute being especially applicable to the disease as it occurs in children. Seguin's myelitis of the anterior horns purposely omits the term "acute," in order to include the subacute and chronic cases of the disease which sometimes occur in adults. The designation essential or idiopathic paralysis can certainly no longer be applied to a condition which has so well defined a pathology as poliomyelitis anterior; and it seems inexcusable that so excellent a pathologist as Niemeyer should have retained this inaccurate term in the seventh edition of his work, published in 1867, at a time when the gross lesion had already been demonstrated.

Historical Account.—This disease has in all probability affected children for hundreds of years, without being differentiated by medical writers from other forms of paralysis. As early as 1784, however, Michael Underwood[1] described a form of paraplegia which occurred in teething children, and especially in those suffering from bowel troubles, which in its clinical history resembles the disease now known as infantile spinal paralysis. In 1836 John Badham,[2] of London, described a similar affection occurring in children, which he considered cerebral in origin. Notwithstanding these publications, the condition did not receive general clinical recognition until, in the publication of J. von Heine's[3] great monograph, entitled "Beobachtungen über Lähmungszustände der unteren Extremitäten und deren Behandlung," 1840, the symptom group of the affection was clearly defined and this form of paralysis distinguished from other forms of paralysis occurring in children. The picture of the affection in question, which Heine gives us in the very first edition of his work, is so accurate in detail that later clinicians had but little to add to the symptomatology of the disease. But, although no objective or subjective manifestation of the disease escaped the notice of this accurate observer, yet he remained ignorant as to the true pathogenesis of the affection. So logical a mind, however, could not but suspect that the disease was the result of an actual lesion of the nervous system, and accordingly we find him indicating the spinal cord as the most probable seat of the lesion. In the second revised edition of his work[4] he terms the disease Spinale Kinderlähmung, or infantile spinal paralysis. Duchenne, de Boulogne,[5] in 1855, besides accurately describing the affection, took a great stride in the direction of precision in diagnosis as to the character and extent of the paralysis, by discovering the relation which the faradic current bears to muscles which are the seat of this paralysis. Here, then, the first stage in the history of the disease may be said to have been completed. But, although clinically the affection was established upon a firm basis, its pathology was yet unknown. Rilliet[6] and Barthez,[7] basing their statement upon negative findings in cases of this disease upon the autopsy table, considered the affection primarily a muscular one, and hence termed it essential paralysis of children, the term essential referring to the idiopathic or non-organic nature of the paralysis. Although this view gained many followers, and some of eminence, yet it was not long before positive findings upon the autopsy table exploded this theory as to the pathogenesis of the disease. In 1863 von Reinecker and von Recklinghausen[8] published the autopsy of a case in which both lower extremities had been the seat of infantile spinal paralysis. Upon a macroscopic and minute examination of the cord it was found that the ganglion cells of the anterior gray horns and the nerve fibres of the antero-lateral columns of that portion of the cord which gave origin to the nerve fibres supplying the paralyzed extremities had undergone atrophy and degeneration (*Deutsche Klinik*, January 31st, 1863). The accuracy of these pathological data was confirmed by similar findings by Cornil,[9] Bouvier and Laborde,[10] Prevost,[11] Lockhart Clarke,[12] and later on by Charcot[13] and Joffroy,[14] Vulpian,[15] Roger and Damaschino,[16] and others.

We cannot close this brief historical account of the affection without reference to the studies of Erb,[17] as to the reactions produced by the galvanic current upon the muscles which are the seat of this spinal paralysis. Finally, we should refer to the identity of this affection, as far as the pathology is concerned, to a similar but more chronic affection, occurring in adults, which was first mentioned by Duchenne fils[5] in 1872, but not thoroughly studied until E. C. Seguin,[18] in 1877, devoted an admirable monograph to the subject. In the last few years many writers have sought to ascribe an infectious character to this disease. This has been based not so much upon bacteriological or pathological findings, but upon the fact that the disease has been found to occur in occasional epidemics, one specially reported by Medin.

Other observers, like Marie, Strümpell, Seligmüller, have reported smaller epidemics. Some have reported the occurrence of the disease in several members of the same family.

PATHOLOGY.—The anatomical seat of the primary lesion of this form of paralysis is the spinal cord. This has been positively determined by numerous autopsies. It consists of an inflammatory process, acute in character, affecting in the first instance the anterior horns of gray matter. The lesion is at first diffuse, but as soon as the acuteness of the inflammatory process subsides it becomes limited in its longitudinal extent to circumscribed portions of the cord, in which even at the outset the inflammation had been most intense; this is most apt to be about the cervical and lumbar enlargements. At these points further changes soon occur, the most important of which are destruction and atrophy of the large multipolar ganglion cells situated in the anterior cornua.

This destruction and atrophy are not limited to the cells, but involve the nerve fibres in this region, and even the cells and nerve fibres of the posterior horns may become involved; sometimes the lesion extends into the white substance of the antero-lateral columns. As a result of the primary lesion in the ganglionic cells of the anterior gray cornua, we have secondary changes taking place in the nerves which take their origin from the affected portion of the cord, and in the muscles to which these nerves are distributed. These changes are atrophic and degenerative in character.

Spinal Cord. I know of no autopsies showing the condition of the spinal cord during the acute stage of infantile paralysis, inasmuch as the disease of itself is rarely, if ever, fatal. We can therefore make no positive statement as to the condition of the nerve centres during this acute stage; we can conclude, however, from our findings later on, that the disease is, in the first instance, an acute parenchymatous inflammation affecting chiefly the ganglion cells of the anterior horns of gray matter in the cord (Charcot).[19] When the autopsy has been made within two years after the onset of the disease, but slight changes can be observed in the cord by the naked eye, although the microscope reveals decided and constant alterations. These changes are typically shown in a case examined by Dr. Fred. Taylor, the particulars of which were presented to the London Pathological Society. It was that of a girl, three years of age, who suddenly became paralyzed, at the age of fifteen months, in the left leg. The paralysis was supposed by the friends to be the result of a blow; the principal symptoms observed at the time of the onset were fever and pain in the left lower extremity, followed by paralysis, and, later on, the development in the paralyzed member of the ordinary clinical phenomena of infantile spinal paralysis. The child was treated by galvanism for five or six months, and the paralysis somewhat improved; but at the age of three years death resulted from bronchopneumonia. Post-mortem examination of the spinal cord showed a diminution in the size of the transverse section of the left half of the lumbar region of the cord. This diminution was most marked anteriorly, although also observable in the left posteror horn of gray matter. The anterior roots of the spinal nerves at this level were smaller than the corresponding roots on the right side. The posterior nerve roots were unaffected. On microscopical examination of a section taken from this portion of the cord it was found that there were but few ganglion cells in the left anterior cornu, and even those remaining were ill-defined and smaller in size, paler in color, and possessing fewer and shorter processes than those of the right side. The absence of these cells was most marked in the external and median groups of ganglion cells.

The nerve fibres passing from the anterior root to the cornu of the affected side were diminished in number and size. The main substance of the anterior horn consisted of a very dense and felt-like tissue, made up of matted fibres, "an increase and condensation of the normally open and spongy basis-structure of the part." In this felt-like structure the remaining nerve cells were embedded; no granular corpuscles were visible. The white matter of the left antero-lateral column was found denser, the connective tissue being increased; while the nerve tubules were smaller than usual and deficient in axis cylinders.

This case shows the most prominent changes found in the cord in cases in which the autopsy has been made comparatively early. Occasionally areas of softening are found, more or less well defined, in different portions of the anterior horns, and at such places there is generally a total absence of proper nerve tissue, ganglion cells, and nerve fibres; but instead there is a low form of connective tissue, filled with large numbers of leucocytes and simple nuclei. In these recent cases the blood-vessels are found dilated. The cord may be affected at any level, although the cervical and lumbar regions are most frequently the seat of permanent lesion. The severity of the inflammatory process varies greatly, so that in some situations there is almost complete recovery, while in other places there is utter destruction, degeneration, and atrophy of nerve cells and fibres. The ganglion cells have been found in all stages of various forms of degeneration; many of them are entirely destroyed, and those that remain are found in a condition of extreme atrophy, having suffered great contraction and diminution in size, the cell processes, and frequently their nuclei, being destroyed. Sometimes the atrophy is of the pigmentary variety. In a case reported by Dr. Humphreys,[20] of Manchester, the number of the polar cells remaining in the affected portion of the anterior horns was compared with the number in the corresponding healthy portion of the cord, and it was found that while on the healthy side there were fifty-two ganglion cells, on the diseased side there were but thirteen.

Should the autopsy be made, as more frequently happens, many years after the original lesion has taken place, we would find changes similar in character to those described, but further advanced in a retrograde direction. The changes can be admirably studied in a collection of autopsies reported by Seguin in his work, and quoted and amplified by Seligmüller in his article on this subject in Gerhard's large work on "Diseases of Children." These changes are now readily appreciated by the unaided eye. The affected portion of the gray anterior horn is apt to be markedly shrunken and atrophied; sometimes even the posterior gray horns will be found slightly smaller than on the opposite side. The white columns, and especially the antero-lateral columns, are found atrophied and sclerosed, sometimes to a limited extent on a level with the lesion, at other times to some distance above and below the lesion; indeed, the transverse section of the cord on the affected side will show a general diminution in size as compared with that of the healthy side. The anterior nerve roots at the level of the lesion are apt to present a grayish, translucent appearance and a diminution in size.

The microscope also shows the more complete atrophic changes which the nerve tissue has undergone; the diseased portion of the atrophied anterior horn is found to contain but few or no multipolar ganglion cells, and even those remaining are shrunken, with their processes atrophied, and found to have undergone various stages of granular and pigmentary degeneration. These cells have been replaced by connective tissue which has become contracted and hardened.

The changes in the white columns are apt to be less marked, although, as already stated, there is some diminution in the size of the antero-lateral column, to a greater or less extent, above and below the lesion. These changes can scarcely be termed sclerosis. They consist of a certain degree of hyperplasia and contraction of the connective tissue, and an increase of the nuclei of the neuroglia. Amyloid corpuscles are also found. The anterior nerve roots undergo a more decided atrophy than the antero-lateral columns; the number of their medullated nerve fibres is decidedly diminished. Many of them have lost their myelin, leaving only the axis cylinders, and, as a whole, the nerve root has become thinner and of a grayish and translucent appearance. The diseased foci in the gray matter are apt to be quite sharply defined, although at the onset of the disease large portions of the cord, above and below the areas of softening, are found congested; these portions, however, are not the seat of destructive changes, and they recover as soon as the inflammatory process subsides. This probably corresponds to the regression which occurs in the symptoms, thus leaving only those muscles paralyzed which derive their nerve supply from the softened areas.

All of these degenerative changes in the cord which I have described as characteristic of poliomyelitis anterior acuta take their origin in an inflammatory process in the vascular (arterial) system of the spinal cord. Such inflammatory changes are found even in the large blood-vessels of the cord, even in the walls of the arteria spinalis anterior and its branches (Socki). Manfredi, Widal and Besançon, and others have produced degenerative changes in the anterior horns of the spinal cord of animals by injections of pure cultures of various microbes. Widal was successful in producing the lesion in seven out of one hundred and seventeen rabbits which he had inoculated with streptococci. Thonot and Masselin believe that the coli bacilli can produce the lesion.

Schultz (1901), in a recent case of this disease in which the onset resembled meningitis, but the subsequent history and, months later, autopsy showed it to be a case of poliomyelitis anterior acuta, obtained by lumbar puncture the spinal fluid and isolated therefrom the meningococcus of Weichselbaum-Jaeger. The occurrence of this disease as a complication or sequel of the acute infectious diseases, such as measles and scarlet fever, would lead one to suspect that this form of inflammation of the cord, like the types of cerebro-spinal meningitis, may be the result of a mixed infection of the primary disease infection and the various pus organisms. Some observers have been led to believe that the toxins of various infections in distant parts of the body may be carried to the cord, and set in motion the inflammatory changes in the blood-vessels which result in the degenerative changes in the anterior horns of the cord.

Changes in the Paralyzed Muscles.—Within a few weeks after the paralysis has taken place the paralyzed muscles become the seat of characteristic pathological alterations; not only do they become atrophied and smaller in size, owing to disuse, but they undergo active degeneration. Portions of such muscles can be obtained for examination by means of an apparatus like Duchenne's trocar, so that the various stages of degeneration can be studied. The first stage in the degeneration is, undoubtedly, ordinary atrophy of the muscle fibres. The fibres are narrower and diminished in diameter, the transverse as well as the longitudinal striations are finer and apparently more numerous. This apparent increase in the number of the transverse striations is due to the diminished thickness of the contractile discs. These phenomena are seen in muscles that have become atrophied from disuse, and are not distinctive of atrophy due to spinal-cord lesions.

In infantile spinal paralysis, however, the muscles soon begin to show further changes. Certain portions of the degenerating muscles begin to lose their striations entirely; here and there we find contractile discs replaced by granular matter, until the whole fibre has become to a great extent granular. This granular matter is probably protein in character, being at first soluble in acetic acid and insoluble in ether; later on, however, the granules are found to be insoluble in acetic acid and soluble in ether, which shows that the protein granules have been replaced by fatty matter. Here and there will be found pigment granules. The muscle corpuscles are found to have increased in number, and in fibres which have undergone a complete granular fatty degeneration we shall find no trace of proper muscular tissue, the fibres being replaced by these muscle corpuscles embedded in a mass of fat granules surrounded by the sarcolemma. This may be termed complete muscular degeneration, and is the inevitable fate of muscles which have not recovered in the earlier stages of ordinary atrophy. Some of the muscles thus degenerated become the seat of further changes. The connective-tissue corpuscles found in the endomysium and perimysium increase largely in number, and form themselves into fibrous connective-tissue bands, which compress the degenerated muscular fibres; gradually the fat is absorbed, and what was formerly muscular tissue has become a firm fibrous cord. This change is known as cirrhosis of the muscles, and does not occur until long after the muscles have undergone hopeless degeneration. These fibrous bands are apt to undergo contracture, which results in structural shortening and deformity. Rarely the connective-tissue corpuscles, contained in the fibrous bands, in their turn become distended with fat, thus giving rise to a deceptive fulness instead of the previous atrophy. This second fatty deposit may be so great as to lead to a diagnosis of pseudohypertrophic paralysis. When such a deposit of fat does occur it is in infantile paralysis of long standing. The ligaments and bony structures also take part in the general lowering of vitality which characterizes the paralyzed limb. The bones do not grow with anything like the vigor of the corresponding bones on the healthy side. This retarded growth results in diminution in the length as well as in the thickness of the bone; the prominences, ridges, etc., are less marked; the bone is more readily bent; closer examination shows that the compact tissue is relatively diminished, while the cancellous tissue is coarser and has scattered through it a larger number of fat cells. The bones are thus softer, but microscopically no changes in the structure of the bone tissue are found. All this results in a weakening as well as a shortening of the bone, and, necessarily, of the limb. Seeligmüller considers this bony change mostly the result of the disuse which is necessarily connected with the paralyzed member; the fact, however, that these atrophic bone changes are noticed in limbs in which the paralysis is insufficient to interfere with the adequate use of the member, would militate against this view, apart from the fact that the changes indicated seem to be far more radical than would be accounted for by ordinary functional atrophy due to disuse.

Partly in consequence of this bone atrophy, and partly as a result of the relaxation of the ligaments and muscles, the joints are apt to become altered. In extreme cases the ends of the bones which form the joint are not in contact, but hang apart from each other, so that the finger can almost invaginate the skin and ligaments between the joint surfaces. As a result, the articulation admits of abnormal mobility—motion resulting in subluxation of one joint surface upon the other. These changes are most readily observed where a muscle which passes over a joint is more or less completely paralyzed; thus, when the deltoid is paralyzed in the arm, the shoulder-joint is apt to show the above-mentioned changes very markedly. No pathological changes have been observed in any other organs of the body.

ETIOLOGY.—From modern investigations we are led to believe that poliomyelitis anterior is an infectious disease occurring sporadically, although rarely also in epidemics. Whether the disease has for its causative pathological agent a specific germ or its toxin, or whether it can be produced as a result of the activity of various germs, such as the pus organisms, etc., is not yet determined. That the disease is an infection is most probable, and from this starting-point all other factors in etiology are to be viewed as subordinate. Poliomyelitis anterior acuta is no exception to the rule in the obscurity of its etiological chapter. We know little or nothing as to the causes which produce the disease. We must, therefore, satisfy ourselves with an inquiry as to the causal relation borne by certain conditions, which precede the appearance of the paralysis, to the more or less acute inflammatory process in the anterior horns of the spinal cord. Before proceeding to this study there are certain factors which can be eliminated, and thus limit the field of inquiry.

Infantile spinal paralysis is by far the most frequent form of paralysis to which children are subject. Jacob von Heine found, among 192 paralyzed children, 158 suffering from this disease.

The disease in its acute form is peculiar to childhood, and is most frequent in the first, second, and third years of infant life. Duchenne the younger has noted one case occurring at the early age of twelve days. Seeligmüller has noted the oldest of his seventy-one cases as six years, but almost ninety per cent. of all cases reported were under three years of age. Sex is not a predisposing cause, the sexes being affected with about equal frequency.

The disease is found all over the civilized world, so that climate can scarcely be considered as exerting a predisposing influence, nor does the season of the year make any difference, cases occurring indiscriminately at all seasons. Wharton Sinkler (*Amer. Journal of Med. Sciences*, April, 1878) states, however, that forty-seven out of fifty-seven cases occurred in the warm months of the year.

Heine has stated that the disease most frequently affects strong, healthy children; and, indeed, one who sees many of these cases cannot fail to have observed many large, robust little patients whose otherwise handsome physique has been deformed by an attack of poliomyelitis anterior. But, on the other hand, most observers find that the majority of cases occur in children who are weak and delicate, even if a strumous constitution cannot generally be affirmed of them.

One of the most frequent causes assigned by mothers for this disease is "catching cold," particularly exposure to the direct action of a "draught." Or another very common cause, as stated by the parents, is a fall from the arms of the nurse or from a chair. Whether a traumatism of this kind can give rise to infantile spinal paralysis proper is questionable. It is conceivable that spinal paralysis, resulting from hemorrhage into the gray matter of the cord, may follow a traumatism; but this is not poliomyelitis anterior, although the clinical symptoms may be those of the latter disease, and it may be impossible to differentiate these cases from those of inflammatory origin.[20]

The disease being one of the first dentition period, it is natural to look to conditions connected with this process for etiological factors in its production.

There is no question that the process of dentition throws the nervous system of the child into a state of exalted irritability, during which eclampsia, tetany, and other neuroses are commonly observed. These nervous phenomena are chiefly conditions of exalted nervous irritability, in which it is conceivable that the gray ganglion cells of the cord take part. From this irritated condition it is only a step to inflammation. Henry Kennedy has called this disease dental paralysis (*Dublin Quarterly Journal*, vol. ix., February and May, and vol. xxii., August and November). The restlessness of children while teething, the disturbed nutrition, want of sleep, and febrile disturbances common to this period of life, all are sufficient to render the spinal cord more sensitive to slight active causes, such as refrigeration, etc.

It may be objected, however, that all of these influences would affect the spinal cord as a whole, while in this disease only the anterior gray columns of the spinal cord are primarily affected. This might be explained by reference to the fact that motor areas of the cord in infants are much more in demand and further developed than the sensory tract. Infants are in constant motion, the extremities are thrown about whether in health or disease; during the waking hours infants constantly move and throw about the limbs and body; as a result the centres for these movements are supplied with an excess of blood, and hence are more prone to take on inflammatory processes.

Acute febrile conditions are commonly assigned as causes for this disease. It must not be forgotten, however, that the disease is in very many cases ushered in by fever, which is a symptom of the inflammation, and cannot be considered an etiological factor. But there are many cases which occur during the course of, or follow upon, the acute exanthemata—scarlet fever, measles, and typhoid fever. Such cases must be carefully distinguished from postdiphtheritic paralysis, the more so since diphtheria often complicates scarlet fever, measles, etc. Duchenne and Seeligmüller report two cases following upon vaccination.

In many of the cases careful inquiry into the family history of the patient will reveal the existence of nervous affections in other members of the same family—either paralysis, convulsions, or insanity. Thus I have seen infantile spinal paralysis of the leg in a little girl, and paralysis of the upper arm in a younger brother of the first patient.

SYMPTOMATOLOGY.—In discussing the symptoms of this disease it is perhaps wise to take up in order the characteristics of the invasion, the appearance of the paralysis, and lastly, the deformities and contractures resulting from the paralysis.

First, the Stage of Invasion.—Although various prodromal symptoms have been laid down in the text-books as preceding the onset of the disease, yet none of these appears to me to be peculiar to this affection, even in slight degree. The children are irritable, slightly feverish, and suffer from loss of appetite; the bowels are constipated or relaxed; some of the little patients complain of pains in the back and limbs. One observer[21] has noted that these patients refuse to walk, or, if they walk, are easily made tired and wish to be carried. I myself have not noticed the latter symptom as part of the history of my cases, and have found very many cases—indeed, the large majority of my cases—in which no prodromal symptoms at all occurred. Cases may be divided, as regards the character of the invasion, into two classes: First, those in which the onset is shown by high fever, with or without convulsions; second, those in which the stage of invasion is entirely absent, the patient becoming suddenly paralyzed.

Cases belonging to the first class will be found to have either the febrile disturbance or the nervous symptoms most prominent. The patient is suddenly attacked by high fever, 100° to 102° or 103° F., rarely above; there are great thirst and restlessness. At the beginning of this fever there may occur a convulsion lasting a short time, and often followed by others, or the fever may be slight; but the child lies in a state of semi-coma for a few days, from which it gradually rallies, when the friends find one or more groups of muscles, or one or more limbs, paralyzed. The fever may last from a few hours to two or three, or even more, days; but, as a rule, it continues only a few days, after which it subsides, and the parents believe the child to be on the road to recovery. Then suddenly paralysis is discovered to have taken place. If the paralysis is slight, it may not be noticed until the initial fever has long passed, so that the parents will assure the physician that there was no fever before the onset of the paralysis.

In cases occurring during the course of convalescence from measles or some other acute febrile affection, the paralysis is supposed by the friends to be due to the general disease.

In many of the cases, in addition to the fever, with or without convulsions or semi-coma, the patients suffer from diarrhœa and often from vomiting. Hyperæsthesia of the limbs and other portions of the body may also occur. There may be frequent micturition, but there is never paralysis of the bladder or loss of sensation.

The cause of the initial fever would appear to be the acuteness of the inflammatory process in the cord. W. Vogt,[22] however, considers the lesion in the cord a result, rather than a cause, of the fever. The fever is not a constant accompaniment of this disease; it was present in about one-half of my cases. Frequently parents do not notice the fever, which may occur at night, when the child is asleep. When the little one awakes in the morning the paralysis is observed, although the fever, if only of a few hours' duration, may have been overlooked. The antecedent fever is noted, however, in the cases in which it is of longer duration. It has been known to last for twelve days; but in most cases it is of less than two days' duration, and commonly lasts only twenty-four hours. The temperature rarely rises above 103°, or, at most, 104°, and even these figures are exceptionally high. We have no good thermometric records; the diagnosis being never possible before paralysis has set in, and the fever has, as a rule, come to an end, although cases have been reported in which the fever lasted after the paralysis was complete.

Convulsions occur, in the opening stage of this disease, in many cases in which fever is present, and also in some in which there is no rise of temperature. This would seem to prove that the convulsions are not dependent upon the cerebral hyperæmia produced by the fever. It is, furthermore, not probable that these attacks, which are epileptiform in character, are due to lesions in the spinal cord, for the muscles which become convulsed are not only those that are afterward found to be paralyzed, but impartially those of the whole body. Some writers, however, state that the convulsive movements are more violent in those muscles which afterward become paralyzed. The attacks vary in duration, number, and frequency. Frequently only a single convulsion ushers in the disease; at other times the patient is thrown into a status epilepticus lasting some hours, and it is conceivable that in this condition the patient may die, the diagnosis of poliomyelitis not having been made. On the other hand, the convulsion may be so slight as to be entirely overlooked, and, if it take place during the night, the fever as well as the convulsion may be entirely overlooked. The recovery from the convulsion may be complete, or the child may fall into a stupor, and even coma, from which it only emerges when all acute symptoms have disappeared. Frequently the little patient has no convulsions, but still is restless and trembling, or apathetic and drowsy. Either of these conditions may be present in the opening stage of the disease, with or without the fever.

Another symptom, to which we must call attention, is one which accompanies all febrile conditions, but is here particularly prominent, namely, hypersensibility—the patient cannot be touched without feeling pain—he cannot be moved without crying out. Some writers have stated that this exalted sensibility is most marked in the spinal column. My own experience does not show that the little patients ever complain of a sensitive spine. On the contrary, I have found these children very easily handled, and the spine very flexible, this fact forming one of the data for the differential diagnosis between this disease and Pott's paraplegia, although patients may have passed through the initial stage of the malady with more or less of the above symptoms, or so little of them as to escape the observation of the friends; yet the

Second, or paralytic stage, is never omitted, and is, in fact, "the disease" (Rilliet and Barthez). The paralysis may develop very suddenly, the child being paralyzed almost as rapidly as though from apoplexy, or it may develop more slowly, the paralysis gradually extending in the course of one, two, or three days. In the first class of cases a large number of the voluntary muscles of one or more limbs become paralyzed simultaneously; in the second class of cases the paralysis extends from one group to another until the maximum paralysis has been attained. Sometimes the paralysis is so complete that the patient lies without being able to move a muscle. At other times the paralysis is so slight that it is unnoticed until the function of the paralyzed member is interfered with.

However complete the paralysis at first may be, yet it is characteristic of this disease that after a short time (one or more days) many of the paralyzed muscles begin spontaneously to recover their power; this is known as the regression of the paralysis. Spontaneous recovery from the original paralysis may be complete in certain individual muscles, although entire recovery for all the muscles never occurs. Many writers state that in most cases the height of the paralysis is attained at the end of twenty-four hours. My experience leads me to give a longer period for the development of the palsy, certainly not longer than a few days, when the paralysis will cease to extend. Regression, however, begins in many cases as early as the second day, continues rapidly for the first few weeks, then much more slowly, although even up to four or five months the muscles may still undergo spontaneous recovery of power. Any power restored after that is due either to the good effects of treatment or to the use of the limb. However complete the restoration of some of the paralyzed muscles may be, it may be positively affirmed that complete recovery in all the muscles affected by infantile paralysis is impossible.

Muscles affected: All the voluntary muscles of the body may be the seat of this paralysis, except those of the head (Seeligmüller reports one case in which the muscles supplied by the facial were affected), eyes, ears, mouth, pharynx, and larynx. On the other hand, the sterno-cleido-mastoid has been found affected, the muscles of the trunk, including those of the back and abdomen, and, above all, the muscles of the extremities.

The paralysis may affect the back, so that the patient cannot sit or stand; the neck, so that the head falls forward or to the side, and it may affect one or more extremities, giving rise either to crossed paralysis (one arm and the opposite leg), or paraplegia (all four extremities or the two lower extremities), both upper extremities, or the arm and leg of the same side (hemiplegia).

Most frequently only one extremity is affected. Next in order of frequency comes paralysis of both lower extremities, while crossed paralysis and hemiplegia are much rarer. The upper extremity is less frequently affected than the lower, while paralysis of all four extremities is extremely rare, but three cases having been reported in the literature (see Seeligmüller).

It is extremely rare for a limb to remain totally paralyzed, nor do we find in any two cases an exactly similar distribution of the paralysis.

Certain groups of muscles will be found to have escaped the paralysis, and sometimes even portions of the same muscle will retain power, while the rest of the muscle is paralyzed.

The anterior tibial group of the leg and the extensors of the thigh are most frequently affected. The psoas, on the other hand, is rarely affected, even in the most extensive paralysis.

In the upper extremity the deltoid is most frequently paralyzed.

The sphincters of the bladder and rectum are never affected. In this respect we have an important difference between this form of paralysis and that following transverse myelitis. It is true that in some very young children the general disturbance with which the disease is ushered in may give rise to a few involuntary passages, but this is only temporary, and will not be present when the paralytic stage has set in. After the sixth to the ninth month has passed, we can no longer look forward to spontaneous recovery in the paralyzed muscles. Muscles which have not improved until then are apt to remain paralyzed, and go on to the third stage of the disease, the atrophic stage, in which extreme atrophy of the paralyzed muscles is the most prominent symptom. It must not be supposed, however, that the paralyzed muscles do not atrophy until six or more months after they have become the seat of the paralysis. On the contrary, atrophy of the fibres of the paralyzed muscles can be found with the microscope very soon (two or three weeks) after the paralysis has set in, and several authorities claim to have observed atrophy, evident to the naked eye, as early as the third week after the paralysis. In my own cases I do not remember to have observed any evident atrophy earlier than three months after the first occurrence of the paralysis. The cause of this atrophy is, as we have already seen under the head of pathology, not simple disuse of the paralyzed limb, but a cutting off of the trophic influence of the nerve cells of the anterior gray horns of the spinal cord; this results in a disturbance of the nutrition of the muscle tissue as well as organic degeneration of the nerve fibres. Disuse of the paralyzed limb undoubtedly aids in producing a diminution in the size of the paralyzed member. As a result of these causes we have a very extensive atrophy of the paralyzed muscles—so complete that frequently the configuration of the bones, with their anatomical points, can be felt or even seen with startling distinctness. Often all muscular tissue seems to have disappeared, leaving only the bones, connective-tissue bands, and skin. As already explained, however, these atrophic members in the last stages of atrophy may undergo a pseudohypertrophy, owing to the deposit of fat in place of the atrophied muscle fibres. In those muscles which undergo recovery after a certain amount of atrophy has taken place, the restoration of volume in the recovered muscle does not directly follow upon restoration to power. The muscle is only gradually restored to its former size some time after power has returned.

Atrophy is not limited to the paralyzed muscles, but affects the bones and ligaments, and even the blood-vessels; the extent and character of the atrophic changes have already been discussed. There is also atrophy of the skin; it is apt to be more delicate and thinner; it is of finer texture, and paler in color at first, although later on it becomes cyanotic in color, owing to the diminished blood supply in the paralyzed limb. This diminished blood supply is due to atrophy of the blood-vessels and the disappearance of the finer capillaries. The muscular coat of the arteries is atrophied, giving rise to a diminished arterial tension. In consequence of this diminished blood supply the surface temperature of the paralyzed member becomes greatly diminished. Fluctuation in temperature is very great, especially when the body has been exposed to cold. Thus the difference between the healthy and paralyzed limbs may be 20°, 30°, or even 40° F. It is almost impossible to keep the paralyzed limbs warm; friction and artificial heat serve to restore warmth for a time, but, unless frequently applied, they do very little good. As a result of the lowered temperature and slowness of circulation, the skin sometimes becomes the seat of ulcerations, which are very slow to heal, and are exceedingly painful. These ulcers affect only the scarf skin, and consist of a desquamation of the epidermis, the derma remaining unaffected. As part of the symptomatology of the paralytic and atrophic stage of the disease, we must devote some space to the discussion of the accompaniments and results of both of these conditions, namely, the deformities so characteristic of the final stages of this affection.

Third Stage.—Deformities Resulting from Infantile Spinal Paralysis.—A careful analysis of the deformities resulting from infantile paralysis will warrant their classification into two groups:

1. Deformities due to trophic changes in the limbs.
2. Deformities depending on the paralysis of muscles.

1. Deformities Due to Trophic Changes. In discussing the symptomatology of this disease, it was seen that, owing to destruction or interference with the trophic centres in the cord, all growth of the parts supplied by the nerves passing from the affected region was arrested, and the development which the affected tissues had attained before the time of seizure was diminished, the tissues retrograding and undergoing degenerative changes. The deformities of this group, then, are due, first, to cessation of growth; second, to retrograde metamorphosis. Cessation of growth is in every direction, and results in shortening and attenuation of the affected member as compared with the condition of the limb in health. Retrograde metamorphosis or atrophy will also cause deformity, either by shortening, or, more commonly, by attenuation; so that lack of growth, aided and reinforced by atrophy and degeneration, results in deformity by producing shortening or attenuation, or both together. From a consideration of the function of the upper, as compared with the lower, extremity of the body, it is evident that deformity due to shortening is of far more importance when it affects the lower extremity than when it affects the upper. Not only is it essential that the two limbs should be of equal length in order that the patient may walk and stand without deformity, but the proper performance of the functions of other parts of the body depends upon the lower extremities being of equal length. For, the trunk being supported by the two lower extremities acting as pillars, the shortening of one of these pillars as compared with the other will result in a corresponding lowering or sagging of that side of the body; the pelvis will become oblique, the normal side being on a higher plane; and were it not that conservative nature seeks to rectify the result of the disease, we should see these patients walking and standing with the body bent over to the side of the shortened leg. To maintain equilibrium the patient is compelled to throw the body to the opposite side, giving rise to a functional lateral curvature of the spine, which, in its turn, again in the effort to maintain equilibrium, is modified by a secondary curve. We have, then, as a result of the shortening of the lower extremity, deformity in walking and functional lateral curvature.

Atrophy and attenuation are of less importance here than in the upper extremity, disability rarely resulting from this cause alone; while, on the other hand, shortening is of less importance in the upper extremity than in the lower; for one arm or hand may be shorter than the opposing member, but were it not for the paralysis which accompanies the shortening, it would be of little importance. On the other hand, atrophy is of great importance in its effects upon the upper extremity. An atrophic shoulder will sag downward, producing even, in some cases, a lateral curvature high up. But, what is more common, the head of the humerus becoming atrophied, and the hand having no resistance below, as is the case with the foot, we have a resulting subluxation, which in itself would interfere with the use of the arm. In one of my cases this subluxation in every direction resulted from the slightest motion, and was an important element in the treatment of the case. Although, in the limits of this article, I consider it more profitable to indicate the *principles* which govern the production of deformities which result from infantile spinal paralysis, rather than minutely to catalogue all of these, I cannot here overlook a seemingly minor deformity which results from the muscular atrophy characteristic of this disease. I refer to the undue prominence of the articular extremities of the bones in cases in which the muscular atrophy has become extreme. This deformity is so marked in some cases as to lead the patients to believe that the joints are dislocated or are the seat of osteophytic growths. Although this undue prominence of the extremities of the bones does not interfere with locomotion, yet it is of great importance in the treatment of these cases; for a careless application of rigid orthopedic apparatus often results in the formation of callosities over these bony surfaces which are painful to the patient, and when once formed are difficult of removal.

The second group of deformities which result from this disease are by far the most important; they are the deformities depending upon the paralysis of muscles. Inasmuch as individual cases differ greatly as to the extent of the paralysis and the number of muscles involved, so also the variety of deformities resulting from infantile paralysis includes almost every form of inability and perverted motor activity. But before considering these deformities it will be proper to consider the laws upon which their production depends. This subject has been studied by Volkmann in the first of the "Klinische Vorträge." Although inability is the immediate result of paralysis, deformity is not the consequence of the paralysis itself, and does not occur until a later stage of the affection is reached, when it is found that permanent contractures have taken place, of which the paralyzed muscles are generally, but by no means exclusively, the seat. As to the cause of these contractures which so deform the already paralyzed limb, many explanations have been advanced. The oldest and most popular is that of unopposed muscular action. This explanation rests upon the theory that all muscles in their quiescent state are the seat of a reflex tonicity. That is to say, it is supposed that the higher centres of the brain and spinal cord are constantly sending out innumerable and minute impulses in response to constant and unconscious peripheral excitation. This constant state of contractility is known as the reflex tonicity of the muscles, and, being constantly present in all of the voluntary muscles, the parts moved by them are kept at rest except when the will or reflex causes throw excess of energy into any single group. The principle is similar to that by which the heavenly bodies are enabled to retain their places in the universe, although constantly acted upon by centrifugal and centripetal forces.

Reasoning from this assumption, it is supposed that as soon as any group of muscles is cut off from the motor centres in the cord, the opponents, being still the seat of the normal muscular tonus, undergo contracture because the equilibrium has been destroyed. Were such the explanation, however, we should expect immediately after the paralysis to see the remaining healthy muscles become permanently contractured. Volkmann did great service in combating this theory, although he has gone to the opposite extreme and proposed one almost equally untenable. He found that in children with infantile paralysis of all of the muscles of the lower extremity, in which the muscular groups on the anterior as well as those on the posterior portion, or calf of the leg, were paralyzed, the tendo Achillis was the seat of contracture, and the foot assumed the equinus position, just as though the anterior tibial group alone had been paralyzed and the calf muscles had remained intact. Again, in cases of talipes equinus, immediately after the performance of tenotomy of the tendo Achillis, if the child were placed in a chair with the legs pendent, the foot, instead of assuming the calcaneus position, in obedience to the unopposed action of the anterior tibial group, is found to place itself in the equinus position; this is explained by the action of the force of gravity upon the foot. On the strength of both of these observations he explains the production of the deformity in many cases by the action of the force of gravity, claiming that the position which this force compels the paralyzed limb to assume, as the patient sits or stands, will be the position in which contractures will most frequently fix the limb. But on consideration we find that, even in the extremity on which the force of gravity is most influential, namely, the foot, this theory is not substantiated; for which one of us has not seen an acquired talipes calcaneus with toes raised and heels bulbous and boring the ground? The study of a recent case of facial paralysis will help to clear up this subject.

It will be found that, after the paralysis has occurred, as soon as the patient has made the first use of the nonparalyzed side, the face is slightly drawn to the healthy side. I say slightly, not so completely as it would necessarily be if the cause of the deviation were the unopposed action of the healthy side, but just enough to make it noticeable. This deviation, I think, can be explained in the following manner: The first facial motor impulse that occurred immediately after the paralysis had taken place found only the healthy side of the face ready to act. It contracted, and as soon as the motor impulse ceased the tissues returned to their relaxed condition; this passive relaxation is almost, if not quite, sufficient to restore the tissues to the position they occupied before contraction. The residual work necessary to complete the restoration the opposing muscles do for each other, and since in our supposititious case the opponent was paralyzed, the healthy muscles had almost, but not quite, returned to their normal position. In other words, the origin and insertion of the muscles have been brought slightly nearer to each other than they should be normally in the condition of rest with increased activity. After a time the shortening will become more marked, and the muscle will assume the contractured appearance so familiar in deformities following long-standing paralysis. The paralyzed muscles, in order to adapt themselves to the contracture and shortening of the healthy muscles, become passively stretched, for it is evident that every time the activity of the healthy muscles is called into play the paralyzed opponent is stretched and becomes longer, just as the healthy muscle becomes shorter. The contracture or shortening of the healthy muscles, which is primarily the result of the use of the healthy muscles, is increased by, and at the same time the cause of, the elongation which the paralyzed muscles undergo. I conceive that the only contractures which are properly the result of the action of gravity are those in which all the muscles of the limb are paralyzed, and in these cases there is no question of the nonapplicability of the theory of muscular tonicity. There is another form of contracture of which the paralyzed muscles themselves are sometimes the seat; this is the result of the final stage of atrophy which the paralyzed muscle undergoes. Then the muscular fibres disappear, the muscles proper being replaced by connective-tissue bands; these contract, and when such contractures occur they counteract other previous contractures of the nonparalyzed muscles.

It follows, then, that paralysis of muscles causes deformity in one of two ways: first, by mere inability resulting from the paralysis; second, by the resulting contractures in the healthy or paralyzed muscles.

Deformities of the Lower Extremities.—Extensive paralysis, involving all of the muscles of the lower extremity, will produce a deformity well described as "flail-like." Here the lower extremity is so flaccid, and the patient has so little command over it, that in walking (with crutches) it swings as loosely as a flail; and yet, however complete the paralysis may be, careful examination will show here and there a muscular group of which the patient has retained the use. The psoas magnus is frequently preserved, so that the thigh can be flexed slightly, although the leg cannot be extended. Another very common deformity at the hip-joint is inability to extend the thigh because of a contractured psoas. In these cases the hip-joint cannot be extended even to a right line with the body; in cases in which the rectus femoris and tensor vaginæ femoris are preserved this deformity is increased in degree. The prominent tensor vaginæ femoris appears to be so important a factor in the production of the deformity that the effect of the contractured psoas is overlooked. Hence disappointment in the operative and mechanical treatment. When deformity occurs at the knee-joint it is generally due to contracture of the outer and inner hamstring tendons. In these cases the muscles which extend the knee are paralyzed, the ligaments of the knee-joint are weakened by disease, and hence, when the patient attempts to rest the weight of the body upon the knee-joint, it closes up like a jack-knife. When the muscles on both the extensor and flexor side of the thigh are paralyzed, it is impossible to use the knee-joint in standing or walking, and the inability is almost as great as in flail leg. The most common seat of the deformities resulting from this disease is undoubtedly the ankle and mediotarsal joints; in other words, the joints involved in the various forms of club-foot. The forms of paralytic club-foot conform more or less closely to the classical varieties. The order of their frequency is, in my experience, as follows: (1) talipes equino-varus; (2) talipes calcaneo-valgus; (3) talipes equinus; (4) talipes calcaneus.

Paralysis of both the anterior and posterior calf muscles is apt to result in the equino-varus deformity, that being the position in which the foot is for the most part held. When the anterior tibial group alone is paralyzed, the deformity is apt to be equinus or equino-varus, for reasons already stated. Paralysis of the peronei alone will result in varus. Talipes equinus and equino-varus are often accompanied by contraction of the plantar fascia. This is particularly apt to be the case if the tibialis anticus is preserved, while the rest of the anterior group is paralyzed. Occasionally one or two divisions of the extensor communis digitorum remain normal, the rest being paralzyed; the result is contracture of the preserved tendon, and hyperextension of the first phalanx of the toes supplied by these tendons. In such cases the shoe of the patient presses upon these prominent phalanges, and produces excoriations, thickening, and bunions, which can often be cured only by tenotomy. When the interossei are paralyzed we have a condition analogous to "main en griffe" of the hand, the first phalanx and all of the toes being extended and the ball of the foot prominent. Dr. N. M. Shaffer has described, under the head of "Non-deforming Club-Foot," a condition which may be characterized as an incomplete talipes equino-varus; this condition often results from infantile paralysis.

Paralysis of the posterior tibial group, including the gastrocnemius and soleus, will result in calcaneus or calcaneo-valgus, contracture taking place in the anterior group owing to the use of the healthy muscles in a limited arc. These patients walk with the toes raised and the heel on the ground; this pressure on the heel results in the formation of incurable callosities of the skin, and inflamed bursæ over the os calcis. Deformities of the upper extremities, although far less important than those of the lower extremities, are equally important when we take into consideration the disability which they cause. I have already referred to the inability caused by paralysis of the muscles about the shoulder-joint and the laxity of the ligaments in these cases. But, in addition to the disability, the pectoral muscles and latissimus dorsi become shortened, owing to paralysis of the deltoid, and the arm is held firmly adducted.

Contractures occasionally are found at the wrist and elbow joints, and their production is explicable on the principle already discussed.

In the trunk the most important deformity that can occur is lateral curvature. Not the form due to the shortening of one of the lower extremities, but a paralytic curvature—that is to say, one due to paralysis of the large or extrinsic muscles of the back, or the deep intrinsic muscles of the vertebræ. When the large muscles are paralyzed the corresponding healthy muscles of the opposite side become shorter and cause a bending of the spinal column, composed as it is of flexible segments, to the healthy side, the convexity of the curve looking toward the paralyzed side. If the curve be low down, a secondary or compensatory curve will appear high up. If the primary curve be high up, no secondary curve will be present. This is the result of the necessities of equilibrium. When the deep or intrinsic muscles of the spine are paralyzed, we have, as a result, rotatory lateral curvature, the most deforming condition the orthopedic surgeon has to deal with. The limits of this paper will not admit of the discussion of the cause of the so-called idiopathic cases of lateral curvature; but of the fact that a large number of cases of lateral curvature are the result of infantile spinal paralysis there is no doubt.

Diagnosis of Muscles Affected.—In examining a case of infantile spinal paralysis for the purpose of discovering what muscles are affected, I adopt a plan somewhat as follows: If the patient is able to walk, he should be made to do so while undressed; the movements of the various joints should then be noted and compared with those of the healthy side; any dragging, inversion, or eversion of the leg should be observed. The patient should then assume the recumbent position, and each muscle in turn must be tested as to its activity, beginning with the psoas; the leg may be raised, and the patient requested to maintain it in the raised position; or, if he is intelligent enough, the patient may be required to perform the action which will bring out the muscle under examination. In infants we are aided in this examination by a condition peculiar to them, by which the limb can be placed in any desired position, and will be retained there if the necessary muscular power is preserved, only gradually falling back to the relaxed state. This peculiarity has been compared to a similar condition present in patients under the influence of catalepsy. Finally, the patient should be examined by the most reliable and accurate test of infantile spinal paralysis, namely, the electric current. In this examination we make use of both the galvanic and faradic currents. We test the degree and kind of excitability of the nerves and muscles to both currents, and compare the result with similar tests made upon corresponding healthy muscles. In speaking of the pathology of this disease it will be remembered that the changes which the nerves and muscles undergo were thoroughly discussed. These changes were of the kind known as degenerative changes. They are not the result of all forms of paralysis, but occur only in those cases in which the lesion which is the cause of the paralysis cuts off the connection between the gray matter (anterior horns in the spinal cord, bulbar nuclei in the case of cranial nerves) and the nerves originating therefrom and the muscles supplied by them. The gray matter exerts upon the nerves and muscles what is known as a trophic influence, and it is the loss of this rather mysterious trophic influence which results in the degeneration of the nerves and muscles thus deprived. Paralysis alone does not cause degenerative atrophy, as is shown in cases of cerebral paralysis, in which the nerves and muscles, although deprived of motor power, still retain their connection with the so-called trophic centres in the gray horns of the cord.

Muscles and nerves which are the seat of degenerative atrophy give rise to peculiar electric reactions, which serve to distinguish muscles paralyzed by anterior-horn or nerve-trunk lesions. If nerves and muscles paralyzed by infantile spinal paralysis are examined five weeks or more after the paralysis has occurred, it will be found that the farado-nervous excitability is very much diminished or, later on, entirely absent. Farado-muscular excitability disappears a little later than that of the nerves. Faradic contractility of muscles is in reality the expression of the faradic contractility of the nerves which ramify throughout the muscle, so that, as soon as the faradic contractility of the nerves is lost, that of the muscles supplied by the nerves is also lost, even if the former are not yet advanced in degenerative changes.

The galvanic current yields even more striking changes. When such a current is passed through a normal nerve the muscles supplied by the nerve will contract. This contraction will be greater at the closing of the negative pole than at the *closing* of the positive pole; or, expressed in formula, this reaction will be K.C.C. > A.C.C.

The *opening* contraction will be A.O.C. > K.O.C.

In a nerve paralyzed by anterior poliomyelitis these reactions will become

K.C.C. < A.C.C., or
K.C.C. = A.C.C.

The opening contraction, if present at all, will also be reversed, A.O.C. < K.O.C.

The contraction will also be altered modally; that is to say, while the normal reaction is quick and sharp, the degenerative reaction is slow and wavering. All of these changes are known as qualitative changes; the former serial, the latter modal qualitative changes.

There is, furthermore, a quantitative change. That is to say, while a certain strength of galvanic current may be needed to produce a certain contraction in a normal muscle, a much stronger current will be needed to produce a similar reaction in the degenerated nerve or muscle. What has been said of the galvanic reaction in the nerves applies also to the muscles supplied by them.

These qualitative and quantitative galvanic changes, together with the diminution or absence of faradic contractility, make up what is known as the reaction of degeneration, and it is a most valuable diagnostic agent for the recognition of muscles affected by infantile spinal paralysis.

Differential Diagnosis.—This disease is so frequent in infancy, and has been so well studied in the past few years, that, in any given case of paralysis in children, the physician, as a rule, thinks of poliomyelitis as a possible condition. It is fortunate that we have in the symptomatology of this disease much that is positive and characteristic, so that it is possible to arrive at a positive diagnosis in almost every case.

We have to distinguish this affection in children from (1) other forms of paralysis, whether cerebral, spinal, or peripheral in their pathology; (2) paralysis following acute disease, such as diphtheria, meningitis (cerebrospinal), etc.; (3) paralysis due to toxic action of poisons, such as arsenic; (4) pseudoparalysis of rickets and marasmus; (5) deformities of congenital origin, such as club-foot and congenital dislocation of the hip; (6) atrophy and disability due to inflammatory joint disease.

Patients paralyzed from cerebral lesions present the following points of difference from those suffering from this disease: First, the history of the onset of the paralysis is different. It is that of apoplexy or of embolism occurring rapidly, accompanied by repeated convulsions, and, above all, there is the fact that the face and tongue, as well as the limbs, are affected. On examination we find a paralysis corresponding to this history; we may have (with right-sided paralysis) aphasia in older children. There is frequently loss or diminution of sensibility, the tendon reflexes are exaggerated, while in anterior myelitis these are either absent or diminished in the tendons of the paralyzed muscles, and clonus may be present. Even if the muscles of the face have recovered, these symptoms will still distinguish cerebral from spinal paralysis. Furthermore, the limbs are well nourished and not atrophied, the surface temperature is not diminished, and the contractures, if existing, are spastic in variety and present in limbs which have not lost contour through atrophy. What is most important, however, are the results obtained from an electrical examination. In these cerebral cases faradism gives good reactions in the paralyzed muscles, while galvanism gives equally good reactions, the formulas being unchanged either in quantity or in quality. On the other hand, in cases of poliomyelitis anterior we have loss of faradic contractility, while galvanism shows the reaction of degeneration in the paralyzed muscles. The electrical examination, together with the history, should certainly yield sufficient data for a positive diagnosis. It is furthermore found that children paralyzed from brain lesions are apt to show a diminution of mental power, which is never present in the patient suffering from poliomyelitis.

Diseases of the spinal cord resulting in paralysis affect directly or indirectly either the anterior gray horns, together with other portions of the cord, or do not affect these horns at all, as, for instance, in secondary sclerosis of the lateral columns. Of the first class we have transverse myelitis, compression myelitis of Pott's disease, and most probably progressive muscular atrophy, and pseudohypertrophic paralysis. Here also belong cases of hemorrhage into the spinal cord. Here electrical examination, although of some, is not of so great utility as in the differentiation from cerebral paralysis. In transverse myelitis we have a paralysis of sensation as well as of motion. There is paralysis of the sphincters, there is the appearance of bedsores, while the history shows no regression of the paralysis, and the presence of long-continued fever. In the myelitis, or rather meningitis with myelitis as a secondary affection, of Pott's disease, the anterior horns of gray matter may or may not be involved, giving rise to various forms of paralysis. When the anterior horns are involved we shall have paralysis (paraplegia) it is true, but we shall also have the symptoms of vertebral caries, reflexes not abolished, but often increased, and paralysis of the bladder. Faradic contractility is generally preserved, although when the affection of the cord is very extensive it may gradually disappear. Progressive muscular atrophy is not frequent in children, and when it does occur the gradual and progressive nature of the paralysis serves to distinguish it from poliomyelitis. There is also a peculiar "cut-out appearance" characteristic of the atrophied muscles in progressive muscular atrophy, the atrophied portions being at first isolated and sharply bounded by well-developed muscles. In pseudohypertrophy of the muscles the gradual hypertrophy which accompanies the paralysis is sufficient to distinguish this disease. In the last stages of atrophy in cases of infantile paralysis, as we have already stated, there may be a deposit of fat in the atrophied muscles, but this occurs so rarely and so long after the paralysis has set in, that the history also will be a certain guide. Hemorrhage into the anterior horns of the spinal cord, when affecting these portions of the cord alone, can with difficulty be differentiated; when it affects other portions of the cord the corresponding symptoms will be sufficient to localize the lesion.

Of diseases of the spinal cord which do not affect the anterior gray horns, the most commonly met with in children is spastic paralysis (Erb) or tetanoid pseudoparalysis (Seguin). These cases were formerly classed with those of infantile spinal paralysis, although the two diseases have scarcely a symptom in common. What has already been said of the differential diagnosis from cerebral paralysis will also apply here, the cord lesion in both cases being a sclerosis of the crossed pyramidal tracts. We have then, here, the absence of the degeneration reaction to both currents, the increased reflexes, the spastic contractures, the absence of atrophy, and sometimes diminished intelligence.

In cases of peripheral paralysis the physical symptoms, those obtained both by the electric currents and by examination, are exactly similar to those present in infantile spinal paralysis. The only important point of difference is that sensation, as well as motion, is apt to be involved in the paralysis of the affected nerve. When the patient is too young for satisfactory tests of sensation to be made, the diagnosis is extremely difficult.

In diphtheria we have the history of the disease (if the diphtheria has not escaped the attention of the patient's friends), the involvement of the muscles of the palate and throat generally, and finally the rapid recovery. We may also have ataxia and paralysis of the eye muscles. The faradic contractility is preserved.

From the paralysis of cerebro-spinal meningitis, the history and what has already been said of cerebral and spinal paralysis will serve to make the diagnosis.

Arsenic and other metallic poisons as a cause of paralysis in children must be extremely rare. I have never seen a case. E. C. Seguin has described several cases in adults in which paralysis resulted from acute arsenical poisoning, and which simulated anterior myelitis.

Cases in which rickets or marasmus have so disabled the lower extremities as to interfere with their use in locomotion are easily distinguished by the fact that there is no true paralysis; these muscles can be used, but walking is impossible, owing to tenderness and softness of the bones in the rachitic patients, and the weakness of the muscles of patients suffering from marasmus.

Congenital club-foot can be distinguished from paralytic cases by the absence of the characteristic electric reaction, and of other symptoms of infantile spinal paralysis.

The disability produced by congenital dislocation of the hips may be mistaken for paralysis, but a careful examination of the hip-joints, together with the peculiar gait and the absence of all the symptoms of this disease (infantile spinal paralysis), will serve as aids in making a diagnosis. Finally, inflammatory disease of the joints, especially of the hip, may give rise to atrophy and disability which might cause a suspicion of the presence of infantile paralysis.[23] When the history of joint disease is taken into consideration, together with the pain and swelling accompanying this condition, it will be hardly possible to be in error for any long period.

TREATMENT.—Inasmuch as there are no characteristic and pathognomonic signs by which a diagnosis can be made in the inceptive stage of the disease, before the paralysis has occurred, our treatment is necessarily one of symptoms and not rational. We treat, in other words, the fever, the convulsions, and the general conditions that may be present. But as soon as the disease itself can be diagnosticated by the presence of paralysis of motion in one or more members, the loss of reflex action, and the retention of sensibility in the paralyzed muscles, then a rational treatment can be instituted. We can attempt a derivative action to the skin by counter-irritation applied either locally to the spinal column, or to the whole of the cutaneous surface. As local counter-irritants in robust subjects, cupping and other forms of local blood-letting have been tried. Iodine may be painted along the whole length of the spinal column, or fly-blisters may be applied over the portion of the cord where the lesion is supposed to be located. General derivation to the skin may be accomplished by a strong mustard bath, repeated frequently in the course of a day. These baths, by reducing temperature, will serve to render the patient more comfortable, and will also exert a beneficial action upon the central disease. A brisk purgative may aid in reducing the congestion of the cord, and under any circumstances will benefit the general condition of the patient. Ice applications to the spine are indicated in cases in which the fever is an important factor in the treatment of the patient. The drugs which may be useful in this stage are those which antagonize the febrile movement, and those which are commonly termed antispasmodic. Of the former class are antifebrin and antipyrin, in doses sufficient to reduce temperature; among the latter are the bromides and chloral, which, together with the antipyretics, will generally succeed in stopping the convulsions. Ergot has been especially recommended by Althaus. He uses Bonjean's ergotine in watery solution (Julius Althaus: "On Infantile Paralysis," London, 1878, p. 51). The dose varies according to age under five years; from 0.01 to 0.02 gm. is injected once or twice a day. The treatment is continued until the temperature has become normal.

During the paralytic stage of the affection the treatment is well understood. Here the indications are, first, to treat the myelitis and thus promote and aid the regression of the paralysis; second, to treat the paralysis.

For the inflammation in the cord we can do but little. Ergot is given with supposed benefit. But the natural course of the inflammatory process is to destroy the ganglion cells in the gray anterior horns; when this has taken place, it is difficult to conceive how any internal medication can restore the destroyed nerve elements. It is claimed, however, and perhaps with some propriety, that those portions of gray matter which are only the seat of congestion can be benefited by internal medication; hence the ergot. With the same object in view counter-irritants to the spine are also used, such as iodine painted externally, blisters and cupping, either wet or dry. Dry cups applied to the spine on a level with the supposed lesion are better than wet cups. For obvious reasons they are also better than blisters.

Electricity is the curative agent in this affection. It may be applied locally to the spine, and also to the paralyzed muscles. Both galvanism and faradism are recommended. In my opinion, however, galvanism is more rational in theory and more effective in practice. Central galvanization of the spine is performed by placing one large flat electrode over the site of the lesion and the other over the farther extremity of the spinal column. An ascending (irritating) current should be employed, of strength sufficient to be felt by the patient; generally from twelve to sixteen elements Leclanché are sufficient. The duration of the applications should not exceed five minutes, and they should be repeated once every second day.

The application of electricity locally to the paralyzed muscles is the most effective use of this agent in this disease. Under the head of deformities we have already discussed its importance as a diagnostic agent. By the use of faradism alone we can recognize whether a patient has been the subject of a spinal-cord or peripheral-nerve lesion, or of a cerebral lesion. In advanced cases of atrophy from this disease the reaction to faradism is entirely destroyed; in these cases, therefore, the application of faradism as a therapeutic agent is certainly useless. I never apply this current until the muscles have sufficiently recovered to show a slight reaction when it is applied. Very few muscles, however—with the exception of those which are entirely destroyed—lose their excitability to galvanism, although the reaction present is generally that of degeneration. Galvanism, therefore, applied to the paralyzed muscles and nerves, causes both to become excited. This stimulus is undoubtedly beneficial, and persevering treatment with galvanism, continued for months and even years, is frequently successful in restoring muscles that were hopeless, to all appearances, when the treatment began. I apply the current by the aid of the interrupting electrode to the paralyzed muscles, and the other pole, generally the cathode, to some indifferent point. Applications to a limb should not exceed three minutes in duration.

Treatment of Deformities.—The principal therapeutic means at our command in the treatment of the deformities are tenotomy and mechanical appliances. Under the latter head I also include massage.

It has long been a question whether it is permissible to cut the tendons of the contractured muscles, and thus virtually paralyze all of the remaining healthy muscles of the limb. But, as is often the case, we find here that what would theoretically appear to be unwarranted, is found, in practice, to be sound and proper treatment. Careful consideration will show that the above objection is only apparently valid. Tenotomy disables a muscle only for a short time. The tendon soon reunites and the muscle is enabled to perform its functions to far better advantage than before. The strained position of the limb is relieved and the patient is enabled to use a joint which was entirely disabled before tenotomy was performed. Conservative surgeons prefer to stretch a contractured tendon, provided it admits of stretching. But such stretching, unless maintained for a very long period, is apt to be of but temporary utility; for a relapse is sure to occur when extension has been remitted. Where time, then, is important, tenotomy is certainly preferable to extension. I do not believe that the argument that tenotomy weakens a muscle is tenable. The active portion of a muscle is certainly not the tendon, but the muscular fibre. Tenotomy results in lengthening the tendon, the muscular fibres retaining their integrity. If healing has been properly looked to, the united tendon will not stretch more than is proper for the restoration of the joint to its proper function. Where, however, the contracture is yielding, traction will readily accomplish all that is necessary, and should be preferred to tenotomy. It will be impossible, in the limits of this article, to describe all of the instruments used for purposes of extension of different muscles. For talipes equinus I know none better than Dr. Shaffer's "extension shoe," the working of which has been thoroughly described in a paper read before the Academy of Medicine. For varus, Dr. Shaffer has devised an equally effective "lateral extension shoe." In calcaneus the chief indication is to raise the heel, the contracture rarely requiring extension or tenotomy. For these cases, as in all cases of paralytic club-foot, the shoe that is worn daily should have inside, covering the sole, a steel plate, to keep the sole firm and to prevent the shoe yielding itself to the deformed position of the foot. If the case be one of equinus, the heel should be fixed to the sole of the shoe by means of a strap passing over the instep. In all cases the shoe should be laced and made so as to open to the toes. The paralyzed muscles in many of these cases can be replaced, to a certain extent, by properly applied elastic straps, to act as artificial muscles. Contracture at the knee-joint should be overcome by tenotomy or extension. If the muscles about the knee-joint do not retain sufficient power to enable the patient to stand or walk with some firmness, we can virtually ankylose this joint by an apparatus in which a rigid bar passes from the hip or thigh down to the foot, without a movable joint at the knee; or a joint may be made at the knee, which, being guarded by an automatic spring, becomes rigid as soon as the patient assumes the standing position. One important principle in the application of apparatus for these deformities must not be lost sight of, and that is, that all apparatus must be so attached to the limb or body that the healthy muscles may be able to control or carry it, while it aids and takes the place of the paralyzed member. On the mechanical treatment of lateral curvature we will say nothing, the field being too large for the limits of this article. In treating the deformities of the upper arm and hand the principles already laid down will serve as a guide.

In the final stages of the disease, when contracture and paralysis have destroyed the function of limbs, and flail joints have rendered utterly useless whole extremities, certain surgical procedures will benefit the patient very greatly. Thus a healthy contractured muscle, which is useless owing to paralysis of its opponent, may have its tendon implanted at or near the insertion of the paralyzed muscle, and thus to a certain extent be enabled to perform the function of that muscle. This operation, known as tendon grafting, was first performed with good result by Nicolodoni in 1882. Goldthwait, of Boston, in 1896 reported a series of very interesting cases of this type. Arthrodesis has been useful in converting a flail leg into an efficient prop, much superior to a splint. Such ankylosis of joints is useful in bringing a useless joint into better position than that in which it has been left by the paralysis and resulting contractures.

Acute Poliomyelitis Anterior in Adults.

There is no doubt that a condition resembling, in its course and symptomatology, the same disease as it occurs in children may affect adults, although far more rarely than children. This has been evident from cases reported since that of Moritz Meyer in 1872 ("Die Electricität in ihrer Anwendung auf praktische Medicin," 2te Auflage, 1861) to the present time. Many of the cases reported as cases of acute poliomyelitis anterior in adults were in reality cases of polyneuritis without sensory symptoms. Indeed, a multiple neuritis of anterior spinal nerve roots would produce a condition simulating poliomyelitis anterior acuta in its symptomatology almost perfectly. The adults in whom this disease may occur are rarely more than thirty years of age. The disease is apt to affect adults who have recovered from an acute infectious disease, such as measles and scarlet fever. One case was reported as following an attack of rheumatism. Another case was supposed to be due to an exposure to cold after active physical exercise. The adult cases occur far more rarely than the infantile cases.

The symptomatology is almost identical with the same disease in children. Pain in the limbs preceding the occurrence of the paralysis is a symptom which has been reported in most of the cases. This pain disappears as soon as the paralysis occurs. The paralysis has the characteristics described in discussing infantile spinal paralysis. Its distribution in adults is characterized by the same lack of uniformity as in children. It is regressive. In adults, however, complete spontaneous recovery is believed to be possible. There is absence of patellar reflex. There are no sensory disturbances except the temporary pain just referred to. One or more muscles, groups of muscles, or extremities may be involved. There is sometimes backache. There are no motor disturbances of the rectum or bladder. Atrophies and degenerations occur as in the same disease in children. Similar electrical manifestations can be demonstrated in the paralyzed muscles. The reactions to galvanism and faradism are the same as in the infantile form of the disease. Deformities are not so apt to occur as a result of contractures in paralyzed muscles and their opponents, owing to absence of the factor of growth, which has such an important influence in disturbing the equilibrium between the healthy and paralyzed muscles of an extremity in young children suffering from this form of paralysis.

The diagnosis of this affection in adults is difficult, because the paralysis of poliomyelitis anterior acuta resembles that due to other pathological lesions to which adults are more often liable. Polyneuritis has already been mentioned. However, fever, followed by a rapidly developing motor paralysis, acute in its onset, which when it has reached its height begins to improve, together with the characteristic electrical symptoms, should enable the physician to make a diagnosis, at least as soon as the fever has subsided and the paralysis has become stationary.

The pathology of this disease in adults is the same as when it occurs in children.

The treatment is that which we have indicated in the same condition when it occurs in children, both in the stage of onset and in the chronic stage.

Poliomyelitis Anterior Subacuta et Chronica.

This form of poliomyelitis anterior is also generally found in adults; it is very rare. The condition resembles multiple neuritis in its symptomatology in a general way, and doubtless most of the cases reported clinically as poliomyelitis anterior subacuta were in reality cases of multiple neuritis. Yet cases have been reported in which post-mortem findings demonstrate that subacute or chronic poliomyelitis anterior is an actual entity, although a rare condition.

As etiological factors we find first metallic poisoning. In these cases this condition may be present alone or it may be accompanied by a toxic neuritis of peripheral nerves. The condition has also been seen during pregnancy. One case reported gave a history of an attack of infantile paralysis during infancy, followed in adult age by a gradually developing chronic poliomyelitis.

Pathologically the findings are similar to those in poliomyelitis anterior acuta, which have been recounted in the earlier portion of this article. Some of these cases, however, while they show degenerative changes with atrophy and sclerosis of the gray anterior horns, show also degenerations in the crossed pyramidal tracts and anterior nerve roots. One case reported by Oppenheim also showed systematic degeneration of the columns of Burdach in the cervical and dorsal regions, together with atrophy of the posterior nerve roots. One case has even shown an extension of the process to the columns of Clarke, and the posterior horns were also slightly involved, in addition to the changes in the anterior horns.

The root of the hypoglossus has also been found involved.

The atrophic changes in the peripheral muscles and nerves, as well as those occurring in the bones, while less marked, are similar to those found in poliomyelitis of children.

The symptoms are as follows: A paresis developing with a paralysis of a single limb or muscle is followed, in a week or month or year, by a gradually developing paresis or paralysis of another limb or of other limbs. This gradually extending, paralysis may continue, at intervals of longer or shorter periods, to involve more muscles until a large portion of the voluntary muscular system is affected, although one case has been reported in which there were bulbar symptoms. The muscles that are the seat of the paralysis gradually undergo atrophy, and give the complete and partial degeneration reaction found in poliomyelitis anterior acuta. The paralysis keeps extending for a year or more, and then may become stationary for the remainder of the life of the patient. In this form of the disease, unlike the acute form, there is observed little or no spontaneous improvement in the paralysis, while in infantile paralysis it is the rule that the paralyzed muscles recover, to a greater or less extent, spontaneously shortly after (*i.e.*, a few days or weeks after) the paralysis has set in. In the subacute and chronic form of the disease there is no spontaneous improvement.

Death generally occurs through some intercurrent disease, such as pneumonia, or, in rare cases, by paralysis of the nerves of respiration.

The differential diagnosis rests upon the absence of bladder and rectal symptoms. The diminished or lost patellar reflex; the absence, with rare exceptions, of sensory symptoms; the atrophy of the paralyzed muscles and limbs, are also important symptoms of the disease.

Progressive muscular atrophy can be differentiated from this condition by the fact that the paralysis in poliomyelitis subacuta and chronica precedes the atrophy, while in progressive muscular atrophy the atrophy precedes the paralysis. From multiple neuritis the condition is distinguished by the absence of sensory symptoms both subjective and objective. From amyotrophic lateral sclerosis it can be distinguished by the absence of the contractures and exalted patellar reflex which is characteristic of this affection.

The treatment consists of electricity, massage, baths, orthopædic apparatus, and drugs. The rules laid down, under acute infantile paralysis, for the employment of these agents in the treatment of the disease hold good here.

Orthopædic apparatus should be so constructed as to give rest and firmness to the paralyzed limb, by fixation of incompetent joints, etc., and to cause healthy muscles and limbs to do the work of those that have been paralyzed. Of the drugs that may be used, intramuscular injections of strychnine are the best. Galvanism is the form of electricity most applicable It should be used in accordance with the directions already laid down.

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REFERENCES.

[1] Diseases of Children, London, three vols., vol. ii., p. 88.
[2] London Med. Gaz., vol. xvii., p. 215.
[3] Jacob von Heine, 1840.
[4] Spinale Kinderlähmung, 1860
[5] Duchenne de Boulogne: De l'électrisation localisée, 1855.—*Ibid.*, third edition, 1872.
[6] Rilliet: Traité clin. et prat. des maladies des enfants, 1853, vol. ii., p. 355.
[7] Rilliet and Barthez: Gaz. méd. de Paris, 1850, p. 681.
[8] Deutsche Klinik, January 1st, 1863.
[9] Gaz. méd., 1864, p. 200.
[10] Cited by Duchenne fils.
[11] Gaz. méd., 1866.
[12] Med. and Surg. Trans., vol. ii., p. 219
[13] Arch. de Phys., 1870, p. 135.
[14] Parrot and Joffroy: Arch. de Phys., 1870, p. 310.
[15] Vulpian: Arch. de Phys., 1870, p. 316.
[16] Gaz. méd., 1871, p. 457.
[17] Erb, W.: Krankheiten des Rückenmarkes, second edition, p. 258.
[18] Myelitis of the Anterior Horns, New York, 1877.
[19] Charcot: Leçons sur les maladies du système nervêux, tome i., 3ème édit., p. 66, Paris, 1877.
[20] Taylor, Dr. Fred.: Med. Times and Gaz., vol. i., p. 187, 1879.
[21] Seeligmüller: Gerhard's Handbuch der Kinderkrankheiten, Tübingen, five vols., 1880.
[22] Ueber die essentielle Lähmung der Kinder.
[23] Gibney, V. P.: The Hip and Its Diseases, New York, 1884.
[24] Etiology of Congenital Talipes Equino-varus. Archives of Medicine, December, 1882.
[25] Hammond: Diseases of the Nervous System.

SPINAL-CORD DISEASES: SPINAL HEMIPLEGIA.

(Synonym: Brown-Séquard's Paralysis.)—This term is applied to a group of symptoms produced by disease or injury of a lateral half of the transverse section of the cord. The array of symptoms to be mentioned become more or less clearly defined according to whether the entire half-section of the cord is affected or only a part thereof. The clinical picture was first described by Brown-Séquard, the description being based upon the results of experiments on animals as well as upon clinical and pathological observations in man. The conclusions of Brown-Séquard have not always been accepted, but Oppenheim has recently called special attention to the fact that, while experimental investigations have varied greatly in their results, accumulated clinical experience altogether upholds the clinical picture which he described.

Briefly stated, the result of lesion of one-half of the cord is motor paralysis of one-half the body below the seat of, and on the same side as, the lesion, and loss of sensation to a corresponding extent on the other side. *The motor paralysis is on the side of the lesion, the sensory paralysis is on the opposite side.* The extent of the paralysis depends on the height of the lesion; if it is in the cervical region, the upper extremity as well as the trunk and lower extremity is affected; if it is at a lower level, the manifestations will be limited to a corresponding part of the body. If the lesion be in the lower lumbar or sacral region, the motor and sensory symptoms will be on the same side, for at this level the sensory fibres have not yet crossed over to the other side of the cord.

The anæsthesia of the opposite side does not involve all qualities of sensation. The senses of pain and temperature are chiefly affected. In well-marked cases these do not escape. Tactile sensation is often unaffected, and, when impaired, is affected about as often on the side of the lesion as on the opposite side. On the other hand, the muscular sense is always impaired on the paralyzed side, that is, on the side of the lesion. Another symptom allied to the latter, ataxia, is often found on the same side when the motor paralysis is slight or when it has begun to improve.

Another notable sensory symptom is hyperæsthesia on the side of the lesion, that is, the side of motor paralysis. In well-marked cases this is nearly always present, though it may be slight in degree. This area of hyperæsthesia is often bordered above by a narrow zone of anæsthesia, the latter due to injury of the posterior spinal roots on the same side. On the other hand, injury of the anterior spinal roots (also of the anterior cornua) may be the cause of atrophy of the paralyzed muscles corresponding to the level of the lesion. Otherwise the paralysis usually assumes a spastic form with increased tendon reflexes and the appearance of the Babinsky phenomenon.

Not infrequently there is, temporarily, vaso-motor paralysis with some elevation of temperature on the side of the lesion. According to the seat of the lesion there may be vesical, rectal, or oculo-pupillary symptoms. Trophic symptoms have been observed in a few instances, sometimes on the side of the lesion, sometimes on the opposite side.

To recapitulate: The symptoms on the side of the lesion are motor paralysis, loss of muscular sense, and hyperæsthesia; on the opposite side, loss or impairment of the sense of pain and the sense of temperature. Tactile sensation is as likely to be affected on the one side as on the other, and, at least in old cases, more likely not to be affected at all. Temporary vaso-motor paralysis, and, very frequently, ataxia are found on the side of the lesion.

The physiological explanation of the symptoms is as follows: The motor fibres in the cord are in the antero-lateral column on the same side as the muscles with which they are in relation, their decussation occurring at a higher level, viz., in the medulla. The nerve fibres for muscular sense are in the posterior column, also on the same side, their decussation not occurring until they have reached the brain. On the other hand, the fibres which convey the sense of pain and that of temperature enter the cord through the posterior root and then pass in one of the commissures to the other side, ascending in the opposite antero-lateral column (it is generally believed in Gowers' column) to the brain. There is much greater uncertainty as to the paths for tactile sensation. Mann believes, and Oppenheim accepts this theory, that any nerve fibres which convey centripetal impulses—that is, impulses from the periphery toward the brain—may convey tactile sensations, though they are commonly conveyed by paths in the posterior columns. This theory readily explains the varying conditions of tactile sensation in these cases. The ataxia is probably due to lesion of the posterior column. The hyperæsthesia has as yet not been very satisfactorily explained.

The lesions producing this array of symptoms are often of traumatic origin, such as gunshot wounds, or wounds with sharp instruments. The lesions due to disease are most frequently those of spinal syphilis. In some instances hemorrhage limited to one side, in others pressure or destructive effects of a tumor, again a circumscribed myelitis or sclerosis, etc., may be the cause of the clinical picture. In some of these instances, especially those of trauma and hemorrhage, the early symptoms are much more marked than the later ones. The vaso-motor paralysis is usually but transient. The motor paralysis is likely to improve. The paralysis that remains is usually of the flexors of the hip and knee and of the dorsal flexors of the foot. Ataxia is likely to appear as the paralysis disappears. If tactile anæsthesia exists it is also usually an early symptom, disappearing at a later period. The disappearance of symptoms is in part due to the absorption of effusions and exudations and lessening of pressure, in part perhaps to functions assumed by the other half of the cord, or even to healing and resumption of functions of affected nervous tissues.

In cases of progressive lesions we may find double Brown-Séquard paralysis—first the symptoms of lesion of one-half of the cord, and then those due to the extension of the lesion to the other side. *Philip Zenner.*

SPINAL-CORD DISEASES: SYRINGOMYELIA.—It is impossible to give a satisfactory definition of a disease with such protean symptomatology and diversity of pathological findings. In general the name is given to a process of new growth in the gray substance, or to intramedullary cavities of varied origin, marked clinically by disturbances of motor, sensory, and trophic nature; by frequent bulbar symptoms, by almost constant reflex changes; usually by extreme chronicity. Reports of cavity formation in the spinal cord date back to a description of Étienne in 1564. Morgagni and Santorini recounted a case in 1740. Numbers of descriptions date from the early part of the last century. Calmeil in 1828 pointed out the influence of developmental anomalies. Ollivier first used the term "syringomyelia," though his conception of the cavity-formation needed later correction. A little later it was recognized that the pathological condition syringomyelia not infrequently was associated, clinically, with muscle atrophies (Landau, Nonat, Lenhossék, Gull). This association did not escape the acumen of Duchenne de Boulogne: "I found in a good part of my cases that electrocutaneous as well as ordinary cutaneous sensibility was affected. This anæsthesia is often so marked that the patient does not feel the strongest current or the ferrum candens."

Up to the publications of Kahler and Schultze in 1882 few clinical facts had been collected, but anatomical views had become sifted and well formulated. Five chief views maintained that the cavities resulted from: (1) a dilated central canal (Stilling, Waldeyer); (2) retrogressive changes in foci of chronic myelitis (Hallopeau, Charcot, Joffroy); (3) molecular degeneration due to vascular changes (Lockhart Clarke); (4) destructive metamorphosis of tumor masses (Grimm, Simon, Schultze); (5) certain developmental anomalies (Virchow, Leyden). In 1882 simultaneous publications of Kahler and Schultze quickened clinical interest and formulated rules of diagnosis. Since then the literature has become immense, the magnificent monograph of Schlesinger in 1901 represents the sum of our knowledge of the disease and has been freely drawn upon in the preparation of this article.

Pathological Anatomy.—The cord may be hard to remove on account of marked kyphoscoliosis. There may be pachymeningitis, or pia or nerve-root thickening. The cord may seem flat and thin, the medulla small; or it may appear swollen in certain regions, especially in the neighborhood of the cervical enlargement; on section there may be cavities varying greatly in shape, vertical extent, and diameter. Frequently there are no macroscopical cavities, but irregular reddish-gray tumors in the gray substance. The medulla oblongata is often involved in the tumor- or the cavity-formation. The process may be limited to one side or to a small part of the cord; or it may extend throughout the cord and medulla oblongata. Usually the formation of tumors or of cavities involves the gray substance about the central canal. The anterior commissure is most often intact. One or both posterior horns may be attacked, or the ventral portion of the posterior columns; if the destruction advances, a large part of the gray matter disappears and the whole of the posterior and a large portion of the lateral columns become involved. The cavity walls may be smooth or ragged, may be lined by ependyma or closed by a proliferation of the glia. There may be evidence of old hemorrhage. As a rule, all changes are most marked in the cervical cord.

Microscopically, the tumor masses consist of glia cells and fibrils. The cavities are lined by a firm membrane that at times shows an epithelial covering. The tumors spring from the central part of the cord, the posterior horns, the posterior commissure, etc., and spread through the gray substance toward the posterior columns along the posterior median septum. The ultimate cause of the growth is to be sought for in certain developmental anomalies of the central canal or of the glia. The central canal may be unduly large or markedly irregular with diverticula. It may fail properly to develop and be marked by persistence of the dorsal process which is a characteristic at a certain stage of fœtal growth; or this diverticulum may be cut off and may persist as a dorsal canal seemingly independent of the central canal (Leyden). At other times nests of embryonic glia cells (ependyma) lie scattered in the neighborhood of the central canal or along the dorsal line of closure about the posterior median septum; and these may spontaneously, or under influence of some irritation (trauma), begin to proliferate and give rise to the glia tumors or gliosis (Hoffman). The cavity-formation may depend on many different processes—on dilatation or diverticula of the central canal, softening after trauma, hemorrhage or inflammation, destruction of tumor masses, retrogressive changes in glia proliferations (the common syringomyelia). But cavities and cysts after hemorrhage, myelitis, disintegration due to trauma, are rarely to be reckoned with the changes known as syringomyelia; they are stationary and not progressive. Another element is necessary, viz., some congenital disposition of the cord—an inherent tendency of the ependyma or glia cells to proliferate. Developmental anomalies of the whole central nervous system or only of the central canal and its neighborhood are found, therefore, in most cases of syringomyelia; anomalies of vessels and of the vascular connective tissues are also common and contribute to further proliferation and later cavity-formation.

Next to the posterior horns and posterior commissure the anterior horns and the posterior columns are the parts of the cord most affected. The cells of the anterior horns are either directly invaded by the gliosis, or are destroyed by hemorrhage, or at times they undergo atrophy at a distance from the process—perhaps as a result of inherent weakness. The ventral portion of the posterior columns—the ventral field of the posterior columns; the dorso-medial sacral bundle of Obersteiner; Schultze's comma tract—most frequently suffers. The pyramidal tracts may either be directly invaded or they may undergo degeneration from pressure of the growth at a higher level of the cord.

Bulbar Lesions.—Pathological changes occur in the median line or laterally, especially along the entering vagus roots. The cavities are as a rule small—mere slits rather than holes. Those lying near the median line are due to developmental anomalies, while the lateral rifts and cavities have their origin in vascular changes, in inflammatory processes. The cavities are lined with glia, but usually there is no distinct evidence of proliferation. The vessels are enlarged and present in unusual number. The central cavity when present is lined with ependyma. The lateral lesions may involve the nerves from the twelfth to the fifth; the twelfth, tenth, ninth, and descending roots of the fifth are most often implicated. The process ends at the pons. The fillet is frequently destroyed. The process is nearly always predominantly unilateral.

In judging of pathological findings one must remember the possibility of various artefacts. Tears may occur along the posterior horn and commissure and in the gray substance from pressure and crushing during removal of the cord (Kolisko). Cavities may result from putrefactive gas-formation, and changes may go on in the specimen while it remains in the hardening fluid if this is not frequently changed during the first days. Van Gieson has called attention to the various artefacts in an exhaustive article.

Etiology.—Not infrequently the disease seems to have direct relation with trauma of some sort. According to Minor a central hæmatomyelia due to trauma is often the starting-point of the abnormal process. Perhaps hemorrhages due to trauma during birth act in the same way (Schultze). It is plausible to think that, in the case of the developmental anomalies described above, the incitement to glia proliferation may be given by trauma; experimental evidence favors such a view (Schmaus). The theory has been advanced that even peripheral trauma or a panaritium, etc., may, with the predisposition already mentioned, and through the agency of an ascending neuritis, be able to start the process of proliferation; this supposition has little probability. Different infections, especially typhoid and influenza, may act like trauma in certain cases and supply the initial irritation leading to later tumor-growth. Excessive temperature changes, particularly exposure to cold, seem occasionally to act in the same way. Syphilis may lead to cavity-formation through vascular and meningeal lesions, but has little influence in the production of the progressive changes which characterize syringomyelia. Leprosy plays no rôle as a causal factor. The relations of trauma to the disease are most important from a medico legal standpoint. Most often the trauma is an accident in the already developed disease. Rarely, in congenitally predisposed subjects, it may be the primal cause of the process. Not infrequently it leads to decided exacerbation of the quiescent disease. Most often its effects are disastrous, due to peculiarities of the disease and not to severity of the trauma (trophic joints, spontaneous fractures, etc.).

Symptomatology.—From the character of the pathological lesions it is plain that symptoms must be protean and capable of almost endless combination. In the most usual localization of the process in the cervical enlargement the picture is fairly typical. Lightning pains in one or both arms, or paræsthesiæ, especially sensations of burning or coldness, or "burning cold," not infrequently precede striking changes. Atrophy of hand or arm muscles is a marked feature; it may be unilateral. The small hand muscles are most often involved; the process may begin in the shoulder group. Usually when atrophy is well marked, sensory changes can be demonstrated. These at first are found over small areas of the hands, arms, or shoulders, and there may be only a moderate diminution of temperature perception, not a complete loss. Vaso-motor disturbances and trophic changes of varied kind may be noted in the skin, subcutaneous tissues, bones, and joints. The knee-jerks are increased; if the process involves one arm predominantly the knee-jerk on the same side will be the livelier. Later on, contractures may occur; the atrophy progresses; unilateral bulbar symptoms may develop; spastic paraplegia becomes marked; further trophic changes are seen; sensory changes cover wide areas and increase in intensity; the sphincters may be affected.

If the cavity-formation involves the dorsal and lumbar cord, pain and paræsthesiæ will be felt in corresponding nerve roots. The muscle-atrophy will affect the adductors, quadriceps extensor, peroneus group, the back extensors, perhaps the glutei and other muscles of the calves. The knee and Achilles reflexes are usually increased. Sensory and trophic disturbances are found in the lower extremities or in the trunk. The sphincters are frequently affected.

When the lumbo-sacral cord is involved there is atrophy of the glutei, knee flexors or foot muscles—often unilateral. Sensory changes are demonstrated in the feet, perineum, bladder. The sphincters are usually affected early, but they may escape. Trophic changes are often peculiar. The leg and foot may remain small or may be unduly large; bone and joint changes, panaritium, malum perforans, are frequent. The patellar as well as the Achilles jerks are usually increased; a weighty sign is loss of the Achilles reflexes with normal knee-jerk.

Association with congenital hydrocephalus or spinal deformities, spina bifida, are common.

Symptoms in Detail.—1. *Sensory Disturbances.*—The essential characteristics of the sensory changes were well described in the first publications of Kahler and Schultze. Laehr, Hahn, Dejerine, Brissaud, Schlesinger, and von Soelder have studied in detail the peculiarities of distribution. Most characteristic is the so-called "syringomyelia dissociation"—the essential preservation of touch and sense of pressure, position, and movement, and more or less complete loss of the sense of pain and the temperature sense. At times only the temperature sense is involved or the perception of heat may be lost and that of cold preserved, or *vice versa*. At times only extremes of temperature are confused and moderate degrees are well recognized (Dejerine). The distribution of the sensory loss follows the rules of segmental innervation (Laehr) in nearly all cases; in the extremities the loss is in bands folllowing the axis of the limb; over the trunk the changes occur in zones about the body. Even in the trigeminus the segmental type prevails (von Soelder). In certain cases, however, the so-called "geometrical" distribution of Charcot holds good; the analgesia or thermanæsthesia affects an entire hand, or the entire arm, or the arm and part of the trunk, etc.—"sleeve," "cuff" "waistcoat," forms of Charcot. This form exists without complicating hysteria (Brissaud, Schlesinger). Even within these plaques Laehr has demonstrated a tendency to segmental distribution of varying degrees of analgesia or thermanæsthesia.

In many cases tactile sensibility is normal, in others there are losses over small areas. Deep sensation may at times be involved, owing to the existence of posterior column lesions. Ataxia is not infrequent. Stereognosis is often affected. Surface sensation and deep sensation are not necessarily affected to an equal degree; there may be loss of pain in deep structures, as bones and joints, while the skin sensations over these parts may be normal; usually, however, they are involved simultaneously. Frequently there is loss of testicular pain on pressure. The mucous membranes are commonly involved.

Pain is common and often severe; it may be constant, boring, not infrequently lancinating; it is felt oftenest in the arms and upper trunk; with high seat of the lesion there may be occipital neuralgia or obstinate pain in the distribution of the trigeminus. Paræsthesiæ are usually present, often a feeling of cold or heat, or a mixed sensation of "burning cold." The pains and paræsthesiæ may persist in regions in which there is objective loss of sensation. The subjective sensations are important in diagnosis as they appear early and often call attention to atrophy and objective sensory changes. The paræsthesiæ of the temperature sense may be extreme and may lead to grave injury through the patient's ungoverned use of counteracting heat or cold. Analgesia and thermanæsthesia depend on lesions of the central gray matter and adjacent conducting paths. It must be remembered that dissociation of sensory qualities may not be an attribute of syringomyelia alone; it is frequent in hysteria and may occur in brain or spinal-cord lesions or in affections of peripheral nerves.

II. *Motor Phenomena.*—Atrophy is the symptom of chief import. It involves the arms most frequently, is often unilateral. The small muscles of the hand are most constantly affected. In early stages there may be the type of a peripheral median or ulnar lesion, manifesting itself in the form of the ape hand or the claw hand; combinations of the two are not infrequent. More frequent is the simultaneous atrophy of all the small hand muscles, the Aran-Duchenne type. The process may skip the forearm and spring to the shoulder group. At times all muscles undergo extreme wasting. The shoulder muscles may be attacked first; frequently individual bundles undergo atrophy, while others remain normal or become hypertrophied. The lower third of the trapezius is commonly involved, the upper part very rarely. The process is seldom symmetrical. The thorax muscles may be involved irregularly—primarily or after the arms. The intercostal muscles and diaphragm are usually spared. The lower extremities, as a rule, follow the arms in point of time. The quadriceps and other muscles of the calf of the leg (foot extensors) are the common seats of atrophy. Various forms of club-foot occur. At times atrophy is masked by fat or diffuse œdema.

Fibrillary twitching is frequent; it may be an early symptom and is often felt by the patient. Tremor, choreiform twitching, and other spontaneous movements occur; they may or may not be limited to atrophic muscles, and are often associated with paræsthesiæ or pain. Tonic cramps occur most often in the lower extremities, but they may involve many muscles and simulate at times hysterical seizures. Gradations toward myotonia have been observed, muscles becoming rigid on exposure to cold. The myotonic reaction has been observed. Contractures are frequent in later stages and may lead to great distortion. The gait shows usually a spastic paraplegia; ataxia is not infrequent; cerebellar gait is rare. All forms of electric reactions may be demonstrated. Often there is only quantitative loss; at times the reaction of degeneration may be found in separate muscle bundles; at times complete reaction of degeneration is present.

III. *Trophic Changes.*—The manifold trophic disturbances of syringomyelia speak rather for separate trophic nerves and centres. Trophic changes may exist without demonstrable loss of sensation. It is difficult to classify the diverse skin lesions that may occur. Peculiarities of sweat secretion are common: hyperidrosis, anidrosis, unilateral or regional sweating, sweating in response to cold and not to heat. Hyperidrosis may be an early symptom, its distribution may correspond to the sensory changes.

Scars of injuries and burns, panaritium (often painless), eczema and deep fissures, blisters, erythema, urticaria, and pemphigus are frequently seen.

Thickening of the skin of the palms and of the fingers may be extreme. Firm œdema of the hands and the peculiar thickening of the hands—the *main succulente* of Marinesco—are not uncommon.

Scleroderma has been noted in a few cases; Raynaud's symptom-complex is rare, gangrene not uncommon. Bedsores may develop in acute cases. Keloid is common. The nails are often thick, brittle, and deformed. Aside from the presence of a tuft of hair over a spina bifida or a spina bifida occulta, an overgrowth of hair rarely occurs.

Joint lesions are most important. They may be the earliest symptom; eighty per cent. affect the upper extremities. Pain may be a prodrome, but usually the developed affection is painless—a striking feature. The change in the joint may come on suddenly, with large effusion or with marked deformity and grating. The changes are due to trophic and not to mere mechanical influences. Atrophic and hypertrophic forms occur. Extreme deformity may result. The finger, elbow, and shoulder joints are the usual seats of trophic change. The lower extremities are more rarely involved. Exostoses about the joints and ossification of muscles are not infrequent. Suppuration may occur. The lesions develop spontaneously or under the influence of trauma, which may be slight.

Fractures of bones may occur spontaneously or with insufficient cause. There is a great preponderance of forearm fractures. Healing may be long delayed and incomplete. Exostoses may form. At times there is overgrowth of the bones as a whole or enlargement of an entire extremity, or of the hand or foot. Usually the enlargements are partial and irregular. They may develop quickly and be associated with inflammation. Hitzig described a case with unilateral bulbar lesions and hypertrophy of the face on the same side. I have seen great enlargement of an arm due to recurrent lymphangitis from panaritium infection.

Two cases of spontaneous tendon rupture have come under my observation: in one there was rupture of the long head of the biceps of the right (affected) arm; in the other, rupture of the patellar tendon in a lumbo-sacral type of the disease.

Thorax Deformities.—Bernhardt was the first to call attention to the frequency of scoliosis and kyphoscoliosis. Scoliosis is important as a symptom; it may occur early and independently of muscle weakness. The kyphoscoliosis occasionally leads to great deformity. It is most frequent in the dorsal region. Sometimes there is great tenderness of the spine, which may be limited to the extent of the deformity or of the process within the cord. Oppenheim regards the scoliosis as a congenital anomaly in certain cases.

Spina bifida and spina bifida occulta are not uncommon.

The *thorax en bateau* is the name given by Marie to a peculiar depression of the upper part of the sternum; it is often associated with subluxation of the clavicles forward.

Hemiatrophy of the face has been reported and may or may not be associated with lesions of the sympathetic.

In this connection may be mentioned the peculiar irregular or "crooked" look of many patients afflicted with syringomyelia. This seems to depend on irregularities of head, face, and thorax, on irregular thickening of soft parts, and on irregular innervation of facial muscles. It is important as emphasizing the influence of congenital anomalies in the pathogenesis of the disease.

IV. *Reflexes.*—The arm reflexes are often absent, and when present they follow the atrophy or the affections of the joints. Increased knee-jerks form a cardinal symptom. Clonus is frequent; unilateral increase is common; even with lumbo-sacral localization the knee-jerk is curiously persistent and usually increased. Absent knee-jerk is found in association with tabes or nerve-root lesions or destruction of lumbar centres. The superficial reflexes are not often absent; abdominal and cremaster reflexes are frequently increased. The Babinski reflex is not constant; its absence is not against syringomyelia, even when there are marked spastic symptoms.

V. *Sphincter Disturbances.*—The bladder is not generally affected early and may never be involved. Sensibility of the mucous membrane may be lost and yet the function be perfect. Difficulty of starting the urine is the usual symptom in the beginning; later there may be incontinence. Diabetes may occur in bulbar lesions. Pollakiuria is frequent and may be bothersome.

Constipation is common, but incontinence of the bowels is rare. Sexual and menstrual troubles are very rare.

VI. *Bulbar and Cranial Symptoms.*—As was stated in the previous description, the anatomical process may involve nerves from the fifth to the twelfth; other cranial nerves may be influenced indirectly by hydrocephalus, tabes, etc. Symptoms on the part of the olfactorius and auditory nerves are very rare.

Taste may be affected, but complicating hysteria may be a cause; the affection is usually unilateral.

Eye symptoms are important. Neuritis and atrophy of the nerve are rare occurrences and probably depend on hydrocephalus or actual gliomata. The pupils are often different on account of lesions of the sympathetic. The narrow pupil and narrowed opening between the eyelids, as well as the retrocession of the bulb, are found on the side chiefly affected. Kocher has shown that lesions of the medulla and upper cervical segments are as competent to produce sympathetic disturbances as are lesions of the lower cervical and first dorsal segments.

Argyll-Robertson pupils do not belong to syringomyelia; if present, they suggest complicating tabes.

Nystagmus occurs more frequently than in any other nerve lesion except multiple sclerosis.

Eye-muscle palsies may occur, but, on the whole, they are rare. They may be recurrent; the abducens is most often affected.

Trigeminus lesions are important. Violent neuralgias or paræsthesiæ may be the first symptom. Dissociation of sensation is usual, and the distribution follows segmental types. The "parietal-ear-chin" line of Kocher marks the upper level of the second cervical segment supply. As the proximal trigeminus becomes involved the first sensory loss is in the scalp and then in areas narrowing concentrically toward the nose (von Soelder, Schlesinger).

The motor fifth is hardly ever affected. The corneal reflex is very rarely absent. Occasional trophic disturbances occur, such as loss of hair or teeth; or the tears may be more abundant on the affected side. Implication of the facial is uncommon; most often the lower portion is alone affected. Often there is no reaction of degeneration.

Hemiatrophy of the tongue is a frequent and may be an initial symptom. Unilateral affections of the soft palate and larnyx are extremely important in diagnosis. In the larynx the usual lesion is paralysis of muscles supplied by one recurrent. Sensory and motor laryngeal changes may be independent of one another. It is important to remember that the laryngeal palsies may develop in an apoplectiform manner with marked vertigo and even loss of consciousness. Vertigo, however, may occur independently of bulbar lesions.

Vomiting may be periodic, occurring in attacks like regular tabetic crises. Heart symptoms are rare.

Headache is not a feature of the disease. Convulsions may rarely occur. Scanning speech has been reported in several cases.

Atypical Forms.—There may be, for long periods, the picture of a spastic paraplegia or an amyotrophic lateral sclerosis. Sensory changes may be absent for years (Bouchard). Bulbar symptoms may come on in an apoplectiform manner and for a long time they may be the only manifestations of the disease. In very rare cases there may be widespread sensory changes—anæsthesia as well as analgesia and thermanæsthesia. In the celebrated case of Spaeth and Schneppel there was practically total loss of all forms of sensation.

In 1883 Morvan published descriptions of a symptom-complex that has since been known by his name. He described the combination of painless panaritium of the fingers with great deformity and accompanied by marked loss of pain- and temperature-perception in the hands and arms. Autopsies of Joffroy-Achard, Prouff, Marinesco, Hoffman, Redlich, Schlesinger, and others have demonstrated the direct association of Morvan's symptom-complex with syringomyelia. On the other hand, the same picture may present itself in leprosy, and only a careful examination will enable one to make a differential diagnosis.

The early appearance of changes in the joints, spontaneous fractures, etc., can lead to confusion only on superficial examination.

Differential Diagnosis.—There is no doubt that syringomyelia represents a clinical if not an anatomical entity. Due attention to the combination of sensory, motor, and trophic changes will usually enable one to make a correct diagnosis. The following represent the chief conditions that may lead to confusion:

1. *Progressive Muscular Atrophy.*—Kahler and Schultze pointed out the importance of sensory changes in distinguishing syringomyelia from cases of muscle atrophy of the Aran-Duchenne type. The doubtful cases are those in which, for years, there are no sensory changes (Croeg, Dejerine). It is necessary to seek for isolated loss or diminution of temperature-perception. Increased knee-jerks, scoliosis, lesions of the sympathetic, trophic changes, paræsthesiæ, ataxia, sphincter disturbances, speak for syringomyelia.

2. *Amyotrophic Lateral Sclerosis.*—Sensory changes are rare, but they may occur (Oppenheim). Bladder symptoms, scoliosis, paræsthesiæ, unilateral bulbar symptoms, trigeminus involvement, nystagmus, are decisive for syringomyelia.

3. *Multiple Sclerosis.*—Tremor, nystagmus, scanning speech, increased knee-jerks, spastic paraplegia, ataxia, sphincter disturbances—these are symptoms that belong to both diseases. Some sensory change is not uncommon in multiple sclerosis, and even dissociation may occur (Freund, Reichel). Optic atrophy, especially atrophy of the temporal half, decides for multiple sclerosis. Marked sensory changes, muscle atrophy, trophic disturbances, scoliosis, speak for syringomyelia. Remissions may occur in either affection, but are more usual in multiple sclerosis.

4. *Progressive Muscular Dystrophy.*—If syringomyelia begins in the shoulder group of muscles atrophy is not rarely associated with partial hypertrophy, and, if cases of dystrophy are complicated with hysterical sensory changes, the two conditions will appear very much alike. Trophic disturbances, increased knee-jerks, segmental sensory distribution, bulbar symptoms, decide for syringomyelia.

5. *Meningomyelitis Luetica.*—Spastic paraplegia and dissociation of sensation may occur in both diseases. Brain symptoms and a Brown-Séquard type of motor and sensory lesions favor lues. Scoliosis and trophic changes are absent. Nystagmus is very rare.

6. *Tabes.*—There may be many symptoms in common. Strongly characteristic symptoms in either direction decide. Thus, for example, the Argyll-Robertson pupil, loss of knee-jerk, ataxia, sphincter disturbances, character of sensory loss, trophic changes in lower extremities, crises, belong to tabes; on the other hand, muscle atrophy, marked dissociation of sensation over large areas, increased knee-jerks, scoliosis, trophic changes in the arms, speak for syringomyelia.

7. *Hæmatomyelia.*—In this disease the symptoms are marked at first, but later some improvement takes place. Syringomyelia is usually steadily progressive.

8. *Plexus Affections.*—Cases have been reported of bilateral plexus palsies, of both the Erb and the Klumpke types. There may be dissociation of sensation as in syringomyelia, and the distribution may be of the segmental type. In some cases only continued observation will decide; as a rule, tenderness of the nerve trunks and of the spine is more marked in the plexus affections, there is no increase of knee-jerks, bulbar symptoms do not occur, and the losses of sensation are limited to the arms.

9. *Hysteria.*—Complications with hysteria may add to the difficulties of differential diagnosis in muscular dystrophies, atrophies, etc., as mentioned above; or hysteria may be added to or may simulate some of the symptoms of syringomyelia. In the sensory disturbances of hys-

teria dissociation is rarely segmental. Suggestion may lead to disappearance or transference of the sensory losses. Deep or superficial reflexes are little modified, trophic changes and atrophies are extremely rare. Bulbar changes do not occur.

10. *Central Tumors.*—(Tubercle gumma, glioma, etc.) Here symptoms are severe and advance quickly. Pain is severe; marked paræsthesiæ, especially of heat and cold, are usual; atrophies and paralyses, particularly paraplegia, come on rapidly. Ataxia and sphincter disturbances are frequent; there is often complete or partial development of the Brown-Séquard complex; if bulbar symptoms occur they are severe and run their course quickly.

11. *Pemphigus, scleroderma, Raynaud's disease, deformities due to arteriosclerosis, pellagra, and lathyrismus,* can rarely give rise to a confusion.

12. *Leprosy.*—The similarity between some forms of leprosy and syringomyelia was pointed out by Steudener in 1867 and by Langhans in 1875, but the publication of Morvan's work in 1883 first awakened general interest in the question. As described above, the Morvan symptom-complex was shown, by carefully made autopsies, to be associated with syringomyelia (Joffroy and Achard, Prouff, Redlich, Schlesinger, and others). But, subsequently, Zambaco published reports which showed that in Brittany, where Morvan had carried on his work and where leprosy was endemic, there occurred cases which merited the name of Morvan's disease, but in which the existence of leprous neuritis was absolutely proved. It is particularly these trophic forms of syringomyelia that are liable to be taken for leprosy, and it is equally true that the anæsthetic and not the tuberculous types of leprosy are confused with syringomyelia. Despite the views of some extremists, the two diseases are undoubtedly distinct. Leprosy has no influence in the production of syringomyelia, and unequivocal lesions of leprosy have never been found associated with syringomyelia; accidental combination may of course be possible. The leprous analgesia or thermo-anæsthesia depends on involvement of peripheral nerves and is usually not so widespread nor so segmentally distributed as in syringomyelia. Evidence of peripheral nerve disease is found in thickening of nerve trunks, particularly the ulna and great auricular. Bulbar lesions, increased knee-jerks, girdle sensation, sphincter disturbance, and scoliosis do not belong to the symptomatology of leprosy. On the other hand, the cutaneous nodes, widespread pemphigus, vitiligo, white scars, and, above all, the demonstration of bacilli in the blood, nasal secretion, etc., decide for leprosy. There are some cases, especially in districts where leprosy is endemic, in which a diagnosis is difficult; as autopsies prove, however, confounding of the two diseases can even then be avoided if a careful examination be made.

Course and Prognosis.—The disease is eminently chronic; cases have been known of thirty, forty, and fifty years' duration. The type of disease dependent on quick glia-proliferation (gliosis without cavity formation) runs a relatively rapid course (from three to six years), but the cases can hardly be separated clinically.

Intercurrent infections and trauma often influence the process unfavorably. Apoplectiform attacks may occur with accentuation of bulbar or spinal symptoms; marked remissions also occasionally occur. The bulbar lesions are on the whole benignant and may last for years unchanged.

Death may occur from bladder and kidney complications, from sepsis following the various trophic disturbances, and sometimes from bulbar lesions, but most often from intercurrent disease.

Treatment.—From the nature of the lesions it is impossible to expect direct results from treatment. In a few cases, due seemingly to lues, specific treatment has proved advantageous. Prophylactic measures play an important part. Such are: avoidance of trauma, of overuse of atrophic muscles; prevention of bedsores and, to a certain extent, of atrophic joints; avoidance of injury to analgesic extremities, and of exposure to injurious temperature changes; above all, great care in the avoidance of bladder complications.

Mud baths and gentle massage may help contractures.

Electricity, galvanic and static, may relieve pain or paræsthesiæ.

Panaritium and suppurating joints must be treated surgically; as a rule, wounds from surgical operations heal fairly. Pain may require phenacetin, antipyrin, pyramidon, salicylates, or morphine. Potassium iodide and mercury should be given in cases of questionable luetic origin, or iodide may be tried for a time in all cases. General tonics can only be of indirect service.

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Some of the More Important Recent Publications.

Albarran and Guillain: Ueber Blasenstörungen bei Syringomyelie. Wien. med. Woch., No. 51, 1901.

Audrey, Ch., et Dalous: Hyperkeratose circonscrite des doigts chez un syringomyelique. Journ. de mal. cutan. et syph., Paris, 1902.

Azema: Un cas de syringomyélie. Écho méd., Toulouse, 1902, xvi.

Bischofswerder: Les Nevromes intramedullaires dans deux cas de syringomyélie avec main succulente. Journ. de Neurol., Paris-Brux., 1901.—Lésions des cordons postérieurs et troubles de la sensibilité dans un cas de syringomyélie. Rev. Neurol., Paris, 1902.—Contribution à l'étude de l'anatomie pathologique de la syringomyélie. Nevromes intramedullaires. Main succulente, Paris, 1902.

Bonhoff, Hermann F.: Trauma in Beziehung zur Syringomyelitis. Inaug.-Dissert., Bonn, Lille, Juli, 1901.

de Buck et de Stella: Un cas de syringobulbie et de syringomyélie. Belgique med. Grand-Haarleue, 1902, ix.

Collier, James: A Case of Deformity of the Skull, Simulating Leontiasis Ossea, Associated with a Condition of Syringomyelia; no physical signs of syringomyelia present. (Case with autopsy.)

Cuchini: Contributo allo studio della siringomielia de origine traumatica. Gass. med. di Roma, 1902.

Fargues: Contribution à l'étude de la topographie des troubles sensitifs dans la syringomyélie, Paris, Nantes, Deroual, 1902.

Fleger, P.: Beitrag zur Casuistik der Syringomyelie und ueber die bei dieser Krankheit vorkommenden Hautstorungen.

Gangolphe: Osteoarthropathie d'origine medullaire et tuberculose. Notes sur les ostéoarthropathies syringomyeliques. Bull. Soc. de Chir. de Lyon, 1901.

Guillain, G.: La forme spasmodique de la syringomyélie. La nevrite ascendante et la traumatisme dans l'étiologie de la syringomyélie. Paris, 1902.—La nevrite ascendante dans l'étiologie de la syringomyélie. Bull. et Mem. Soc. med. de Hôp. de Paris, 1902.

Goldbaum: A New Symptom in Syringomyelia. Neurologisches Centralblatt, 1901.

Huet, E., et Cestan, R.: Sur deux cas de syringomyélie à topographie radiculaire des troubles sensitifs et des troubles moteurs. Rev. Neurol., Paris, 1902.

Hudervernig, C.: Zur Pathogenese der Artbropathien bei Syringomyelie. Neurol. Centralbl., Leipzig, 1901.

Hoedlmoser, G.: A Peculiarly Localized Arthropathy in a Case of Syringomyelia with Genital Hypoplasia. Wiener klinische Wochenschrift, 1901.

Ingebrans et Brassart, H.: Syringomyélie posttraumatique. Écho méd. du Nord., Lille, vi., 1902.

Koelichen, J.: Contribution à l'étude de la syringomyélie et de l'hydromyélie. Gaz. lek. Warszawa, 1902.

Kienboch, R.: Critik der sogenannten traumatischen Syringomyélie. Jahrbücher f. Psychiatrie, Vienna, 1892.

Launois, P., et Roy: Exostoses multiples, Syndrome syringomyélique (Amputations spontanées des doigts, thermanesthésie) chez un homme de trente et un ans hystérique et tuberculeux. Bull. et Mem. Soc. méd. de Hôp. de Paris, 1902.

Libotte: Un cas de syringomyélie au début. Journ. de Neurol., Paris-Brux., 1902, viii.

Losen, Adolf: Ein Beitrag zur Morvan'schen Krankheit (Syringomyelie). Inaug.-Dissert, Würzburg, April to September, 1901.

Meyer, Adolf: Report of a Transverse Lesion of the Median Thoracic Segments, Leaving Intact the Posterior Columns, and Causing Syringomyelic Dissociation. Journ. of Nerv. and Ment. Dis., December, 1902.

Pearce, F. S.: Syringomyelia. Medical Fortnightly, St. Louis, December, 1902.

Preobrachensky, P. A.: The Pathological Anatomy and Pathogenesis of Syringomyelia. Roussky Archiev Pathologyi, June, 1902.

Renon, L.: Des Fractures spontanées chez les syringomyéliques. Presse médicale, Paris, July, 1902.

Rosenfeld: The Distribution of the Temperature Sense in Syringomyelia. Deutsche Zeitschrift für Nervenheilkunde, 1901.

Raymond: Syringomyelia of the Medulla and Pons. Semaine médicale, September, 1901.

Stolper, P.: Syringomyelie, Gelenkerkrankung, Trauma. Curztl. Sachverstand Ztg., Berlin, 1902.

Schroell, August: Zur Kasuistik der Syringomyelia. Inaug.-Dissert. München, October, 1901.

Sachs, Paul: Die differentialdiagnostischen Beziehungen des Morvan'schen Symptomenkomplexes zur Lepra und zur Syringomyelie. Inaug.-Dissert., Berlin, Juli, August, 1901.

Sainton and Ferrand: Syringomyelia with "Thorax en Bateau" and Trophic Disturbances Resembling Myxœdema.

Schlesinger: Die Syringomyelie, Leipzig, 1895; also 1901.

Taubert: Ueber Erythromelalgie bei Syringomyelia des Cervikal-Marks. Deutsche med. Wochenschrift, 1903.

Westphal, A.: Ueber die Bedeutung von Traumen und Blutungen in der Pathogenese der Syringomyelie. Archiv für Psychiatrie, Bd. 36.
Westrum, W.: Klinische Beiträge zur Kenntniss der Syringomyelie. Inaug.-Dissert., Erlangen, December, 1901.

SPINAL-CORD DISEASES: TABES.—Tabes is the term which is gradually being universally adopted to describe the disease popularly known as "locomotor ataxia." The name "ataxie locomotrice" was given to this affection by Duchenne in 1858 and is still quite popular. It is objectionable, however, because it is merely descriptive of a symptom, which at times may not appear until late in the course of the disease, or which may be entirely absent. "Posterior spinal sclerosis" is also unsatisfactory, as it refers only to the most easily discoverable lesion. "Tabes dorsalis," or "wasting of the back," was applied by Hippocrates to certain symptoms supposed to be due to venereal excesses, but was restricted to this disease by Romberg.

Tabes is the most common form of chronic organic disease of the nervous system. The pathological process underlying the affection is a parenchymatous degeneration terminating in sclerosis, which principally involves the sensory neurones. The peripheral motor neurones are also frequently implicated. In other words, it may be looked upon as a degenerative disease affecting various parts of the entire nervous system, while the most pronounced and extensive lesion is found in the posterior columns of the spinal cord. The morbid process may attack the cranial nerves and their nuclei as well as the peripheral nerves in the extremities. It may thus produce blindness from gray degeneration of the optic nerves, or paralysis of ocular muscles from degeneration of the nerve nuclei. The brain cortex does not always escape. The parts first affected in tabes are usually the fibres which originate in the spinal ganglia, *i.e.*, the fibres of the posterior roots which traverse the posterior columns.

Etiology.—In the vast majority of cases there is an antecedent history of syphilitic infection, antedating the first signs of the disease by from one to thirty-five years. In most cases the period ranges from five to fifteen years, the previous existence of syphilis being either demonstrable or admitted by the patient.

Statistics collected from various reliable sources show that from seventy to ninety-five per cent. of all tabetics give a history of previous syphilis. Hence it has been assumed by nearly all clinical investigators that tabes is one of the results of syphilis. Strümpell has expressed the view, which has been favorably received, that tabes does not arise from the syphilitic bacteria themselves, but from a toxin derived from them. It has therefore been almost universally considered as a sequel of syphilis, and has been variously characterized as a "post-," "para-," or "metasyphilitic" process. On the other hand, it is well known that only a small percentage of those who have contracted syphilis develop tabes. It cannot be consistently denied, however, that tabes also occurs without any discoverable evidence of previous syphilis. With the previous knowledge of an antecedent syphilis in a given case, we are by no means certain that the tabetic degeneration is the result of such early infection. It would seem that in most cases additional exciting or accessory causes are operative, such as exposure to cold, over-fatigue, alcoholic, sexual or other excesses, or a congenital or acquired neuropathic constitution—causes which predispose to the development of tabes, as well as to other degenerative processes, in the nervous system, in those patients who have contracted syphilis at some remote period.

Tabes has at times been considered as resulting from trauma, but in all such cases that have been investigated it has been shown that tabetic symptoms existed before the injury. It is a well-established fact, however, that the tabetic process is accelerated under such circumstances.

Symptoms.—Among the early symptoms of the disease first noticed by the patient are pains in the trunk and extremities; disturbance of the bladder; impotence; rectal pain; diplopia; ocular paralysis; failing vision; cutaneous hyperæsthesia or anæsthesia; incoördination in walking; visceral symptoms known as "crises" affecting the gastro-intestinal tract, bladder, or rectum, and occasionally laryngeal "crises."

Pain is often one of the earliest symptoms of tabes, and may antedate all other symptoms for many years. The character of the tabetic pains is as a rule pathognomonic. They are irregular in their distribution and are usually described by the patient as "shock-like," "sharp," "piercing," "cutting," or "stabbing," being rapidly repeated at the same spot, which often becomes extremely sensitive to the slightest touch. They may also resemble the painful sensation as if the muscles and bones were being crushed, or as if a piece of nerve was pulled. They may be so sudden in their onset that a strong man is surprised into a loud exclamation of pain while feeling otherwise well. They may occur every few moments for minutes, hours, or days. Although they differ essentially from true neuralgic, muscular, or periosteal pains, they are often erroneously considered as being of such origin. Hence it is a common experience for the neurologist to receive such patients with their announcement that they had previously been under treatment for rheumatism or neuralgia. In order fully to appreciate the significance of these pains, it is necessary to study this symptom carefully and minutely, for it may exist for several years before other symptoms are at all prominent. In the majority of instances, the pains most frequently affect the lower extremities. They may, however, be limited to the inframammary, intercostal, dorsal, or lumbar regions. Indeed, they are known to attack almost any part of the body. They may thus appear in the form of trigeminal facial pain or be located in the scalp. On the other hand, in some patients, pain is either entirely absent or only a slight, dull, circumscribed, and aching pain is occasionally complained of. If such pains do not appear in the early period of the disease, they are not likely to appear later.

Crises.—At almost any stage of the disease suddenly recurring paroxysmal attacks of severe gastralgia may take place, accompanied by exhaustive vomiting, which resists all ordinary methods of treatment, but seems to subside spontaneously. These attacks are known as "gastric crises." Sometimes persistent gastralgia may be the only symptom complained of. In such a case careful examination will often reveal an area of cutaneous anæsthesia in the epigastric region, thus leading to further investigation which discloses the underlying cause of the pain. Instead of these "gastric crises," there may be severe and unaccountable diarrhœa associated with violent colicky pain that may sometimes simulate an attack of renal colic. In some instances the rectum may be the seat of severe pain that is remittent in character. This pain not being relieved by ordinary means, its true nature being overlooked, surgeons have been led to the fruitless operation of forcibly stretching and paralyzing the anal sphincter and removing any hemorrhoids that perchance are present.

"Laryngeal crises" occur only in a very small percentage of cases. The most common form is true laryngeal spasm, with noisy inspiration and expiration, cough, and often considerable dyspnœa. The paroxysms may resemble those of whooping-cough or of laryngismus stridulus. Death during these attacks is extremely rare.

Incontinence or retention of urine is frequently an early symptom. Considerable effort is required in micturition, the urine flowing slowly. Quite often the bladder is not completely emptied and the residual urine may undergo decomposition and thus set up a cystitis.

Impotence may also occur as an early manifestation, but it usually develops as the disease advances.

Diplopia, ocular paralysis, or *failing vision* may be the first symptom that leads the patient to consult a physician. For several years before other symptoms are clearly manifested, or at any time in the early period of the disease, there may be frequent diplopia, or transient attacks of paralysis affecting the ocular muscles; these attacks are of nuclear or peripheral origin. The paralyses of the external ocular muscles are often bilateral, but not symmetrical, often unilateral, and frequently affect only single muscles. Ptosis and paralysis of one or more muscles supplied by the oculomotor nerve, and abducens paralysis, are the most frequent. As a rule they develop suddenly and usually disappear after a longer or shorter period, with or without treatment. Relapses are frequent. Attention may first be drawn to the disease through a sudden third- or sixth-nerve paralysis, either partial or complete. The duration varies from a few hours to a year or more, or the paralysis may become permanent. Sometimes both eyes are affected, and a progressive and complete ophthalmoplegia may ultimately develop.

Atrophy of the optic nerve is the most serious ocular complication of tabes. It occurs in about ten or fifteen per cent. of the cases. For a long time it may be the only symptom of the disease, thus appearing several years before other characteristic phenomena are manifested. It rarely develops in the later period of the disease. The atrophic process is the result of gray degeneration of the optic nerves similar to that which attacks the posterior column of the spinal cord. The failure of sight usually commences with a peripheral limitation of the field and loss of color vision (the visual field for green contracting early); but sometimes central vision is defective from the very beginning. The atrophy is almost always bilateral, being more advanced in one eye than in the other, and ultimately progresses to complete blindness. It is rare for tabetic patients who become blind at an early stage of the disease to become ataxic later; but if the ataxia has become well pronounced, it does not always improve with the subsequent development of optic atrophy. In the majority of instances, the occurrence of optic atrophy seems to inhibit the further progress of the disease. This is a peculiar clinical fact which has never been satisfactorily explained.

Incoördination, or ataxia as it is familiarly termed, is a common symptom in many cases of tabes and most frequently affects the lower extremities. It has occasionally been noted by the patient himself, who first discovers difficulty in standing or walking with closed eyes.

As a rule, the lower extremities are affected first. When the sclerosis begins in the cervical portion of the cord, the ataxia, as well as other symptoms, may, for a longer or shorter period, be confined to the upper extremities. It is a curious clinical fact, previously mentioned, that, in cases in which optic atrophy appears, the ataxia often ceases its further progress.

Incoördination is a disturbance of the associated muscular action which is essential in the maintenance of equilibrium. Coördinate muscular action is kept under the patient's control to a certain extent by the attention and vision. As soon as the patient fails to watch his movements, or the eyes are closed, the ataxia is materially increased and may become uncontrollable. Thus, while standing with closed eyes and the feet close together, he may gradually or suddenly fall to the ground (static ataxia), being deprived of the sense of position of the legs, unless the eyes are opened. Incoördination affecting the lower extremities is productive of the characteristic tabetic gait ("locomotor ataxia"). In attempts at walking, when the condition is well pronounced, the foot is lifted from the ground at a much higher elevation than normal, and, being poised with considerable uncertainty, it is suddenly brought to the ground, striking forcibly on the heel.

The ataxia is due to an obstruction or obliteration of afferent impulses conducted from the periphery through the various sensory tracts. It therefore follows as a result of sclerosis of the posterior columns of the cord, or of degeneration of the peripheral sensory fibres in the muscles and joints, being directly conditioned by a loss of muscle and joint sensibility.

While in some cases it is often the most striking symptom, occasionally developing during the first years of the disease in conjunction with other discoverable signs, in many instances the ataxia is scarcely perceptible or demonstrable, or does not appear at all at any time during the course of the malady. Hence the designation of the affection as "locomotor ataxia" is a misnomer.

Sensory Disturbances.—Various paræsthesiæ are often complained of, such as numbness or formication in the extremities—a sensation as if the soles of the feet were resting upon rubber or fur; a band-like feeling around the body, usually at the level of the midthoracic region, as if a tight corset or belt enveloped the body. This sensation is known as "cincture feeling" or "girdle sensation." Or the patient discovers that sensibility in his legs is absent in various areas. In the upper extremities there may be numbness in the course of the ulnar nerve affecting especially the fourth and fifth fingers. In addition to the pains and paræsthesiæ described by the patient, disturbances of cutaneous sensibility are often found upon examination, in association with the loss of muscle and joint sensibility just mentioned. Impairment of sensation may be entirely absent, but in most cases of tabes some objective sensory disturbance is always found. It may vary from slight diminution of tactile sensibility to the most pronounced analgesia. The different qualities of sensation should always be tested carefully. In a large percentage of tabetics (four-fifths) there is an area of diminished sensibility to touch situated like a band about the chest in the midthoracic region and varying from three to four inches in width. This tactile loss may be associated with analgesia in the same area. A diminution in the sense of touch, pressure sense, and the sense of position of the limbs, usually appears in the early stage, while the higher degrees of anæsthesia are developed later. The temperature sense may remain unimpaired until the last stage of the disease. But analgesia is one of the earliest and commonest forms of sensory disturbance. The areas of analgesia may be distributed over the trunk and extremities. In the lower extremities it involves the sole of the foot, the heel, the toes, the anterior or lateral portions of the legs, or the inner surface of the thigh. The transmission of painful sensations is retarded in some cases, the prick of a needle being interpreted at once as a touch, and recognized as a painful sensation from three to ten or fifteen seconds later. This is generally described as "delayed conduction."

The loss of joint sensibility and of the sensibility of the deeper muscular structure occasions interference with the normal muscular "tonus" and results in deficiency or complete relaxation of muscular tension (hypotonus). This condition will explain the fact why tabetic patients submit to extreme passive movements of the extremities without complaint of pain. It may also account for the occurrence of hyperextension of the knee-joints often seen in tabetics (genu recurvatum).

Although patients often complain of weakness in the legs, it is only in exceptional instances (in which the motor neurone system becomes implicated) that such condition can be actually demonstrated. As a rule, the muscular power and resistance to passive movement are unimpaired. When muscular atrophy or actual paralysis exists, they must be considered as complications arising in the course of the disease.

The Loss of the Knee-jerk.—One of the earliest and most constant objective signs of tabes is the loss of the knee-jerk. As a rule it does not disappear suddenly. The pains may exist for a long time before the knee-jerk disappears. In the study of a large series of cases the knee-jerk symptom is found to be variable in its character. In quite a number of instances of undoubted tabes both knee-jerks may be active, but they usually disappear as the disease advances. This occurs when the upper portion of the cord is first affected. In other cases, the knee-jerks may be well marked on one side and lost on the other. Again, they may be apparently absent, but demonstrable only upon so-called reinforcement. Both may be equally feeble, or may differ in degree of weakness

It has been claimed that in about one per cent. of healthy people the knee-jerk is absent. The correctness of this assertion is questionable. Such an anomaly is so rare that its possibility need only be remembered. The writer has tested over one thousand healthy children from three to fourteen years of age, and the knee-jerk was demonstrable in every case. Its absence is due to an interruption in the so-called reflex arc in relation with the corresponding centre situated in the lumbar region of the cord. Much patience is often required in satisfactorily determining whether the knee-jerk is present or absent. The ordinary and customary method of testing for the knee-jerk while the person's legs are crossed, or the feet resting on the floor, will suffice when the knee-jerks are quite active. Under such circumstances the position of the limbs is immaterial. The utmost care, however, is necessary when there is any doubt as to the presence of the reaction. It will then be advisable to have the patient sit upon a high chair or upon the edge of a table, so that the feet are free from the floor. As a rule, both sides should be examined. In many instances the anticipation of the tap upon the tendon occasions involuntary rigidity of the flexor group of muscles, thus producing sufficient opposition to overcome the action of the quadriceps. Hence, before and during the examination, the patient should close his eyes, and his attention should be directed from the purpose of the examiner, either by conversation or by rapid interrogation. Or he may be directed to make some muscular effort with his hands, such as forcibly interlocking the fingers, elevating the arms, etc. This is known as "re-enforcement." With this object in view any other similar expedient may be resorted to that suggests itself to the examiner. It is never safe to state that the knee-jerk is absent, unless repeated and varied tests have been made with the clothing removed.

Reflex Iridoplegia.—Another early and most important evidence of tabes is the loss of the reflex action of the iris to light. This is familiarly known as the "Argyll-Robertson symptom," but in recent years it is more correctly described as reflex iridoplegia. It is present in about eighty per cent. of all cases. Being a phenomenon somewhat analogous to that of the loss of the knee-jerk, it is found to be just as variable in the extent of its manifestations. Its absence, however, does not exclude the diagnosis of tabes. The longer the duration of the disease, the more likely are we to find this sign. When present it is generally bilateral. In rare instances it is unilateral—*i.e.*, affecting only one eye, or the degree of reaction may differ in the two eyes. It is usually unaccompanied by any disturbance of vision. As a rule, the pupils react in convergence of the optic axes. In some cases of tabes the pupils are absolutely rigid, and do not react to light or in convergence. They may also be unequal, partly dilated or contracted. The inaction of the pupil when exposed to light is not indicative of a lesion in the spinal cord, as was erroneously supposed by many before tabes rested upon a firm pathological basis, but is the result of interference with the reflex conducting path in its course between the optic nerve, corpora quadrigemina, and oculomotorius. It is therefore due to a lesion within the brain, and may be looked upon as an almost infallible sign of central nerve degeneration involving the sphincter nuclei of the third nerve or their efferent fibres when the eyes are otherwise apparently normal.

The examination of the pupils for reaction to light requires the closest observance in its performance. This apparently simple procedure is deserving of careful attention, and certain precautions are absolutely essential in order to avoid erroneous conclusions. The following method should be pursued: Place the patient in a position facing a window. Daylight is always preferable. Instruct him to gaze steadily upon some large object at least twenty feet distant, and to keep both eyes open. The eyes are then covered or shaded either with the examiner's hands or with two pieces of dark card-board. The patient in the mean time must continue gazing in the direction just mentioned. In a few moments one eye is suddenly uncovered and exposed to the light, when in the normal state the pupil (which always dilates in darkness or subdued light) immediately contracts. The other eye is then tested in the same manner. The next step is to note if the pupils contract in convergence or accommodation. After the patient has been looking in the distance for a short time, with both eyes uncovered, he is suddenly told to look at the examiner's finger, or some small object held within two inches of the patient's nose. In the normal condition the eyeballs converge and the pupils contract. The pupillary reactions should not be tested before a gas flame, as the patient is apt to, and in fact generally does, "fix" upon the flame, thereby causing contraction of the pupils in accommodation and convergence, which may easily mislead. A very common source of error to be guarded against, which is similar in its result, is the failure to bear in mind the natural tendency of the patient to look at the examiner as soon as the eye is uncovered. Bilateral reflex iridoplegia may also be associated with myosis. While the former often exists without the latter, myosis is as a rule accompanied by loss of the pupillary light reflex. The myosis, however, is due to a lesion affecting the spinal cord and involving the so-called cilio-spinal centre situated between the fourth cervical and the second dorsal segments. As the pupil-dilating fibres pass from thence out by the rami communicantes into the cervical sympathetic, degeneration of these fibres causes the permanent contraction of the pupils.

Arthropathy.—Trophic disturbance in the bones and joints is an occasional phenomenon of tabes, but it is of sufficiently frequent occurrence (in about three or four per cent. of all cases) to command attention. This form of joint affection is known as "tabetic arthropathy," and most commonly involves the knee-joints, although the hip-joint and the large joints of the upper extremities may also be similarly affected. It has often been known to arise during the early or pre-ataxic stage of the disease. Painless swelling and complete disorganization of the joint are pathognomonic of tabetic arthropathy. It usually arises suddenly and develops rapidly. Sometimes following a trivial injury, the joint becomes swollen and the surrounding tissues œdematous, but there is complete freedom from pain, redness, or fever. The joint structures, including the ends of the bones, undergo rapid destruction.

The long bones at times become brittle and thus easily fracture either spontaneously or from a slight traumatism. Among the trophic cutaneous disorders, perforating ulcer of the foot is the most common. It is usually situated on the plantar surface of the foot, either under the base of the great toe or of the fifth metatarsal bone, or at the heel. It generally begins as a callus or corn, and is painless, even when the ulcerative process is quite deep and extensive.

Diagnosis.—The appearance of a classical case of the well-advanced disease, as described in the text-books, is a familiar picture. There is a superabundance of convincing proof to establish the fact that this, probably the commonest form of organic nervous disorder, often remains unrecognized for months or years during its early stages, although ample evidence of its presence may be discoverable by proper methods of investigation. To the most sanguine neurological mind the approach of the medical millennium does not imply the restoration to life and normal function of sclerosed and destroyed nerve structures; but if our modern therapeutic measures are to prove curative in this disease, they must be utilized before organic changes are too far advanced. Our only hope of success in the treatment of tabes rests in a correct diagnosis at the earliest possible moment. The early diagnosis of tabes—which, so to speak, is chronic from its very beginning—is of incalculable value, inasmuch as it saves the patient much misdirected and useless medication. When unrecognized tabes has existed for some time, various pronounced symptoms may appear, and, although a part of the disease, may conceal its true character. Its presence is frequently unsuspected by the attending physician until the signs are so conspicuous that they almost speak for themselves. Although static ataxia frequently occurs in tabes, it is by no means pathognomonic. The fact that a slight swaying is of common occurrence in healthy individuals should always be borne in mind. Static incoördination is often present in hysteria or pronounced neurasthenia, during convalescence after prolonged illness, in transverse myelitis, and in polyneuritis resulting from diphtheria, alcohol, lead, arsenic, etc. Some forms of alcoholic polyneuritis are commonly mistaken for tabes on account of their resemblance to that affection (see the sections on Neuritis and Polyneuritis in the article on *Neuritis*). Upon superficial examination the presence of static ataxia with anæsthesia and absence of the knee-jerk, points to tabes. But as these symptoms are usually associated with tenderness on pressure over the affected nerve trunks, diminished muscular power or actual paralysis, and decrease or loss of faradic irritability in the affected muscles, we are enabled to exclude tabes. The absence of the knee-jerk in these cases is due to involvement of the motor fibres of the anterior crural nerve or its branches, and is usually an accompaniment of weakness or diminished resistance in the quadriceps. The loss of the knee-jerk in uncomplicated cases of tabes, however, is attended as a rule with preservation of muscular power in the extensor group, even when the disease is well advanced and there is pronounced incoördination. This peculiar feature of tabes can be easily demonstrated, and in my experience is of extreme value. When the peripheral sensory nerves are especially affected, as in certain forms of toxic polyneuritis, particularly from arsenical poisoning, the disease has been termed pseudotabes. On account of the presence of well-marked ataxia, absence of the knee-jerks, and anæsthesia, it closely resembles the true disease. A consideration of the antecedent history, mode of onset, and development will generally enable us to reach a satisfactory conclusion as to the nature of the trouble. At times the differential diagnosis between tabes and some atypical forms of polyneuritis is attended with much difficulty. On the other hand, in some tabetic patients the peripheral nerves of the lower extremities may undergo degeneration, and thus lend confusion to the otherwise stereotyped picture. I have repeatedly seen chronic transverse dorsal myelitis mistaken for tabes, owing to pain in the lower extremities, inability to stand with closed eyes, and cutaneous anæsthesia. Such an error must be ascribed to gross carelessness or neglect in the examination. The exaggerated knee-jerks with probable ankle clonus, and the loss of muscular power sometimes with atrophy, should serve to make the diagnosis clear. Some cases of cerebrospinal syphilis so closely simulate genuine tabes that their differentiation can be accomplished only after a careful study of the development and course of the symptoms. Paretic dementia and tabes are sometimes found associated, but when the mental symptoms predominate, such as changes in the patient's character, diminution of the intellectual functions, speech disturbances, attacks of unconsciousness, etc., we must favor the diagnosis of the former.

The most important subjective symptom is the peculiar paroxysmal pains, while the two principal objective signs of tabes are the absence of the knee-jerk and the loss of the pupillary light reflex. It may be safely said that the coexistence of the latter is equivalent to the diagnosis of tabes. It rarely happens that both are absent at the same time, yet such cases do occasionally occur. We must then depend upon the association of other symptoms and must watch for further developments. The presence of either one, in conjunction with the fulgurating pains, or bladder disturbance, or the areas of anæsthesia over the back, is sufficient evidence to warrant the diagnosis. When a man over thirty years of age, with a history of ancient syphilitic infection, complains of the pains characteristic of tabes, we should at once suspect its existence, whether other signs are present or not. Should these typical pains be associated with one or more of the objective symptoms, the diagnosis may be made with confidence. It is a fact well known to all neurologists, that among physicians in general the failure to recognize the presence of tabes is more common than its diagnosis. On the other hand, an incorrect interpretation of phenomena which resemble those of tabes is of frequent occurrence. Such conditions can be obviated only, first, by a clear conception of the clinical peculiarities of the disease; second, by a practical familiarity with the method of examination, combined with its application to the individual case.

Duration, Course, and Prognosis.—Tabes is not invariably progressive in character, but it is always chronic in its course, the average duration of the disease being about ten years, although in uncomplicated cases it has frequently lasted for from twenty to thirty years. In rare instances it is very rapid in its progress, terminating fatally in a few years. As the clinical types differ materially, the course and duration of the disease vary with the character and severity of the symptoms. Remissions have been known to occur, and under suitable management the disease often becomes stationary in its early stages. Occasionally, even in well-advanced cases, the amount of improvement is often very great. The development of cystitis may at times lead to fatal pyelonephritis, and falls or slight injuries may result in fractured bones or in a rapid advance of the pathological process. The characteristic pains, slight ataxia, and absence of knee-jerk and pupillary light reflex may exist for many years without any further manifestations. In some cases the symptoms are so moderate that the patient may live in comfort and be able to be about for many years, while in others the intensity of the symptoms may be so pronounced that the patient becomes bedridden in a year or two.

Treatment.—Although the tabetic degeneration cannot be cured, much can be accomplished by improving the general health of the patient, and thus, in many instances, delaying the further progress of the disease. Hence such measures as prolonged rest in bed, if necessary, judiciously applied hydrotherapy, massage, and static electricity often prove valuable. It is essential to avoid fatiguing exercise or excesses of any kind. Certain subjective symptoms may also be relieved. Objective symptoms, such as optic atrophy, reflex iridoplegia, and absent knee-jerks, always remain permanent despite any form of treatment. The effect of drugs on the tabetic process is very misleading on account of the spontaneous remissions that are known to occur in the course of the disease. Besides, the result of the administration of medicinal remedies in a given case cannot be predicted upon the basis of its beneficial influence in another patient. As the disease varies in its type in different individuals, the plan of treatment will have to be modified accordingly. The patient should be cautioned to avoid any unnecessary exposure to falls or other injuries, for the osseous structures are often brittle and fractures are easily produced. The condition of the bladder must be carefully watched and the urine frequently examined. At the first indication of decomposition of residual urine, or of any symptoms of cystitis, the bladder should be irrigated and the patient instructed in the aseptic use of the catheter.

Tabetic patients who have had syphilis, but who have never received antiluetic treatment since tabetic symptoms have developed, should be given a thorough course of active medication for several weeks. If this has already been carried out without relief, it is useless—nay, even harmful—to repeat the procedure. Not only have I never seen such patients improved by this means, but I have repeatedly noted an increase in the degree of many of the symptoms, presumably as the result of interference with the general nutrition. One difficulty in this matter lies in the possibility of mistaking cases of exudative cerebrospinal syphilis for tabes, *i.e.*, an inflammatory for a degenerative condition. When such a differentiation is not clear or is apparently impossible, the patient should be given the benefit of any reasonable doubt, and antisyphilitic drugs administered.

Pain.—If the action of the bowels is regulated and the diet and general habits of the patient are properly controlled, the frequency and severity of the tabetic pains will be invariably ameliorated, or the attacks may subside entirely. The faradic wire brush, or linear cauterization applied over the vertebral column in the region corresponding with the posterior roots that are presumably associated with the location of the pain, often proves effective. Various anodyne liniments, or the application of an ice-bag or of hot water to the seat of the pain during the attack, give relief in some cases. When necessary, the various coal-tar products may be tried. The most useful are acetanilid and phenacetin. As a last resort codeine or morphine may be administered. During a "gastric crisis" the best method of relief is the subcutaneous injection of morphine or codeine.

Suspension.—This is often useful in selected cases, but it should never be used indiscriminately. The patient may be suspended in a Sayre apparatus for about two or three minutes twice a week. The same result (*i.e.*, stretching of the vertebral column) may be accomplished by having the patient sit on the floor, and then forcibly flex the head and trunk upon the thighs, while the lower extremities are kept straight.

Educational Exercises for Controlling the Ataxia.—This plan of treatment was introduced to the medical profession in the year 1889 by Dr. H. S. Frenkel, of Heiden, Switzerland. A large variety of exercises may be practised. They may be executed with the patient in a recumbent position; while sitting; in an erect position; and various movements may be carried out while walking.

Exercises for the Trunk and the Lower Extremities.—While recumbent: (*a*) Lying on the back, raise body into sitting position and return to recumbency. (*b*) Flex thigh upon abdomen, leg upon thigh, then extend and elevate entire extremity and slowly return to original position. (*c*) Elevate entire extremity while in extension and return (Goldscheider).

The following movements have been recommended by Dana as a modification of Frenkel's method:

"1. Sit in a chair, rise slowly to erect position, without help from cane or arms of chair. Sit down slowly in the same way. Repeat once.

"2. Stand with cane, feet together; advance left foot and return it; same with right. Repeat three times.

"3. Walk ten steps with cane, slowly. Walk backward five steps with cane, slowly.

"4. Stand without cane, feet a little spread, hands on hips. In this position flex the knees, and stoop slowly down as far as possible; rise slowly; repeat twice.

"5. Stand erect, carry left foot behind and bring it back to its place; the same with the right. Repeat three times.

"6. Walk twenty steps, as in exercise No. 3; then walk backward five steps.

"7. Repeat exercise No. 2, without cane.

"8. Stand without cane, heels together, hands on hips. Stand in this way until you can count twenty. Increase the duration each day by five, until you can stand in this way while one hundred is being counted.

"9. Stand without cane, feet spread apart; raise the arms up from the sides until they meet above the head. Repeat this three times. With the arms raised above the head, carry them forward and downward, bending with the body until the tips of the fingers come as near the floor as they can be safely carried.

"10. Stand without cane, feet spread apart, hands on hips; flex the trunk forward, then to the left, then backward, then to the right, making a circle with the head. Repeat this three times.

"11. Do exercise No. 9 with heels together.

"12. Do exercise No. 10 with heels together.

"13. Walk along a fixed line, such as a seam on the carpet, with cane, placing the feet carefully on the line each time. Walk a distance of at least fifteen feet. Repeat this twice.

"14. Do the same without cane.

"15. Stand erect with cane; describe a circle on the floor with the toe of right foot. Same with toe of left. Repeat twice.

"Between the fifth and sixth exercises the patient should rest for a few moments."

All exercises must be performed slowly and deliberately and repeated several times according to the amount of fatigue produced. Some of the principal movements have just been described. Many modifications or additions may be followed, according to the condition of the patient. For more elaborate details relating to all forms of exercises for the upper and lower extremities, the reader is referred to Frenkel's book on "The Exercise Treatment of Tabetic Ataxia."

As all tabetic patients are not ataxic, and as all ataxic tabetics are not suitable subjects for such exercises, this method of re-educating the cerebral centres for coördination will be found to have well-defined limitations. Great care and watchfulness are necessary in carrying out this plan of systematic exercise, particularly in advanced cases. Unless practised persistently and systematically, preferably under the immediate supervision of a competent attendant, the results are usually unsatisfactory. Under suitable conditions, patients who were formerly unable to stand without assistance have been enabled to walk. *William M. Leszynsky.*

SPINAL-CORD DISEASES: TUMORS.—Practically all of our knowledge of spinal-cord tumors that is of any import for clinical medicine has come in these last two decades. It is true that, over thirty years ago, von Leyden put medical literature under a great debt by his published studies of one very interesting case, and within a few years after that he succeeded in showing that the diagnosis of the location and of the nature of a spinal-cord tumor is not impossible to the careful clinician. Before this only the pathological anatomists had given any attention to tumors lying within the spinal canal. Of these, two men deserve mention, because of the thorough manner in which they studied the subject and suggested at least the possibility of progress in clinical medicine up to a point where even this obscure condition might be recognized with certainty, its progress foreseen, and possibilities of surgical interference discussed. These two men are Virchow, in Germany, and Cruveilhier, in France.

The most important practical progress in our knowledge of spinal-cord tumors was to come from England. In 1886 Gowers, having demonstrated many times that it was possible to determine exactly the location of tumors of the spinal cord, recommended that when the diagnosis was satisfactory and conclusive, operative interference should be undertaken. Some years before this Erb, at Heidelberg, had made the same suggestion, though it did not for the moment attract much attention.

Gowers' recommendation was destined to bear fruit very shortly. In 1887 Gowers and Victor Horsley, after thorough discussion of a case of spinal-cord tumor, proceeded to operation, and Horsley removed the tumor successfully, the patient recovering completely and without any serious sequelæ. This classical case deserves to be recalled as the first step in a new and brilliant chapter of surgical therapeutics. It is described in a paper by Horsley and Gowers in the *Medico-Chirurgical Transactions*, London, 1888.

The patient had suffered from pain referred to the middorsal region for four years, which was suspected at first to be due to an aneurism. Certain neurotic symptoms superadded to the pain made some observers consider the symptoms functional. The pain continued off and on for four years; then the left leg became weak and later the right, with complete loss of power. Sensation was impaired and retention of urine occurred. Absolute palsy of the legs was present just before the operation was decided on, with loss of sensation in the trunk as high as the ensiform cartilage, and severe girdle pains were felt in the sixth and seventh intercostal spaces, more on the left than on the right. From time to time the legs became rigid in extensor spasm and the reflexes were much exaggerated. There was no tenderness and no deformity of the spinal columns. Potassium iodide had been used in vain.

At the operation the arches of the fourth, fifth, and sixth dorsal vertebræ were removed, but no tumor was found. The third and seventh arches were removed without any more success. As the patient's condition was good, his second dorsal arch was also removed, when the lower end of the tumor appeared. A portion of the first dorsal arch was cut away to facilitate its removal. It proved to be a fibromyxoma that could be easily lifted from its bed in the lateral column of the cord. The patient made a good recovery and gradually sensation and motion returned. A year later he was doing sixteen hours of work a day, standing and walking most of the time. Horsley and Gowers suggested that spinal tumors were more operable than tumors of the brain, and reported a certain number of cases collected from the literature in which operations would probably have been successful.

This demonstrated that spinal tumors were not as hopeless as had been thought. In the *American Journal of the Medical Sciences* for 1895, page 614, Dr. M. Allen Starr collected the reports of 122 cases of tumor of the spinal cord, with regard to 100 of which fairly satisfactory histories were obtainable. In all of these the diagnosis might have been made before death, and of the 100 cases there were 75, in Dr. Starr's opinion, in which the tumor could have been removed. He also reported, apart from the 127, 22 cases in which operations had been performed. In 2 of these the tumor was not found. In 1 it was impossible to remove it when found. In 11 cases death took place soon after the operation. Eleven patients operated upon recovered, and in 6 the paraplegia completely disappeared; in the other 5 there was relief of symptoms, especially of pain, and some improvement in the gait. Dr. Starr considers then that in nearly seventy-five per cent. of the cases spinal tumors can be operated upon successfully.

In the Versammlung Südwest. Deutsch. Neurologen, held at Baden, 1902, Professor Schultze gave a synopsis of 8 cases of spinal tumors in which operations had been performed. In 2 cases there were errors of diagnosis; of the remaining 6 there were 3 recoveries—2 complete, 1 partial. There were 2 deaths, shortly after operation, and 1 patient remained unimproved. This would give somewhat less than fifty per cent. of prospect of relief from operation.

Dr. Collins, in the *Medical Record* for December 6th, 1902, reports 70 cases of spinal tumor from the recent literature, 30 of which were operated upon. He concludes that spinal-cord tumors are twice as operable as brain tumors, and the results of operation are twice as successful. Fifty per cent. of intraspinal tumors are operable and one-third to one-half of these cases are benefited by operation. Of the 30 operations, 12 were completely successful, 8 were partially successful, and 10 failed to give relief, or the patient died shortly after operation. Of the 70 cases reported, 41 were almost surely operable with hope of relief; 26 were wholly beyond hope. While, then, the outlook for operation in cases of spinal tumors is quite hopeful, Dr. Collins considers that it is not as good as has been represented by previous authorities.

These reports serve to show the present status and the evolution of the surgical treatment of spinal tumors. They serve also to bring out very clearly the fact that neoplasms affecting the spinal cord are by no means hopeless. This has led to thorough discussion of the diagnostic points of spinal tumors, so as to make assurance of their presence and localization as absolute as possible for the guidance of the surgeon. Nowithstanding the progress in this matter, every year some cases are reported in which the tumor fails to be found at operation. In the very first case operated upon (Horsley's cited above) the opening in the spinal canal was made somewhat too low at first. Dr. Collins points out that recent experiences of Starr, Oppenheim, and Schlesinger show that there is danger of localizing the spinal tumor one segment too low, even at the present time. With this precaution it must be admitted that the diagnosis of spinal tumors is as certain as any other bit of internal diagnosis, and definite localization can usually be reached without serious doubt remaining.

Division of Tumors.—Tumors of the spinal cord—that is, new growths affecting the spinal portion of the central nervous system—may spring either from the nervous substance of the cord itself or from some of its coverings. These include not only the spinal membranes (that is, the meninges), but also the periosteum of the spinal canal and the bony column that acts as the support and protection for the cord. It seems better, with the authorities on this subject, to include the bony tumors of the vertebræ. All these tumors give a certain similarity of symptoms, so that we shall consider first tumors of the vertebræ, then tumors which have their origin from the periosteum or from the extradural fat-tissue, then intradural tumors which spring from the inner surface of the dura, from the arachnoid membrane, from the ligamentum denticulatum, from the nerve roots, or from the pia mater, and finally true medullary tumors, which spring from the nervous substance of the cord itself. We may say at once that by far the most important group of tumors is the intradural.

Tumors of the vertebræ have been arranged by Bruns, according to their importance, in the following order: Carcinoma, sarcoma, and osteosarcoma, as also sarcomatoid tumors with myxomatous degeneration, or fibrosarcomata, exostoses, or osteomata, especially multiple exostoses, echinoccus cysts, and finally gummata. There is a pseudo-tumor of the vertebra, due to exaggerated callous formation after fracture of a vertebra, which acts exactly like a tumor, and should accordingly be treated among them.

By far the most important and the most frequent form of tumor of the vertebræ is *carcinoma*. In the great majority of the cases the tumor is not primary, but secondary to cancer in some other part of the body. Vertebral cancer follows particularly cancer of the breast; much more rarely does it occur after stomach or uterine cancer. It is likely, then, to affect especially women, and as a matter of fact the cases of cancer of the vertebræ reported in men are extremely rare. Vertebral cancer may occur many years after an apparently successful operation for cancer of the breast. Bruns reported a case in which eight years had intervened. The late Dr. William Pepper showed to his clinic a case in which over six years had elapsed since the removal of the breast. Primary cancer of the vertebræ occurs very rarely.

As might be expected from the original seat of the tumor, secondary cancers of the vertebræ occur especially in the middle and upper dorsal region, occasionally in the lower cervical region. Primary carcinoma of the vertebræ by contrast occurs more particularly in the lumbar region. Secondary cancer does not limit itself to one vertebra, but apparently from the beginning attacks several. There are in the literature a number of cases in which practically every vertebra from the cervical region down to the sacral region had become carcinomatous. The process may spread by continuity, but it would seem that frequently each vertebral body becomes the seat of a new metastatic focus of malignant disease.

Notwithstanding the wide distribution of the carcinomatous process, the area in which there is pain on pressure or in which there are neuralgic pains due to the irritation of the growing tumor may be very small. Even when there is extensive involvement of the vertebral column, deformity may be absent. The usual deformity is a sinking together of the whole spinal column, a change which the French call *entassement*. In a number of cases patients have been distinctly decreased in height by this sinking together of the vertebræ. Often the bodies of the vertebræ become almost as thin as paper, and it is hard to understand how the patient can hold himself erect. Occasionally there are sudden dislocations of the vertebræ, and these may occur after even very slight trauma. When displacement of the vertebræ occurs, however, there is no true angular deformity as in Pott's disease, but rather a rounded deformity develops. Occasionally thickening and other deformities of the spinous processes can be detected and are pathognomonic. The process extends into the nerve substance very slowly and never goes very far. The spinal nerves may become affected as a consequence of the involvement of the intervertebral openings. The nervous affection may be due only to compression, or it may be a true carcinomatous development. If there is a sudden movement of the vertebræ on one another, the spinal cord may become compressed by the resultant deformity. Slow compression is also possible, because of gradually produced deformity of the vertebral column. The carcinoma may affect the extradural fatty tissue and so compress the cord. In these cases a complete carcinomatous cylinder may surround the dural sac. The tumor is, however, soft in consistence, and so the compression symptoms are unimportant and the real cause of the nervous disturbances is often collateral œdema due to interference with the return blood supply of the cord. In cancer of the vertebræ it is very seldom that the nervous substance of the cord itself becomes malignantly diseased.

Primary sarcomata of the vertebræ are not so rare as primary carcinomata. Sarcomata, however, usually occur in the lumbar or the sacral region and the affection develops by continuity from a tumor in the neighborhood. The viscera in the pelvis particularly are likely to be the seat of the primary tumor. Sarcomata are more malignant than carcinomata. They readily involve the dura, and may even penetrate this membrane and infiltrate the cord itself. A long portion of the spinal column may be affected by a sarcoma before serious symptoms begin. Much more frequently than carcinomata of the spinal column, sarcomata involve the transverse processes, the spines, and the vertebral arches, and may, by pressure of the tumor thus formed, cause perforation of the skin. Sarcomata may occur in very early years, though they are more frequent in advanced age.

Exostoses and osteomata may grow from the transverse processes, or from the spinal arches, or from the bodies of the vertebræ. When they grow from the posterior part of the body of the vertebra, or forward from the arch, they cause compression of the cord and of the nerve roots. They seem to be somewhat more frequent in the lumbar and sacral regions. Usually when an exostosis is present in the spinal column, other portions of the skeleton present similar outgrowths. They should be looked for on the ribs, in the supra-orbital region, along the spine of the scapula, and on the clavicles. Their discovery usually makes the diagnosis of the variety of tumor in the spinal cord plain without more ado.

Echinococcus cysts are rather rare in the spinal column, but they have been noted in a number of reported cases. Sometimes they cause a sudden dislocation of the bodies of the vertebræ and may lead to acute compression symptoms.

Gummata of the spinal column occur most frequently in the upper part of the cervical region. Not infrequently, as has been pointed out by Gowers, they are associated with ulcers of the pharynx. It is always very difficult to differentiate this condition from tuberculous caries of the vertebræ. The differentiation is, however, extremely important, because of the success of therapeutic measures in the syphilitic process. In suspected cases the therapeutic test constitutes the best differential diagnostic sign that we have. When a suspicious symptom develops, especially in relation to the upper cervical region, the patient should be carefully questioned as to his history, as to syphilis, and in any case mixed treatment should be used.

If a vertebral tumor is diagnosed, then its nature can sometimes be determined. The most important element is to know the nature of the primary tumor. Sometimes this will be found to be a lympho sarcoma, and in this case there is some hope that the use of arsenic for a long time, either internally as Fowler's solution or, better still, as sodium arseniate subcutaneously, may do some good. When a tumor of the spinal cord is primary, it is more likely to be malignant than benign. The occurrence of vascular murmurs in the affected region speaks for sarcoma. Symptoms of osteomalacia make the diagnosis multiple myeloma. Osteomata run a very slow course, though it cannot always be said, as Bruns does, that they cause less pain than tumors which run a more rapid course. The echinococcus cysts may be recognized by puncture of the tumor and the finding of hooklets in the secretion. In a number of reported cases echinococcus cysts have been considered by very good authorities to be cold abscesses. In almost any case of vertebral tumor, one of the iodides, potassium or sodium, according to the preference of the physician in charge, should be employed. In most cases, unless the history is very clear and the condition absolutely sure, a mercurial inunction course should be given. The condition in malignant tumors is so hopeless that the erysipelas toxins, or the mixed toxins suggested by Coley, should be employed, and it will sometimes be found that they furnish relief, or even an absolute cure, in unexpected circumstances.

Character of Tumors.—The tumors that develop within the spinal canal are divided into those of the cord itself and those of the meninges. The most frequent are those of the meninges, the proportion being nearly two to one. Of the meningeal tumors, some are intradural and some extradural.

In contrast to the tumors of the vertebræ, most of the intraspinal tumors are primary. In the extradural space, the most frequent tumor is the lipoma, which develops in the extradural fatty tissues. Next after this in frequency is the sarcoma which often develops from the periosteum of the vertebræ, though it also sometimes grows on the outer surface of the dura. There may be tuberculous tumors that grow within the spinal canal without any connection with the vertebræ. Such tumors may extend in their vertical diameter and cover a large portion of the cord. Echinococcus cysts may develop in the extradural space, and a very rare form of tumor, the enchondroma, has been encountered here. In one or two reported cases teratomata have also been encountered.

When tumors begin in the extradural space they very seldom find their way through the dura. Practically all of the tumors that occur outside of the dura are single. Lately a few cases of multiple extradural tumors have been reported.

Intradural tumors spring from the inner surface of the dura, from the arachnoid membrane, from the pia mater, or from the ligamentum denticulatum. True neuromata having their origin in the nerve substance, or pseudoneuromata springing from the sheath of the nerve, are not unusual in the intradural space. Bruns has reported a case in which the nerve root ran directly through the centre of such a tumor. The pathological anatomy of intradural tumors is more diverse than that of the tumors which occur in the extradural space. Practically any of the connective-tissue tumors may occur. Fibromata and fibrosarcomata, as well as genuine sarcomata and the sub varieties, angiosarcomata and myxosarcomata, have been reported. In a few cases pure angiomata have been found.

In children particularly there are a certain number of tumors that occur in connection with congenital malformations, associated with patent or latent spina bifida. These tumors are apt to occur, especially in the lumbar region, though they may invade the lower dorsal region. The most frequent variety is the lipoma. Neuromata are especially apt to occur in the cauda equina. Not infrequently malignant degeneration takes place even in tumors which are really not malignant at the outset. Neuromata are apt to be multiple in the cauda equina. At times degeneration of tumors affecting the nerve substance causes the presence of what is known as brain sand. Such tumors are spoken of as psammomata.

Solitary tubercles occur not infrequently in the intradural space, though tuberculosis affecting the membranes is apt to be diffuse. Nearly the same thing is true of syphilitic processes. Perfectly circumscribed gummata are not very frequent, but diffuse gummatous meningitis is not so rare. Echinococcus cysts are very rarely encountered in the intradural space. Some of them have been found free in the arachnoidal space. Aneurisms of the spinal arteries, theoretically, should be encountered occasionally, but as a matter of fact they are very infrequent.

In general it may be said that the pathological anatomy of tumors which occur within the spinal canal is not different from that of the same form of tumors when they occur in other parts of the body. The consistence of these tumors is rather hard, practically always harder than that of the cord itself: hence the compression symptoms that are produced. Only diffuse sarcomatous and carcinomatous new growths are soft in consistence, and such tumors are apt to be very vascular, making any question of their removal futile. As a rule tumors that grow within the dura are apt to be circumscribed in size, and seldom exceed that of a dove's egg. The limitation in size of spinal tumors is rather favorable for their removal by surgical procedures, and for this reason the prognosis of intradural tumors that are non-malignant is not as serious as it would otherwise be.

Differentiation of Vertebral Tumors.—In differentiating carcinoma of the spinal column from Pott's disease, it may be said in general that Pott's disease is an affection of youth or childhood. It must not be forgotten, however, that tuberculous caries of the vertebræ comes at a later age than any other form of bone tuberculosis. Carcinoma is quite rare, though sarcoma is not infrequent before adult life. It has been said that the intensity of the neuralgia caused by carcinoma is always greater than that due to caries. This must not be accepted as an absolute rule, however, according to the observation of Bruns and Schlesinger. The most important differential diagnostic point between caries and vertebral tumors is the kind of deformity present. Angular deformity is characteristic of Pott's disease. Carcinoma causes a rounded deformity, or else causes, as has been already noted, a shortening of the whole spinal column. If tumor-like masses can be felt alongside the spinal column, or in the pelvis, as is not infrequently the case in sarcoma, the differentiation from Pott's disease is easy. Evidence of the existence of tuberculosis in other organs, or of a cold abscess, makes the decision in favor of Pott's disease. It must not be forgotten, however, that as a consequence of the dyscrasia of cancer, myelitic processes may occur in the spinal cord, and Schlesinger has reported a case in which, notwithstanding the history of carcinoma of the breast, the affection of the spinal cord was a true caries.

Tumors of the upper part of the cervical cord begin usually with pain, and before long areas of anæsthesia develop. The pain is felt along the distribution of the cervical plexus in the area supplied by the supraclavicular nerve, the nervi occipitales minores, at times also the nervi occipitales majores, and practically always in the distribution of the great auricular nerve. Atrophic conditions and palsy of the sterno-cleido-mastoid muscles and the musculi circulares usually develop. The deep anterior cervical muscles, as well as the superficial and deep muscles of the neck posteriorly, are likely to be involved in the same process. After the neuralgia, hemiplegia involving the arm and leg on the side of the tumor gradually develops. In contradistinction from cerebral hemiplegia, there is no involvement of the facial or of the hypoglossal nerves. Anæsthesia occurs on the opposite side as a Brown-Séquard phenomenon. The paraplegic condition, as a consequence of a tumor in the cervical cord, never lasts long, as the involvement of the phrenic nerve soon causes death from respiratory failure.

Tumors of the cervical enlargement of the spinal cord present first a stage of the Brown-Séquard phenomenon. When the tumor is limited to one-half the cord, atrophy and paralysis with anæsthesia and neuralgic pains in the arm on the side of the tumor are soon noted. A spastic paralysis and a disturbance of muscular sensation in the corresponding leg are usual accompaniments; anæsthesia occurs in the leg on the other side and in the opposite side of the trunk, and on the ulnar side of the other arm when the tumor in its growth causes a transverse lesion, a spastic paralysis, and anæsthesia of both legs with palsy of the trunk muscles and anæsthesia of the trunk up to the second rib, are the usual results. In this case there is also paralysis of the arms. If the tumor involves all of the cervical enlargement, there is complete anæsthesia of both arms. If there should be direct involvement of the uppermost dorsal nerve root, myosis and immobility of the pupil occur. If the tumor is strictly limited, these symptoms occur only on one side, though usually they develop on both sides a little later

Tumors of the dorsal spinal cord cause first the Brown-Séquard symptom, and later give spastic paraplegia of the leg and abdominal muscles, and anæsthesia of the trunk up to the level corresponding to the height of the tumor. The neuralgia occasioned is at first one sided, but later it assumes the character of a complete girdle pain. The hyperæsthesia does not follow exactly the intercostal spaces, but is more horizontal in its reflexes. Atrophic paralyses of the intercostal muscles can usually not be demonstrated, though they are noted in the abdominal muscles.

When the tumor begins to compress the cord, and before the compression is so severe as to cause an interruption of the flow of nervous impulses the skin and tendon reflexes are all exaggerated. Patellar clonus and ankle clonus are present. At times even a slight touch upon the lower extremities causes a distinct tremor clonus which was described originally in this country by Brown-Séquard, and designated by him as spinal epilepsy. As the transverse lesion of the cord becomes complete the tendon and skin reflexes decrease. As a rule, however, the skin reflexes remain even after nervous communication through the cord has been completely interrupted. In the so-called Brown-Séquard palsy the paralysis on the side of the tumor is mostly of the spastic variety, and the tendon reflexes are exaggerated. Sometimes when the lesion is very high in the cord an atonic palsy with loss of reflexes is established. Severe trophic disturbances and even a qualitative change of the electric excitability, sufficient to constitute a reaction of degeneration, does not occur as a rule in these cases of paralysis. There are, however, a considerable emaciation and a distinct quantitative reduction of the electrical excitability of the muscle. Sometimes there is, because of a readily produced œdema of the skin, a lowering of the electrical excitability of the paralyzed muscles which simulates the loss of electrical reaction. In these cases, however, while the faradic current may fail to produce any effect, the galvanic current, if strong enough, will always produce quick muscle contraction.

The condition of the bladder and of the rectum, when tumors of the cervical or dorsal cord exist, depends entirely on the extent of the interference with cord functions. At the beginning there is usually only some slight difficulty at the commencement of urination, though the call to urinate is more frequent and more imperative. After a time, voluntary urination becomes impossible and urinary retention sets in. Somewhat later the bladder sphincter loses its power and incontinence results. This takes the intermittent form, so that the bladder empties itself every now and then without the will of the patient, and sometimes the anæsthesia is so marked that he does not notice the flow of urine until he becomes wet. If the whole spinal cord becomes affected, all the bladder reflexes disappear, and its muscles become palsied Nearly always, when paralysis of the bladder occurs, cystitis develops, and this leads to pyelitis and nephritis, and hastens the fatal termination.

The rectum goes through nearly the same functional disturbances as the bladder. At the beginning there is constipation and then later emptying of the rectum becomes impossible by will power. After a time a paralytic condition sets in, though the sphincter maintains enough contractility to retain fæcal material for some time. At intervals of several days, the rectum empties itself spontaneously, especially if there has been the slightest increase of peristalsis or any tendency to diarrhœa.

With regard to the sexual functions, in tumors of the dorsal and cervical region there are certain characteristic symptoms. They occur, of course, only in men. At the beginning of the affection potency remains, and it may even happen that there is an increase of sexual desire. In tumors of the cervical cord priapism may become an annoying symptom. This may not persist constantly, but the slightest manipulation of the penis, as, for instance, for purposes of catheterization, may cause an erection, and this may interfere with the necessary insertion of the catheter in these cases. When there is a complete transverse lesion of the dorsal cord, impotence is inevitable.

Interference with the vaso-motor nervous mechanism and the absence of movement may lead to œdema of the affected leg or legs. In these cases there is dry scaliness of the skin that resembles ichthyosis very closely. The joints may suffer from trophic disturbances, and it must not be forgotten that contractures set in and ankylosis may develop. Bedsores are not frequent in tumors of the cord high up, but when the transverse cord lesion is complete, then skin ulcerations occur as easily as in affections of the lower part of the cord.

Tumors of the lumbar enlargement of the cord cause at first pain in the region of the lumbar plexus. This is usually one-sided, and is referred to the anterior and inner side of the thigh, the knee, and the leg. Next in order comes paralysis of the ilio-psoas muscle, the quadriceps, the adductors, and the tibialis anticus. The Brown-Séquard phenomenon may occur in one-sided affections of the upper part of the lumbar enlargement. When the whole cord is affected, complete paralysis and anæsthesia of the lower extremities develop; at first only in the region of the lumbar plexus, later in the whole leg. Ankle clonus may be present when the knee-jerks are absent; bladder and rectal disturbances and sexual impotence are not so common in lumbar tumors as in those in the sacral region.

Tumors of the sacral cord, if they leave the lumbar enlargement unaffected, cause characteristic symptoms of their own. These are paralysis and wasting of the muscles of the lower leg and of the foot and of the posterior portion of the thigh, especially the gluteal and perineal muscles. At first this may be one-sided, and later, as the tumor develops, it may affect both sides. Anæsthesia is noted first in the foot and then at the back of the leg and thigh, and finally in the perineum and the genitals. Total paralysis of the bladder and rectum occurs, and impotence is a marked feature from the beginning. The Achilles reflex is often absent, though the knee-jerk is present. Bedsores and cystitis occur early in the case.

Tumors of the Cauda Equina.—The lumbo-sacral cord is commonly considered to run from the upper border of the twelfth, or from the lower third of the eleventh dorsal vertebra, to the lower border of the first lumbar vertebra, or at the very most to the middle of it. The lumbar enlargement lies usually beneath the twelfth dorsal vertebra. The sacral portion of it corresponds to the first lumbar vertebra. Below the middle of the second lumbar vertebra, then, there is no longer any cord substance, but only a thick bunch of nerves, the so-called cauda equina. As certain of the nerves that come from the lumbar enlargement of the cord run in the spinal canal, it is easy to understand that the same symptoms may occur as a consequence of a tumor in the lumbar enlargement as when the cauda equina is affected by a similar lesion. There are some differential diagnostic peculiarities, however, which make it possible to draw a distinction at times with complete assurance as regards tumors of these two regions. The first and most important distinction is that tumors of the meninges, when they begin to affect the spinal cord itself, usually cause unilateral symptoms. Tumors in the caudal region, however, usually cause from the very beginning bilateral symptoms. It is possible, however, for a tumor of the cauda equina to cause unilateral symptoms at first. Tumors of the lumbar cord usually cause completely symmetrical paralyses and areas of anæsthesia. This symmetry is apt to be lacking in tumors of the cauda. Caudal tumors are apt to cause very severe pains that persist in spite of treatment and that are very extensive. The pain is apt to be especially severe and obstinate in the sacral and coccygeal region. Tumors of the lumbar cord exceptionally cause very severe pain, so that this distinction is not very important. Friedrich Schultze claims that very marked and extensive fibrillary tremors are a sign that the cord itself is affected, rather than the nerves of the cauda. Bladder and rectal disturbances and trophic lesions of the skin follow both kinds of tumors.

The possibility of more than one tumor developing at the same time within the spinal canal must not be forgotten. In a certain number of reported cases the presence of more than one tumor has been recognized by the definite symptoms produced by each of them, and especially by the successive development of symptoms pointing to more than one localized area of irritation or pressure. Gowers calls attention to the fact that the greatest difficulty exists in the cases in which an intracranial tumor precedes the growth within the vertebral canal, and the symptoms of the spinal tumor are overlooked in the presence of the severe manifestations of the intracranial growth.

There is one form of disease which closely simulates a tumor in the symptoms which it produces. This is hypertrophic pachymeningitis. It always affects the cervical region, and hence the question of its exclusion must always be considered before an absolute diagnosis of the presence of a cervical spinal tumor is made. The differential signs are: that the manifestations of hypertrophic pachymeningitis are usually bilateral, while in the case of a tumor the initial symptoms, at least, are unilateral; and that the manifestations produced by pachymeningitis, instead of being very localized, show an involvement of a considerable portion of the cord in vertical extent.

The symptoms of extradural and intradural tumors of the spinal cord are very similar. There are certain slight differences which with care can be utilized in determining the localization of a tumor. The first symptom in any case is almost sure to be pain. In general, the first mechanical effect of the presence of the tumor is compression of the nerve roots, and then of the spinal cord itself. In this matter, tumors within the spinal canal differ but very little from those which spring from the vertebræ. For a considerable time, at the beginning of the symptomatic course, an irritative condition is noted, which affects especially the sensory nerve roots, causing neuralgias. The reason for this is not far to seek. Intradural tumors occur more frequently in the posterior part of the cord, or posteriorly and laterally. As a consequence, irritation of the motor roots occurs less frequently and seldom leads to recognizable localizing symptoms.

As a rule the pains are intense and typically neuralgic in character, but lack the tender points of true peripheral neuralgia. The pains are described as lancinating or tearing, and are not infrequently accompanied by causalgia—that is, a burning pain in the skin of the region supplied by the irritated nerve. Very often there is an accompanying hyperæsthesia of the skin which makes even the slightest touch unbearable. The pains are always increased when the spinal column is moved, or when there is any shaking of the body, as in coughing or sneezing. The pains may last for days and weeks without any intermission, though there may be intervals of comparative painlessness. The complete destruction of a nerve root causes a stoppage of the pain, and it may take some time for the tumor in its growth to reach another nerve root.

As in the case of vertebral tumors, herpes zoster may occur in the painful hyperæsthetic part. While in vertebral tumors the pains are from the beginning usually bilateral, in intradural tumors they are much more likely to affect only one side. It is easy to understand, however, that tumors of the meninges may affect both sides of the spinal cord, or both nerve roots at a given level, and so cause bilateral neuralgia. At times there are evidences of irritation of the motor roots, though these are seldom present. Painful cramps or tonic contractions of the abdominal muscles, for instance, or of the cervical muscles causing torticollis, have been noted. In these cases the lesion usually affects the sensory roots and the motor symptoms are reflex.

With regard to paralyses and anæsthesia, it must be remembered that the destruction of one nerve root seldom causes the development of such a condition. At least three or more nerve roots must be affected before anæsthesia, or muscle paralysis, will be a prominent feature of the case.

Pain is the most prominent feature of the early history of tumors interfering with the function of the spinal cord. It is prone to occur in attacks that are described as stabbing or tearing in character. It is not unusual, however, for the patient to suffer from dull aches between the severe attacks, or the initial stage of the affection may be characterized by a more or less persistent dull aching discomfort in certain muscles. The result of this is, that not infrequently the diagnosis of chronic rheumatism is made and the patient is treated for that disease. It is not an unusual thing to find that several physicians in attendance upon a given case have spoken of a spinal tumor as muscular rheumatism. As Gowers has pointed out, the pain produced by spinal tumors is intense, and at times so hopelessly obstinate to medical treatment that it has more than once led the unhappy sufferer to attempt suicide. This must be borne in mind by the medical attendant.

The diagnosis of neuralgia is not infrequent in the primary symptomatic stage of a spinal tumor. In contradistinction to true neuralgia, however, there is, as was pointed out by Dr. Starr, an absence of tenderness, as a rule, in the nerves along the lines in which the pain is felt. When the tumor is within the spinal canal, movement does not usually increase the pain; though this is apt to be the case when the tumor is in the bones. Pain is greatest when the tumor is situated so as to compress the cord directly laterally or posteriorly—that is, when it affects directly the sensory nerve trunks.

It must not be forgotten, in diagnosing tumors of the spinal cord, that the irritation of the sensitive nerve substance may give rise in predisposed individuals to symptoms of functional disorder of the spinal cord. Hysterical manifestations are not an unusual accompaniment of the initial stage of tumors of the cord, and often make the diagnosis more difficult than it would otherwise be. The physician's fear is always lest he should exaggerate the significance of neurotic symptoms. As a matter of fact, however, there is more danger of his minimizing the significance of the symptoms of the organic disease present, and so wasting precious time in the initial stage of the affection, when operation may save the spinal cord from lasting injury due to long-continued pressure.

The most characteristic feature for the diagnosis of a spinal tumor, its character and localization, is undoubtedly the course of the symptoms and the careful observation of the history of the case. The symptoms of tumor begin usually with unilateral pain, associated commonly with hyperæsthesia. A little later, one-sided cramps in the muscles are prone to occur, followed before long by paresis and atrophy in the affected muscles. This practically constitutes an index of a lesion involving half the cord. As the growth of the tumor progresses, the other side of the cord also becomes affected and paraplegia develops. A not infrequent accompaniment of this group of symptoms is localized pain, or, in some cases, deformity of the spinal column.

Treatment.—As we have already said, the most favorable form of spinal tumor, as regards therapeutics, is that of syphilitic origin. As Gowers says, syphilis can be excluded only when there has been no possibility of infection. In many cases of late syphilitic lesions there is no history of secondary syphilis, and in others there is no history of a primary sore. Hence it is certain that in some cases of late lesions of syphilis a history of both primary sore and secondary symptoms will be absent, and such cases are actually met with not infrequently in neurological practice. In practically all cases, then, antisyphilitic treatment should be tried for a period of from four to six weeks. The treatment of syphilitic conditions of the spinal cord should be prompt and energetic. The pressure must be lessened as soon as possible, otherwise degenerative changes and at times even hopeless destruction of nervous elements will take place. The influence of a few days' loss of time may make a difference of weeks in the duration of symptoms, and may even make the ultimate condition much less satisfactory.

In cases that are non-syphilitic very little can be accomplished by medication. Sedatives must be employed for the pain, and yet with the greatest care, since habits are so easily formed and anodynes lose their effect. Cocaine may be employed by subarachnoid injection to aid the action of morphine. The state of the bladder must be watched very carefully, it must not be allowed to become overdistended, yet the catheter must be used with every possible aseptic precaution, including especially the cleansing of the fossa navicularis before the introduction of the instrument; otherwise severe cystitis will be likely to develop in the lowered vitality of the vesical mucous membrane. Because of the diminished nutrition of all tissues, bedsores must be carefully guarded against, and if the patient shows early a tendency to their development, a water-bed must be secured without delay.

Spinal tumors that are not within the substance of the spinal cord itself may not infrequently be removed by surgical procedures. As we noted at the beginning of this article, at least fifty per cent. of all tumors are operable, and of these more than one-half may be practically cured or relieved completely of their annoying symptoms. It must be remembered that Gowers and Horsley insist that the early removal of a small growth in the spinal cord may possibly be followed by the regeneration of conducting fibres that are on the other side of the cord, and by the return of their function, lost only through the effects of pressure. As soon, then, as a definite diagnosis of the presence of a spinal-cord tumor is made, operation should be recommended and the state of the case, with the possibility of a complete cure, set before the patient. Delay in this matter can do no possible good, and a delay of even a few months may cause irremediable damage to the delicate nerve structures. In estimating the chances of a successful issue, it must be remembered that the effect of the operation upon the patient's general condition is distinctly unfavorable.

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SPINE, DISEASES OF THE.—Syphilis.—Syphilis, in either the inherited or the acquired form, may cause deformity of the spine with accompanying symptoms that can hardly be distinguished from those of Pott's disease. As compared with tuberculosis it is a very uncommon disease of the spine. Its manifestations are likely to be general in character, the local deformity being one of many evidences of disease.

Syphilitic disease of the spine, causing destruction of tissue and deformity, demands the same protective treatment as would progressive deformity from other causes. Appropriate medical treatment is of course indicated in addition.

Malignant Disease.—Malignant disease of the spine is uncommon, particularly so in childhood. Sarcoma is more common than carcinoma, and it may affect the spine primarily, while carcinoma is almost always secondary to disease elsewhere, as of the breast.

The symptoms of malignant disease are usually more severe than those of tuberculosis. The pain, for example, is often persistent and is not relieved by support or recumbency. The constitutional symptoms are more marked and the steady progress of the disease toward a fatal termination is soon apparent. Not infrequently the tumor may be palpated through the abdominal wall, and the deformity characteristic of destruction of the vertebral bodies is often absent. Paralysis is a frequent and often an early symptom.

Malignant disease of the spine is a fatal affection and the treatment can be but palliative.

Acute Osteomyelitis.—Infectious osteomyelitis of the spine is uncommon. The characteristic symptoms are similar to those of acute infectious processes elsewhere, namely, sudden onset with fever and constitutional depression. There are local pain and tenderness about the spine. Abscess quickly forms, and paralysis, from the rapid extension of the disease to the spinal cord, is a frequent complication.

The later symptoms due to pyogenic infection are often pyæmic in character. Necrosis of the affected vertebral bodies may result in the formation of large sequestra. The death rate is about fifty per cent.

Treatment.—The immediate evacuation and drainage of the abscess is indicated together with the removal of the necrosed bone if possible. Subsequently the spine should be supported.

A more chronic and more localized form of osteomyelitis may occur, but it is practically impossible to distinguish its symptoms from those of tuberculous disease. In this class of cases an abdominal or pelvic abscess may be the first indication of disease.

Actinomycosis.—Actinomycosis of the spine is an extremely rare disease. Its diagnosis may be made by the microscopical examination of the discharge from the sinuses that almost always form early in the course of the disease.

Traumatism.—Severe sprains, rupture of ligaments, or fractures of the spine may simulate disease, particularly when the injury is of the cervical region. Diagnosis is in some instances practically impossible until the effect of local support has been tested, when as a rule, if disease be absent, the symptoms, even though of long standing, quickly subside.

Fracture of the spine in the middle region without displacement may cause angular deformity, and when proper support has been neglected, symptoms of pain and weakness similar to those of Pott's disease may persist indefinitely.

Sudden forcible compression of one or more of the vertebral bodies without displacement and without severe immediate symptoms, other than the slight deformity, may be the result of injury, especially falls from a height. These cases are not uncommon and are usually mistaken for Pott's disease, especially as the deformity may not be evident until several weeks after the injury.

The *diagnosis* should be made clear by the history.

Treatment.—In all such cases and whenever weakness of the spine persists and when motion causes pain, a support should be applied. Fracture of the spine should be treated as are fractures elsewhere, by reposition if possible or practicable, and by support until the integrity of the parts has been reëstablished.

Traumatic Spondylitis.—Kümmell has described a form of rarefying osteitis of the spine induced apparently by injury. It is characterized by symptoms of pain and weakness, referred to the back, and by a rounded kyphosis of the dorsal region. Motor disturbances of the lower extremities are frequent. Such cases may be explained either as direct effects of injury, or as due to subsequent infection—tuberculous or otherwise—of the weakened parts.

The *treatment* is similar to that of Pott's disease.

The Rachitic Spine.—The rachitic spine has been mentioned in the consideration of the differential diagnosis of Pott's disease, and it is described in more detail elsewhere. (See *Spine, Tuberculous Disease of the.*) It is a deformity that appears, usually during the first or second year of life, in children who do not walk. The typical rachitic kyphosis is a rounded projection of the middle and lower region of the spine. It is in fact simply an exaggeration of the contour that is normal in the sitting posture. The deformity is more or less rigid according to its duration. If it is extreme, it may be accompanied by a compensatory backward inclination of the head—"posterior torticollis."

Treatment.—Aside from the constitutional treatment of the predisposing disease the indications are to overcome the rigidity and the limitation of motion of the spine, to support it if necessary by a light back brace, and to avoid, as far as possible, the postures that favor the deformity. In severe cases of rickets the recumbent posture on the stretcher frame which has been described under Pott's Disease (see article entitled *Spine, Tuberculous Disease of the*), is the treatment of selection.

The "Typhoid Spine."—During the course of, or during convalescence from, typhoid fever symptoms of pain, weakness, and stiffness of the back may appear, induced in certain instances apparently by sudden movements or strains. Often there may be local sensitiveness to pressure or motion; and a slight posterior projection in the lumbar region of the spine, the part most often involved, is not unusual.

The cause of the symptoms is apparently infection of the fibrous coverings and attachments of the spine similar to the more common and more severe forms of periostitis in other situations that may complicate this disease. It may be stated also that in exceptional instances typhoid infection may be accompanied by abscess, by destruction of bone, and by actual deformity.

Treatment.—The treatment should be symptomatic. During the active stage if the pain is severe the patient should be kept in the recumbent position. Locally the application of the Paquelin cautery is of service in relieving pain, and the application of adhesive plaster strapping over the sensitive area may add to the comfort of the patient. As soon as it is practicable a back brace or corset should be applied. Recovery is the rule, although a certain amount of restriction of motion may persist.

The same symptoms may follow other forms of contagious disease, notably scarlet fever, but as a rule they are less persistent and severe.

Gonorrhœal Arthritis.—Gonorrhœal infection is uncommon. Its symptoms resemble those of the preceding affection; ankylosis is, however, more common as a result; in fact, gonorrhœal arthritis is supposed to be one of the causes of spondylitis deformans.

The treatment consists in support for the purpose of preventing deformity and relieving discomfort.

Cervical Arthritis.—The joints of the occipito-axoid region are sometimes involved in what appears to be a form of infectious arthritis, sometimes following diphtheria or other contagious disease. It may be distinguished from tuberculosis by its acute onset, and from acute torticollis by the fact that all the motions of the head are restricted.

Treatment.—The treatment consists in support during the acute stage, as by a collar or jury mast, followed by massage and manipulation to overcome the stiffness.

Spondylitis Deformans.—Spondylitis deformans is a chronic affection of the spine terminating in ankylosis and deformity.

The disease is apparently a chronic inflammation which affects primarily the ligaments and the periosteal coverings of the spine, a form of ossifying periostitis which binds the vertebræ firmly to one another. It may begin on the lateral or on the antero-lateral aspect of the spine. It may be limited to a particular region, but in most instances it progresses until it involves the entire spine, and often the articulations of the ribs as well. The intervertebral discs atrophy, but in some instances the margins of the cartilages proliferate and become ossified in a manner characteristic of osteoarthritis.

Under the general term of spondylitis deformans are included, in all probability, several varieties of disease. For example:

1. The ankylosis of the spine may be simply a part of a general rheumatoid arthritis involving the larger and smaller joints—rheumatoid arthritis of the spine.

2. The spine may be involved together with one or more of the adjacent joints, which show the characteristic

symptoms of the so-called hypertrophic form of arthritis deformans—osteoarthritis of the spine. This form has been designated by Marie as spondylose rhizomélique (σπόνδυλος spine, ῥίζα root, μέλος extremity), implying a disease of the spine, together with the adjoining "root" joints.

3. The disease may be limited to the spine and even to a particular region; in such cases it may be quite different from rheumatoid arthritis or osteoarthritis. This form may follow acute rheumatism; it may be induced apparently by gonorrhœa or by other forms of infection. It may begin acutely like inflammatory rheumatism, or it may be chronic in character and progress slowly.

FIG. 4422.—Complete Ankylosis of the Entire Spine. The patient, about one year before coming under observation, fell down a flight of stairs, rupturing the bony adhesions between the vertebral bodies at the points of greatest deformity (as seen in the picture). The accident was followed by great pain and marked sensitiveness at and near the points of injury, and these symptoms persisted for many months.

In the cases of spondylitis deformans, as distinct from general involvement of the joints, there is often an acute onset, called lumbago, from which the patient dates the beginning of his trouble. This is followed by a gradually increasing stiffness of the spine and accompanying deformity, with intercurrent attacks of so-called lumbago. In the well-marked cases the patient complains of stiffness, weakness, pain in the loins, pain radiating forward along the ribs; sometimes of weakness in the limbs, of headache, nervousness and the like, symptoms that may be caused directly by the inflammatory process, or by implication of the nerve roots, or by an accompanying neurasthenia. The direct symptoms are increased by jars which are exaggerated by the inelasticity of the spine. The disease is usually progressive and terminates finally in complete rigidity of the spine, which is bent into a long kyphosis most marked in the upper dorsal region, the lumbar lordosis being obliterated in many instances.

When the disease is limited to the spine or to the spine and larger joints, the occipito-axoid articulations are not usually involved; but in the cases of general rheumatoid arthritis, stiffness of the neck may be an early symptom.

Treatment.—The local treatment is symptomatic. The application of the cautery adds to the patient's comfort, and self-suspension at intervals may relieve the dragging sensation in the muscles. Rubber heels are of service in lessening the jar. A brace or plaster corset may be applied if the pain is aggravated by motion. It should serve also, together with the avoidance of predisposing attitudes, to prevent extreme deformity of the spine. Such protection is of great service if it is applied early in the course of the disease, especially in those cases in which it is localized, as it sometimes is in the lumbar region.

ADOLESCENT KYPHOSIS.—A form of extreme kyphosis, accompanied by stiffness and discomfort, is not infrequently seen in adolescence. It appears to be a static deformity induced by overwork. It can hardly be classified with spondylitis deformans, although there may be some difficulty in distinguishing between the two. The treatment is, if possible, prevention in avoiding predisposing postures and in strengthening the muscles. In more advanced cases, forcible correction after the Calot method, followed by support, massage, and exercise, may be of service.

The kyphosis of old age is a familiar deformity that does not require special mention.

OSTEITIS DEFORMANS.—Osteitis deformans is described elsewhere. It is a general disease characterized by hypertrophy and softening of the bones. The deformity of the spine is similar to that of spondylitis deformans, but the local discomfort is far less marked.

THE NEUROTIC SPINE.—This affection is far more common in adolescence and adult life than it is in childhood, and in females than in males. The subjects are usually of a nervous or neurasthenic type, often overworked and physically depressed. In certain instances, however, the exciting cause appears to be direct injury. The patient usually complains of a dull pain in the back of the neck, or in the lumbar or sacral region, of a constant tired feeling, and not infrequently of sharp neuralgic pain localized about a certain point in the spine, often the vertebra prominens. The contour of the spine may be normal, but there is usually a well-marked tendency toward a forward droop, the curve of weakness. A common symptom of the neurotic spine is the extreme local tenderness, or hyperæsthesia of the skin over certain spinous processes. Thus, if one passes the finger gently along the spine the patient will often shrink or cry out when the sensitive point is reached. The pain is usually localized about the spine, and there is no limitation of movement or especial discomfort on motion. The symptoms are distinctly subjective, thus differing from those of actual disease.

Treatment.—The treatment of the neurotic spine must include, of course, the general condition of the patient. Locally, a light back brace or a long corset, reinforced with steel bands, adds to the comfort of the patient. The application of the cautery lessens the local sensitiveness. Massage and exercises may be employed with advantage. Complete recovery is usually long delayed.

THE HYSTERICAL SPINE.—The hysterical spine is usually classed with the neurotic spine. The local subjective symptoms may not differ particularly from those of the neurotic spine, but in certain instances actual deformity may be present. This is usually exaggerated lateral distortion of the lumbar region. This deformity may appear after injury, but, except as a possible cause of a particular manifestation of the mental condition, it is usually apparent that injury cannot explain the symptoms or the deformity.

Treatment.—The local treatment is similar to that of the neurotic spine.

PAIN IN THE LOWER PART OF THE BACK.—Pain, discomfort, and weakness are sometimes symptomatic, being caused by disease or displacement of the pelvic or abdominal organs. Similar discomfort is a common symptom among overworked women. It is usually present also whenever the lumbar lordosis is exaggerated, as a compensatory deformity for dorsal Pott's disease, or because of flexion of the thigh after hip disease.

The *treatment* must be directed to the conditions of which it is a symptom.

Pain and weakness in the lumbar region may be induced by strain or other injury. In such instances it is usually increased by sudden motion or overexertion, and it may be persistent and disabling. Such cases are often classed as chronic lumbago. The cause is apparently strain of the deep ligaments or muscles of the spine, but the symptoms may be exaggerated, doubtless in certain instances by gout, rheumatism, or other disease of this character.

When motion causes pain and when the symptoms are persistent, support in the form of a back brace is indi cated, the Knight brace or plaster corset being convenient forms. During the more acute stage the cautery, followed by the application of intersecting straps of adhesive plaster covering a wide area, will often relieve the pain. Later, massage, electricity and the like, may be of service.

FIG. 4423.—Sciatic Scoliosis.

SPONDYLOLISTHESIS.—Spondylolisthesis, or exaggerated lordosis, is a deformity in which the body of one of the lower lumbar vertebræ, most often the fifth, is displaced forward and downward. The displacement is usually accompanied by distortion of the affected vertebra. The spinous process remains in its normal position, while the laminæ become elongated or separated from the displaced vertebral body. Spondylolisthesis was first described by Killian in 1854 and more recently by Neugebauer in 1890.

The ordinary causes are congenital malformation, injury, and possibly disease of the lumbo-sacral articulation. Lane states that slighter degrees of the deformity are often observed among laborers. The effect of the displacement is to exaggerate the lumbar lordosis and to increase the prominence of the sacrum and of the iliac crests. The deformity is most often seen in women, causing no particular symptoms; in fact, its chief interest lies in its effect upon childbirth.

Treatment.—Support may be required if the symptoms indicate it. In the slighter grades of deformity a strong corset reinforced by steel bands is efficient.

DEFORMITY OF THE SPINE SECONDARY TO SCIATICA.—Persistent sciatica often induces a change in the attitude and contour of the spine. As a rule the patient habitually inclines the body away from the painful part, in order to relieve the limb from weight, and bends the body slightly forward to relax the tension on the sensitive nerve or plexus of nerves. Thus the pelvis on the affected side projects, there is a lateral lumbar convexity toward the opposite side, and often the normal lumbar lordosis is lessened or lost, so that the final result may be a permanent lateral curvature together with a flattening of the lumbar region. If the sciatica is a symptom of a more widespread neuritis of the lumbar plexus, muscular weakness and muscular spasm may cause variations in the typical attitude, but this is unusual.

Aside from the direct treatment of sciatica support may be indicated if movements of the spine aggravate the pain. This is always indicated when there is danger of persistent distortion. The patient should be suspended and corrective jackets applied at frequent intervals. As the attitudes and symptoms described may be caused by disease or injury of the sacro-iliac articulation, this region should in all instances be carefully examined.

Neuritis of spinal nerves in other regions of the spine may cause symptoms of reflected pain and local sensitiveness. These are increased by motion, and a certain amount of deformity, similar in character to that due to sciatica, may be present.

The treatment is similar to that indicated for the former affection. *Royal Whitman.*

SPINE, SURGERY OF THE.—It is essential, before we enter upon the study of the surgery of the spine, that we should have a fairly thorough acquaintance with the most salient points in its anatomical construction.

The spinal column is not a straight structure, but presents a series of curves corresponding to its various portions. The cervical portion presents a concavity; the dorsal a convexity; the lumbar a concavity; while the sacrum and coccyx are slightly convexed. On account of its being made up of a large number of vertebræ, which are separated from each other by intervertebral substance and are held together by elastic ligaments and muscles, it presents a flexuous and flexible column, capable of a considerable degree of motion, without injury either to its muscles or ligaments or to the spinal cord itself. The spinal canal is about twenty-seven inches in length, larger in the neck and loin where it presents a rather triangular shape, and narrower and more nearly round in the remaining portions of the canal. It is also to be remembered that the spine has a slight lateral curvature, the convexity of which is toward the right side; an exception to this rule exists in left-handed individuals.

The spinal cord is seventeen or eighteen inches in length and occupies only about two thirds of the canal—hanging loosely in it and not by any means filling up the whole contour of the canal. It extends from the upper border of the atlas to the lower border of the first lumbar vertebra, at which point it terminates in a slender filament of gray substance, known as the filum terminale. The spinal cord is vested by three membranes: the dura mater, the arachnoid, and the pia mater. The dura mater is separated from the spinal canal by loose areolar tissue and a plexus of veins—this membrane being a continuation of the one which surrounds the brain. Special attention should be given to this plexus of veins, as in many injuries of the spinal column these veins are ruptured by hyperextension, thus forming clots of blood, which impinge upon the spinal cord, producing symptoms of paralysis. Attention is also to be paid to the fact that the dura mater is not adherent to the spinal canal, which has its independent periosteum; nor does the dura mater send any of its prolongations into the fissures of the cord as occurs in the brain. The arachnoid is a continuation of the same membrane that surrounds the brain, and is connected with the spinal nerves, so as to form a sheath for them as they pass into the intervertebral foramina. The outer surface of this membrane is connected with the dura mater to a limited extent, thus leaving a considerable space, known as the subdural space, while the inner surface is connected with the pia mater by slender filaments of connective tissue. The inner surface of the arachnoid is separated from this membrane by a considerable interval known as the subarachnoidean space. The pia mater covers the entire surface of the cord, being intimately adherent to it, forming its neurilemma and sending a process into its anterior fissure. It also forms a sheath for each of the filaments of the spinal nerves and invests the nerves themselves.

There are thirty-one pairs of spinal nerves divided according to the corresponding regions of the spinal canal. In the cervical region there are eight; in the dorsal, twelve; in the lumbar, five; in the sacral, five; in the coccygeal, one. A spinal nerve arises by two roots, the anterior or motor root and the posterior or sensory root. We should bear this latter division in mind, as pressure upon the anterior root in any region will produce loss of motion or paralysis in that region where the nerve is distributed, while pressure only upon the posterior root will cause loss of sensation or anæsthesia in the part to which the nerve is distributed. Our attention is also called to the fact that the roots of the spinal nerves from their origin in the cord run obliquely downward to their point of exit from the intervertebral foramina, the amount of obliquity varying in different regions of the spine and being greater in the lower than in the upper portion.

Diseases and injuries of the spine may be classified under two heads—congenital and acquired. Under the first of these divisions occurs spina bifida, while under the latter we have the following classification: First, pathological changes produced by disease, and secondly, those produced by traumatism.

Spina Bifida.—Spina bifida, or hydrorrhachis, is a congenital deformity due to the non-development of the posterior vertebral arches, thus leaving an aperture through which the membranes protrude, this condition resembling hernia as seen in other portions of the body. The varieties of this affection are known as meningocele, where the contents of the sac are composed of the spinal membranes only; meningomyelocele, where the contents of the sac consist of the cord and its membranes; and lastly syringomyelocele, where the central canal of the spinal cord is dilated, thus forming the tumor. The tumor varies from the size of a small cherry to that of an adult's head, and occurs most frequently in the lumbar and sacral regions, as these portions of the spinal column are later in their development than those in the upper regions. The shape is usually round and the surface smooth; at times there is, in the median line, a furrow which presents a pit-like depression above and below. The tumor occasionally is covered with skin, either of a red color or normal in aspect, but thin and translucent; while in other cases there is an absence of skin altogether, the outside covering being derived from the dura mater. It is very important that this affection should be correctly diagnosed, and in most cases this can readily be done. The affections simulating spina bifida may be mentioned as lipomata, and dermoid cysts or other varieties of cysts in this locality. A large per cent. of children affected by this condition die soon after birth It is a congenital

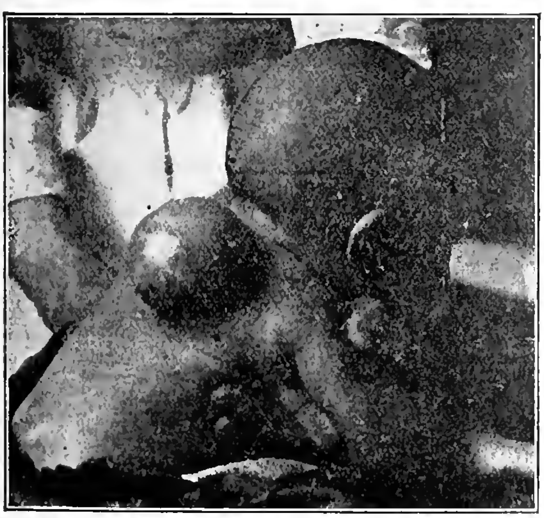

FIG. 4424.—Case of Spina Bifida; Showing the Sac before Operation.

trouble and always occupies the central position of the canal, and its fluid communicates with the fluid of the brain. Pressure upon the tumor diminishes it in size and promotes tension of the fontanels, and, when continued for any given length of time, it is followed by stupor or convulsions. By an examination around the base of the tumor, the outer lining of the bony partitions of the spinal canal can be made out, and by the use of a hypodermic syringe it is possible to withdraw a small quantity of fluid—cerebrospinal fluid, as will be found upon examination. Should the case prove to be a dermoid cyst, or cyst of any other kind, or a lipoma, all of these symptoms will be found wanting.

FIG. 4425. The Same Case as that represented in Fig. 4424; Showing the Results of the Operation.

The treatment of spina bifida may be divided into palliative and operative. In the palliative treatment, pads of absorbent surgeon's wool or gauze saturated with lanolin are applied, and gentle pressure used, either by the roller bandage or by a properly applied apparatus. The sac is sometimes enveloped with a solution of collodion, the purpose being to constrict the sac and thus diminish the bulk of the tumor.

Among operative measures, one plan is to draw out a small quantity of fluid at a time, either through a puncture or by an aspirator (a very small quantity of the fluid being drawn off at a time, say about ten or fifteen drops), and then, after sealing the opening with collodion, to apply slight pressure over the sac. This plan is to be repeated every twenty-four or sixty hours, depending largely upon the symptoms which develop. When an incision is made at the side of the tumor, it must always be in an oblique direction, and every precaution must be taken to make the parts perfectly aseptic.

Besides evacuating the contents of the tumor, injections of iodine or of alcohol are sometimes made into the sac. This treatment, however, is very unsatisfactory, as the majority of cases thus treated prove. On account of the many fatal terminations which have occurred as a result of this mode of treatment, a complete excision of the sac has been resorted to. The sac is first opened and its contents evacuated, and then, if the nerves and filaments of the cords are found in it, they are pushed back into the spinal canal and the sac ligated. If the tumor is covered with skin, an elliptical incision is made on each side of the growth, the two flaps are dissected down to the neck of the tumor, the membrane is punctured and the fluid let out, the sac is opened as suggested above, and a sufficient amount of it cut away to approximate the edges closely. Great care should be taken not to injure the nerves or the cord if they appear in the tumor; they should be carefully replaced in the spinal canal, and the edges of the membrane should be closely approximated by a separate row of catgut sutures and the skin flaps brought together by silk or silkworm gut sutures. If after opening the sac the nerves are found to be adherent to the posterior part of the sac, they should be separated by careful dry dissection, and pushed back into the spinal canal. Should the tumor be devoid of skin, it is best to borrow some skin from the adjacent region and make a skin graft over the surface of the wound left by such transfer.

Should the opening be a large one, bone grafts may be taken from the adjacent bone, or borrowed from an inferior animal, the chasm being thus filled up, or, as has been suggested by a recent writer, large silver wire may be placed across the opening, thus preventing the hernia from again making its appearance.

It is unnecessary to say that the strictest asepsis should be enforced in this operative procedure.

Dermoid cysts, lipomatous tumors, and cystic tumors of other varieties occurring in this region should be dealt with in the same manner as in other portions of the body.

Among the acquired diseases which call for surgical treatment may be mentioned, first, the various curvatures of the spine. As these have already been treated under other heads, I may pass at once to the consideration of certain features in the treatment of Pott's disease. (The subject, as a whole, is discussed under the title *Spine, Tuberculous Disease of the*.) Should pressure of the cord be present, in this disease, an operation for relieving this pressure by removal of laminæ should be performed. If fluctuation exists, denoting the presence of pus, the cavity should be evacuated by an ordinary trocar and cannula or an aspirating needle. Should the pus not be withdrawn as readily as expected, on account of broken-down tissue, the removal of this tissue can be facilitated by the use of an aseptic wire bent in the shape of a small hook. After the abscess cavity has been completely evacuated, it is advisable to inject a ten-per-cent emulsion of iodoform in glycerin. While iodoform does not act as a germicide, it has been satisfactorily demonstrated that it retards the growth of the tubercle bacilli. Numerous trials of this method have fully convinced me of its great utility in materially cutting short the disease. About one-half drachm of the emulsion is injected the first time, and if no unpleasant symptoms result this quantity, if necessary, may be increased at the next application. An interval of about seven or eight days should occur between the injections. When the needle is withdrawn, the puncture in the skin is closed with collodion or liquid celluloid, and a compress and bandage are applied to the part so as to cause the walls of the abscess to collapse. As the last step, the patient is placed in bed, slight extension and counter extension are instituted, and absolute rest is enjoined. If the first injection proves beneficial, it will seldom be necessary to employ more than two or three of them. It is to be borne in mind that iodoform is not efficacious in cases of mixed infection, but only in those cases in which the disease is produced by the tubercle bacillus. When the disease occurs in childhood and when early diagnosed, the deformity can be entirely or almost entirely corrected and the spine made to assume its normal position. The details of the method which it is necessary to pursue will be found in the following article.

Contusions or Sprains of the Spinal Column.—On account of the complex structure of the vertebral column, and of the large number of veins and nerve filaments which issue from the spinal cord contained within it, direct injuries inflicted upon this column may at times be followed by great loss of function. The symptoms presenting themselves depend very largely upon the degree of injury that has been sustained; this may be slight in extent, producing only temporary stiffness or soreness over a limited area; or it may, on the other hand, be more serious in character, as when the ligaments of the spine are either partially or completely torn away. Such serious results are observed in runaway accidents and after railroad collisions. When the ligamenta subflava are involved, severe hemorrhage of an extradural character may occur and paraplegia result; this, however, in many cases, is only of short duration, the extravasated blood being absorbed and recovery being the rule. When examined externally, the injured portion of the spine presents either a slight or considerable swelling, together with great tenderness and pain. In some cases the pain is so great at the point of injury that the patient involuntarily immobilizes the spine and in this way avoids any rotation or flexion of the column, the slightest degree of which often throws him into spasms. It is of the utmost importance in the examination of these cases that a correct diagnosis be made between contusions and fractures or dislocations of the spine. Cases of severe contusions present symptoms closely analogous to those of a fracture or a dislocation, such as partial or complete paralysis, corresponding to the seat of injury, and produced by either extra- or intradural hemorrhage. These symptoms of paralysis, however, are transient, readily passing away after absorption of the effused blood. In some cases in which hemorrhage has been severe the symptoms are prolonged, and the diagnosis between contusion, fracture, and dislocation is made out only by a careful examination of the bony canal and the discovery of signs which are revealed after the swelling has sufficiently subsided.

FIG. 4426.—Fracture of the Spine due to a Fall from a Height of Eleven Feet. Picture taken ten weeks after the occurrence of the accident. (Courtesy of Dr. Royal Whitman, of New York.)

The treatment for contusions of the spine is conducted upon general principles, namely, rest, position, etc.: pain is relieved by hot or cold applications, or by the administration of anodynes if the pain is severe. All friends and acquaintances of the patients are to be kept out of the room, light must be excluded from the eyes, and every precaution must be taken for relieving them of anything of an irritative character.

One of the unfortunate symptoms following contusion is great irritability and nervousness. As soon as the swelling subsides, ointments such as brown citrine or compound iodine are to be freely rubbed over the part. To allay irritability and nervousness, chloral hydrate, bromide of potassium, or hydrobromate of hyoscine should be administered.

Fractures of the spine are quite rare as compared with fractures in other portions of the body. The portions of the column most frequently fractured are the cervical and dorsal regions, while the lumbar and sacral are very seldom the seat of this injury. The two vertebræ which are most commonly broken are the fifth and sixth cervical. Fractures of the cervical vertebræ terminate more frequently in death than do fractures of any other portions of the vertebral column. These fractures, as a rule, occur during middle life and are more frequent in the male than in the female, this being due to the fact that the occupation of the male renders him much more liable to these accidents. These fractures occur in the body and arches, and there is every reason to believe, from statistics on this subject, that in the great majority of them they occur much more frequently in the arches than in the body of the vertebra. When these fractures occur, the majority of them are due to forcible flexion of the spine, the head and neck approximating, or the chest and the pelvis. Such injuries are apt to be produced by the caving in of an embankment, by a fall from a high scaffold, or by the doubling of the body in passing through a tunnel, as has been exemplified in several cases that have come under my personal observation. Whenever the injury is of such a nature as to produce a fracture in the vertebræ, it is always accompanied with considerable laceration of the muscles and ligaments, and often with hemorrhage, which may be extradural or subdural. At times there is crushing of the bodies of the vertebræ, with greater or less displacement.

Fracture of the spine in the middle region without displacement may cause angular deformity, and, when proper support has been neglected, symptoms of pain and weakness similar to those of Pott's disease may persist indefinitely (Fig. 4426.)

The symptoms of fracture of the vertebræ are generally pronounced; they consist of deformity, crepitation, and partial or complete paralysis below the seat of fracture. There is usuallygreat shock attending these injuries. In fracture of the vertebræ in the lower lumbar, sacral, and coccygeal regions, on account of the absence of the spinal cord, we have very seldom either a complete or a partial paralysis, but all the other signs of fracture are generally present.

The prognosis of fracture of the spine, especially when it occurs in the upper spinal region, is very unfavorable; if the patient should recover from the shock attending such injuries, he is very likely to be paralyzed the rest of his days.

Gunshot fractures of the vertebræ partake of the character of a compound fracture, and consequently are frequently complicated with infection and thus make the prognosis much more unfavorable.

In the treatment of fractures of the spine, the patient should be placed in a recumbent position and extension and counter-extension should be maintained. Gentle pressure should be made in such a manner as to relieve and correct the deformity. An air- or water-bed is preferable to any other contrivance for placing the patient upon. If it should be impracticable to obtain such a bed, a short hair mattress made perfectly smooth should be procured; but under no circumstances should the patient be placed upon a feather mattress. Extension can be maintained by applying Buck's extension apparatus to both legs, the weight and pulley being placed at the end of the bed, and counter-extension being maintained by a leather cap which fits the head and comes under the chin. In many cases this counter-extension can be improved by having the foot of the bed elevated higher than the head. If more than one vertebra has been injured, the parts may be held in position, and probable deformity prevented, by placing compresses of surgeon's wool on each side of the injury and holding them in place by adhesive strips. It is found necessary in almost every case to catheterize the patient, and great attention should therefore be paid to the toilet of the bladder, so as to keep this organ from chronic inflammation. The patient should be kept scrupulously clean, with plenty of fresh air, and a simple but nutritious diet should be prescribed. In quite a number of cases it will be discovered that a portion of the lamina is pressing upon the cord, and should this be recognized, an operation known as laminectomy should be performed. On account of the fatality of fractures of the spine and the helpless condition in which many patients are left from the effect of this injury, surgeons have felt themselves warranted in taking any steps, it matters not how heroic, for the purpose of saving or at least benefiting the injured. For this purpose, in recent years, the operation of laminectomy has been devised. It is true that the operation has not furnished as brilliant results as could be desired, yet some of the remarkable recoveries that have been obtained by this operation have led many surgeons to believe that, should the operation be performed early enough, many lives might be saved which now are lost, and new laurels added to surgery. I am of the opinion that the delay in resorting to this operation has led to degenerative changes in the cord, and is responsible for the many unsuccessful issues; I would therefore urge an immediate operation in every case of fractured lamina. In a number of cases, owing to the amount of swelling, it is impossible for a surgeon to tell exactly what the conditions are until he has cut down upon the vertebræ and examined them. Aseptic surgery has made this possible, and when in doubt the surgeon should cut down upon the vertebræ and thus give the patient every opportunity for a complete recovery. The operation is performed in the following manner: The patient is placed with his face slightly downward and with a small hard pillow under the lower ribs, thus giving the spinal column a gentle curve; the parts are cleansed and made thoroughly aseptic, and an incision is made of from three and one half to four inches in length, parallel with the tips of the spinous processes; the middle point of this incision corresponding with the seat of fracture. The muscular structures are now detached from the sides of the spinous processes, and the posterior surface of the lamina is brought into view. With a periosteotome the periosteum is separated from the bone; a procedure which should be carried out with great care, so as to preserve as much of the periosteum as possible. The wound is now held open by retractors and, if there is any hemorrhage, it should be entirely controlled, either by hæmostatic forceps or by the application of hot, sterilized water. The spinous processes are divided by a strong pair of bone forceps, thus enabling the operator to gain a perfect view of the laminæ. The laminæ are then either simply elevated or bit off by a pair of rongeur forceps. The membrane and spinal cord are now inspected. Should the dura mater show by discoloration the presence of blood, it should be incised, the imprisoned blood evacuated and the hemorrhage controlled, and the parts thoroughly irrigated with either a saline solution or sterilized hot water. After the cord and nerves have been carefully examined, cleansed, and placed back in the best possible condition, the dura mater should be adjusted and its edges brought together by interrupted catgut sutures. The muscular structures are sutured by the same material and the skin approximated by silk or silkworm sutures. After the operation, the patient should be placed on an air- or water-bed, shock should be combated, and every detail in the after-treatment should be carefully carried out.

Dislocations of the Vertebræ.—In the great majority of cases dislocations are associated with fractures, but, in a few instances which come under the surgeon's observation, the dislocation is entirely uncomplicated with fracture. These injuries are either produced by forced flexion or by hyperextension, and may be either unilateral, bilateral, or complicated with hemorrhage in the cord. The vertebræ that are more prone to dislocations are the last dorsal, first and second lumbar, and the last cervical. With all of these dislocations we have either a partial or a complete laceration of ligaments and muscular structure, together with such complications as rupture of blood-vessels, injuries to nerves, and laceration of the intervertebral discs. As a rule, these discs are readily recognized, as they show a very great displacement from their normal position. Dislocations are distinguished from a fracture by an absence of crepitation or preternatural mobility. The great weight of authority is against any effort to reduce these dislocations, as by so doing it is feared that a more serious complication may arise and the patient lose his life; yet in some cases I believe it is the duty of the attending surgeon to attempt a reduction. This may be effected by traction, aided by flexion and rotation. It is the duty of the surgeon, before proceeding with this method, to inform the patient's relatives and friends of the great danger which accompanies this undertaking, and to obtain from them their sanction before he resorts to this measure.

Hemorrhage of the Cord.—This may be either extradural, subdural, or intraspinal. The symptoms following extradural hemorrhage are at first somewhat akin to those of laceration of the muscular tissue surrounding the spinal column; but later on, owing to the extravasation of the blood, great pain is felt in the region involved, and still later, in some cases, symptoms of paralysis supervene. In the subdural variety the pain and paralysis occur much earlier and are then followed in almost every case by paralysis. On the other hand, in the intraspinal variety, symptoms of paralysis come on immediately, thus simulating fracture or dislocation of the spine. In some cases of hemorrhage of the spinal cord, where the hemorrhage is slight, absorption may take place and an ultimate recovery ensue. In other cases in which the symptoms are prolonged, the patient, instead of getting better, gradually grows worse; in which event it is the duty of the surgeon to operate and evacuate the blood or remove the clots that have formed.

Abscess of the Spinal Cord.—In all cases of abscess of the spinal cord, when diagnosed, an operation for the speedy evacuation of the pus should be performed and drainage established.

Tumors of the Cord.—These tumors are either of a benign or of a malignant type, and when recognized they should be dealt with in the same manner as are similar tumors when found in the brain. *Paul F. Eve.*

SPINE, TUBERCULOUS DISEASE OF THE.—(Synonym, Pott's disease.) Pott's disease is a chronic destructive process that affects the bodies of the vertebræ, the anterior and weight-supporting portion of the spinal column. As the disease progresses the part of the spine above the weakened point sinks downward and forward, throwing into relief the spinous processes at the seat of disease. Thus an angular posterior projection is the

1. 2.

FIG. 4127.—Spinal Lesions in Pott's Disease. 1, Disease in two distinct regions of the spine; 2, a section of the spine showing the production of angular deformity.

characteristic deformity of Pott's disease, or rather of any process attended by local destruction of one or more of the vertebral bodies. If one vertebral body is destroyed, the projection is sharp and well defined; if several are involved, it will be less angular; and if one side of a vertebral body breaks down, there may be a slight lateral distortion as well.

The size of the deformity and its effect upon the individual depend in great degree upon its situation. If it is at either extremity of the spine the deformity is small, because so little of the spine is affected compared with that which remains free from disease. Thus, angular deformity in the upper cervical region simply shortens the neck, and disturbs the poise of the head. In the lowermost region it shortens the trunk and induces a peculiar attitude, but in either case the posterior projection or "hump" is slight; but when the middle of the spine is involved the opportunity for deformity is great and the entire spine may enter into the formation of the kyphosis.

PATHOLOGY.—The first indication of disease is usually found in the anterior part of a vertebral body beneath the longitudinal ligament. From this point the infected granulation tissue, following the course of the blood-vessels, invades and destroys the adjacent spongy tissue. In other instances the disease may begin in several minute foci in the interior of a vertebral body near the upper or lower epiphysis. These, coalescing, gradually enlarge, forming a cavity; collapse follows and the deformity appears. Less often the disease advances beneath the anterior ligament as a form of tuberculous periostitis, without implicating deeply the substance of the vertebral bodies. The posterior part of the spinal column usually remains free from disease, unless it comes into direct contact with it.

The course and outcome of the disease depend upon its character. If the area of primary infection is limited, the local resistance may check its further progress and cure without deformity may follow. In other instances, although the area of active disease is small, it continues to progress and the deformity slowly increases, although unaccompanied by pain or by constitutional symptoms. In the majority of cases, however, the tuberculous granulations advance rapidly, destroying the bone or other tissues with which they come into contact. The usual retrograde metamorphosis to cheesy degeneration follows, and then very frequently liquefaction or abscess formation takes place.

In characteristic cases that come to autopsy during the progressive stage of the disease, one finds, on dividing the thickened tissues in front of the spine, a cavity the walls of which are lined with tuberculous granulations in various stages of degeneration and containing puriform fluids. The adjoining vertebral bodies present a worm-eaten appearance, and one or more of them is partially destroyed. Small fragments of necrosed bone and "bone sand" may be present, together with larger masses of degenerated tissue; less commonly sequestra of considerable size may be found, loose or embedded in the diseased area.

As the disease progresses it may force its way into the vertebral canal and press upon the spinal cord, involve its coverings, and cause paralysis of the parts below. Such a complication is more frequent when the disease begins in the centre or posterior portion of a vertebral body. In such instances the paralysis may precede the deformity. Pressure on the cord may be caused also by an abscess or a projecting fragment of bone. The calibre of the spinal canal may be lessened also by the pressure of the superincumbent weight upon the softened and thickened tissues at the seat of disease, but as a rule its capacity is not directly lessened by the characteristic angular distortion. In fact, pressure paralysis more often complicates cases in which the deformity is moderate or slight in degree than those in which it is extreme.

In rare instances tuberculous disease may appear in two regions of the spine simultaneously, but it usually begins in one or two adjacent vertebral bodies, one or both of which are partially destroyed. From this point the disease extends in either direction, and in ordinary cases the final area of deformity and rigidity shows that from three to six bodies are more or less involved before a cure is established.

At all stages of the disease resistance to its progress and local efforts at repair are evident in the affected parts. This is accomplished occasionally by contact and solid union of the adjoining surfaces of softened bone, but this is possible only when the area of the disease is small. If several bodies are destroyed there is usually backward displacement of the upper segment of the spine as it sinks downward. Thus the anterior surface of one or more of the bodies of the upper segment may be apposed to the upper surface of the lower body. In such instances the ankylosis is in part fibrous, in part cartilaginous, and in part bony. This may include the articular processes, the pedicles and laminæ; in fact, ankylosis may be established here before repair has advanced appreciably in the anterior portion of the column.

Cure may be complete, no vestige of the disease remaining; or the diseased products may undergo calcareous degeneration and may be enclosed in newly formed tissue. In other instances the disease is simply quiescent, and may show its presence from time to time by recurrent symptoms of discomfort, by abscess formation, or even by paralysis many years after apparent cure.

ETIOLOGY.—The etiology of tuberculosis of the spine does not differ from that of other bones; the subject is considered elsewhere.

Relative Frequency.—Tuberculosis affects the spinal column more frequently than it does any other single bone or joint. This point is illustrated by the statistics of tuberculous disease treated in the out-patient department of the Hospital for Ruptured and Crippled during a period of fifteen years: Tuberculosis of the spine, 3,207 cases; hip-joint, 2,230 cases; other joints inclusive, 2,408 cases.

Age.—Pott's disease, although far more frequent in the middle period of childhood (from the third to the tenth year), may occur at any time from earliest infancy to extreme old age.

STATISTICS FROM WHITMAN'S ORTHOPEDIC SURGERY.

	Cases.	Per cent.
Less than one year	38	3.1
Between one and two years	176	11.2
Between three and five years	627	50.2
Between six and ten years	234	18.3
Between eleven and twenty years	89	7.2
Between twenty-one and thirty years	43	3.5
Between thirty-one and fifty years	31	2.6
Over fifty years	11	.8

The youngest patient was two months old, the oldest seventy-one years.

Sex.—Sex exercises comparatively little influence upon the liability to disease of this region. In 3,822 cases 53.2 per cent. were in males and 46.8 per cent. in females (*loc. cit.*).

The Situation of the Disease.—The dorso-lumbar section of the spine is most often affected. Cervical disease is comparatively infrequent.

In the series of 1,355 cases (*loc. cit.*) the attempt was made to locate the origin of the disease by the most prominent spinous process in the tracing. The following are the conclusions:

Cervical.		Dorsal.		Lumbar.		Lumbo-sacral.	
First,	3	First,	26	First,	94	13	
Second,	3	Second,	43	Second,	96		
Third,	15	Third,	42	Third,	64		
Fourth,	20	Fourth,	46	Fourth,	57	No deformity.	
Fifth,	13	Fifth,	49	Fifth,	6	Cervical,	2
Sixth,	22	Sixth,	76			Dorsal,	31
Seventh,	24	Seventh,	82		317	Lumbar,	22
		Eighth,	97				
	100	Ninth,	92				55
		Tenth,	110				
		Eleventh,	71				
		Twelfth,	120	Disease in two regions of the spine, 16.			
			854				

From these statistics, which do not differ essentially from those reported by others, it appears that the disease is much less common in the cervical than in the dorsal region. This may be explained by the greater strain to which the middle and lower part of the spine is subjected, as well as by the relatively larger proportion of cancellous tissue which offers the opportunity for infection.

PROGNOSIS.—Pott's disease is the most serious of all the tuberculous affections of the bones and joints, because of the relative importance of the structures directly and indirectly implicated. Prognosis must include also the indirect influence of the deformity. In the typical "humpback" deformity the contents of the thorax and abdomen are necessarily compressed, the blood vessels are distorted and the calibre of the aorta is thereby often much diminished, respiration is made difficult, and the circulation is impeded. As a consequence the heart is usually hypertrophied or dilated, and valvular insufficiency is not infrequent. Thus the vital functions which are carried on at a disadvantage even under favorable conditions become impossible under the added strain of unfavorable surroundings, overwork, or disease. It is a matter of common observation that few of those who are markedly deformed reach old age. On the other hand, it may be assumed that slight deformities, or those which do not as directly interfere with the vital functions, exercise but little influence upon the future well-being of the patient. This emphasizes the importance of early diagnosis and efficient treatment.

The direct mortality of Pott's disease cannot be accurately estimated, but at least twenty per cent. of all patients die during the progress of the disease and within a few years after its onset, from causes directly or indirectly dependent upon the local lesion. Some of these die from general dissemination of the tuberculous infection and tuberculous meningitis; some from exhaustion following septic infection or from amyloid degeneration and exhaustion dependent on long-continued suppuration; some from tuberculosis of the lungs, and many from intercurrent affections that are fatal because of the devitalizing influences of the disease and its complications.

SYMPTOMS.—The most positive sign of Pott's disease is deformity. At an early stage of the process there may be but a slight irregularity in the contour of the spine, and if several adjacent vertebral bodies are affected the projection may be somewhat rounded in outline. But as compared with other deformities of the spine, that of Pott's disease is characteristically angular, because its cause is loss of substance.

This angular deformity was once thought to be essential for diagnosis, but it is simply the result of disease that may have existed for months, a disease whose presence may be detected long before it reaches the destructive stage.

The spine is the most important support of the body, an elastic column that accommodates itself to every movement of the trunk and limbs. The early symptoms of a destructive disease must be therefore pain and functional disability. The spine also contains the spinal cord, from which branch the nerves that supply the organs and members of the body, and in certain instances the sudden onset of paralysis due to extension of the disease backward might occur early in the process. Or, again, abscess, one of the common accompaniments of tuberculous disease, might, because of its size or situation, become the most noticeable symptom.

These are symptoms that may be misleading, and it is well, therefore, to consider them apart from those that indicate the primary effect of the disease upon the spine considered as an elastic support. These direct symptoms usually precede and always accompany the secondary or complicating symptoms, and upon them the diagnosis depends.

The primary and diagnostic symptoms of Pott's disease may be classified as follows:

(*a*) Pain.
(*b*) Stiffness.
(*c*) Weakness.
(*d*) Awkwardness.
(*e*) Deformity.

The *pain* of Pott's disease is not usually localized at the affected vertebræ nor is it accompanied by sensitiveness to pressure or infiltration and swelling of the overlying tissues, as is usually the case when other bones are involved; for the vertebral bodies are within the trunk, almost as far from the spinous processes as from the anterior surface of the body.

Thus sensitiveness to direct pressure is unusual, and palpation, except in the cervical region, is of little diagnostic value.

The pain of Pott's disease is not localized, because the nerve filaments that supply the bodies of the vertebræ are insignificant parts of nerves that are distributed to distant points—to the head, to the limbs, to the front and sides of the body, and to these parts the pain is referred. Thus "earache" or "stomachache" or "sciatica" may be symptomatic of Pott's disease of the different regions of the spine. This pain is by no means constant; it is rather occasional, induced by jars or by sudden unguarded movements. Often at night when muscular protection is relaxed, sudden movements during sleep cause discomfort or pain and the child moans, or is restless, and sometimes wakens with a cry—"night cry."

Stiffness of the spine is in some degree voluntary, in that the patient adapts himself to the disease and avoids, if possible, strain and jar, but the essential stiffness of Pott's disease is caused by the involuntary muscular tension and contraction of the muscles about the seat of disease. The degree of muscular spasm varies with the sensitiveness of the diseased tissues; thus it may fix the spine, or it may limit only the extremes of motion. Reflex muscular spasm precedes deformity and continues until a cure is established; it is therefore the most important of the diagnostic symptoms of Pott's disease.

A destructive disease of the most important support of the body it is a direct as well as an indirect cause of *weakness*; the younger the patient, the more apparent is this symptom which is shown by the "loss of walk," the refusal to stand, or the instinctive desire for support at an early stage of the disease.

Awkwardness.—Pain and weakness and rigidity of the spine induce changes in the habitual attitudes and movements of the patient that are often almost diagnostic of the disease and of the part of the spine involved.

The deformities of Pott's disease may be classified as—Bone deformity, muscular deformity, compensatory deformity.

The characteristic angular projection due to destruction of bone has been described already.

Muscular deformity is the distortion due to muscular spasm or contraction. Wry-neck, symptomatic of cervical disease, and psoas contraction, a common accompaniment of disease of the lower region, are the familiar examples.

Compensatory deformity signifies the general effect of the local disease and local distortion upon the spine as a whole. Thus an angular projection must be balanced by a compensatory incurvation, and lateral distortion in one direction by lateral distortion in another. These secondary changes in contour often attract attention before the primary local deformity is detected.

Although angular deformity is characteristic of the disease, lateral deviation of the spine is not infrequent. It may be direct distortion at the seat of disease, caused by the destruction of the side of a vertebral body; more often, it is a secondary effect of such irregular erosion at one or the other extremity of the spine. It may be caused by muscular contraction, or it may be due to simple bodily weakness. In such instances it is a transitory distortion.

Aside from direct deformity, there is usually at the earliest stage of the disease a slight change in the outline of the spine; it no longer forms a long regular curve when the body is bent forward, but an irregularity of contour, of limitation of normal flexion, is almost always apparent.

Secondary Symptoms.—Abscess.—In the retropharyngeal space the tumor of an abscess may interfere with respiration and deglutition. In the thoracic region it may, from the physical signs, be mistaken for pleurisy or empyema, and in the iliac fossa, when accompanied by psoas contraction, it may interfere with locomotion.

Paralysis is usually one of the later symptoms, but if the disease begins in the centre or posterior part of a vertebral body it may implicate the cord before deformity appears.

Abscess and paralysis are classed as complications because they must be explained by a proper diagnosis. Their appearance is always preceded and accompanied by the essential symptoms of Pott's disease.

General Symptoms.—If the disease is active or if an abscess is approaching the surface there is usually a slight but constant elevation of the temperature, but the positive value of the symptom in early or quiescent cases is doubtful. A patient suffering from tuberculous disease of the spine usually presents the evidences of a painful and depressing affection and in many instances the appearances of inherited or acquired weakness; but these general symptoms are of comparatively little value in diagnosis.

Of the early symptoms of Pott's disease two have been noted as of especial importance—the impairment of normal mobility and the change in the contour of the spine. The contour of the spine varies considerably in the adult. It is affected by the occupation and by many other circumstances; of this the round shoulders of the cobbler or the weaver, the stoop of weakness and of old age, are familiar examples, but in childhood distinct variations from the normal contour almost always have a pathological cause. As the normal contour is the effect of the balancing of the body in the upright posture, it is evident that if the outline of one part is permanently changed, compensation for this change must be made in another part. Thus, when deformity is well marked the normal curves of the spine are often completely reversed, and even at an early stage of the disease the abnormal contour will often attract attention long before the characteristic angular projection has become apparent.

Although the spine is a flexible column that is constantly changing in outline with every movement and posture, yet the range and character of this motion vary greatly in its different parts. In the cervical and lumbar regions motion is extensive, but it is comparatively limited in the thoracic region because the intervertebral discs are thin, because of the overlapping spinous processes, and because it forms a part of the rigid thorax. It is evident that the symptoms of a destructive disease will show themselves far more quickly in those regions of the spine where motion is free than where it is slight, and that these symptoms will differ somewhat in character with the function of the part involved. Thus, in considering early diagnosis, and in fact treatment and prognosis, one should divide the spine into sections:

1. The neck part, that allows free motion of the head, ending at the third dorsal vertebra.

2. The rigid thoracic part, which includes the third and tenth dorsal segments.

3. The lower portion, made up of the two lower dorsal and the lumbar vertebræ, in which the principal movements of the trunk are carried out. One must bear in mind the distribution of the nerves because the characteristic pain is referred to their terminations, also the parts in relation to the spine at different levels that may be implicated in the disease. Thus, remembering that the symptoms of Pott's disease are in general stiffness, weakness, pain, and deformity, one will always apply these symptoms to a particular region of the spine and will picture to himself the effect of such stiffness, weakness, and deformity at this or that vertebra; the effect of an abscess in this or that situation, and the area of paralysis that might be caused by pressure on the cord at one or another level.

The Rational Signs.—The symptoms of Pott's disease vary not only with the region of the spine involved, but also with the age and surroundings of the patient.

Tuberculous disease of the spine is usually an insidious chronic affection which does not often attract attention in its incipiency. The child may cry after overexertion or injury, but at other times it may appear, to the unobservant eye, to be in its usual health. When the diagnosis is finally made, however, the parents always remember that something was "wrong" with the child, that it was fretful and disinclined to play, that it liked to lie on the floor, that it was awkward in its movements, that it was troubled by a cough or indigestion or by oppression of breathing. These symptoms, which are readily explained by the disease, do not as a rule attract attention until deformity appears.

An exact history of the case is often of importance both as to prognosis and as to treatment. For example, one should inquire if the immediate relatives of the child have suffered from phthisis or other form of tuberculosis;

also if the child has always been strong, and if recovery from the ordinary ailments of childhood was prompt or tedious, in order that one may judge of the quality of the patient. One next asks, not "How long has the child been ill?" for this is usually understood to refer to the duration of the more decided symptom, but, "When was the child last perfectly well?" Then as to the onset of the first symptoms, whether it was sharp and decided, or gradual and ill defined; and whether the symptoms were preceded by contagious disease or by injury. If there is a history of injury it should be made clear whether the injury was the direct cause of the symptoms, or if it may have simply aggravated or brought to light the dormant disease. To establish injury as the sole and direct cause of symptoms, the patient must have been well at the time of the accident, the symptoms must have followed immediately and have continued since; and, finally, the symptoms must be of such a nature as to be explained by a definite injury.

Physical Examination.—Although histories are usually indefinite and misleading, it is commonly made clear that the affection is chronic, although its course has been varied by acute exacerbations. This is the characteristic of tuberculous disease.

The diagnosis is, however, almost entirely dependent upon the physical examination. This begins on the first sight of the patient, when one notes the general condition and the actions and postures. These show the adaptation of the body to the disease, the conscious and unconscious efforts of the patient to guard the weak part from strain that induces pain and discomfort.

The object of the physical examination is to compare the part suspected of disease with the normal, and the examination must be purposeful.

When one asks the patient to pick up a coin from the floor—the popular test for Pott's disease—one employs it to test the mobility of the lower region of the spine, the region in which the motions of stooping and turning the body are carried out; remembering that such movements are often not restrained in the slightest degree by disease in the upper portion of the spine.

Such tests must not only be purposeful, but they must be adapted to the age and intelligence of the patient. The child that refuses to pick up a coin will often gather up its clothing, because it wishes to be dressed again. If it will not stoop it will usually rise if placed in the recumbent or sitting posture, which is an equally useful test. A child will walk toward its mother if placed at a distance from her. It will always turn its head toward her, and therefore voluntary motion of the cervical region may be tested by changing the mother's position, while the child is held by the examiner.

Young children who struggle and resist passive motion, if placed on the table, submit quietly when held in the mother's arms.

The most important of the early signs of Pott's disease is the peculiar stiffness due to the reflex action of the muscles. This spasm limits movement in all directions. It is always present from the beginning of the disease until consolidation is finally completed.

The muscular rigidity is most marked in the neighborhood of the disease, but it extends to a greater or less distance, according to the acuteness of the local process and the susceptibility of the patient. Even at an early stage the situation of the disease is usually shown by a slight irregularity of the spine in the centre of the area made rigid by muscular spasm, as well as by the change of contour. This change in outline and flexibility may be demonstrated by bending the patient forward. If the spine forms a long, even, regular curve, and if there be no evidence of pain or rigidity when such an attitude is assumed, Pott's disease is extremely improbable. If, on the other hand, the outline of the curve is broken, if the motion of one section of the spine is restrained by muscular rigidity, disease may be suspected, and, if other evidence of tuberculous ostitis is present, the diagnosis may be made with certainty.

By a careful physical examination one may expect to detect Pott's disease at any stage and to fix upon its location, or at least upon the point suspected of disease. One will then ask one's self if tuberculous disease of the bodies of the vertebræ of this particular region will satisfactorily explain all the symptoms of which the patient complains; if, for example, the pain corresponds to the distribution of the nerves, if restraint of function will explain the attitudes of the patient, if the change of contour is significant of a destructive process, and the like.

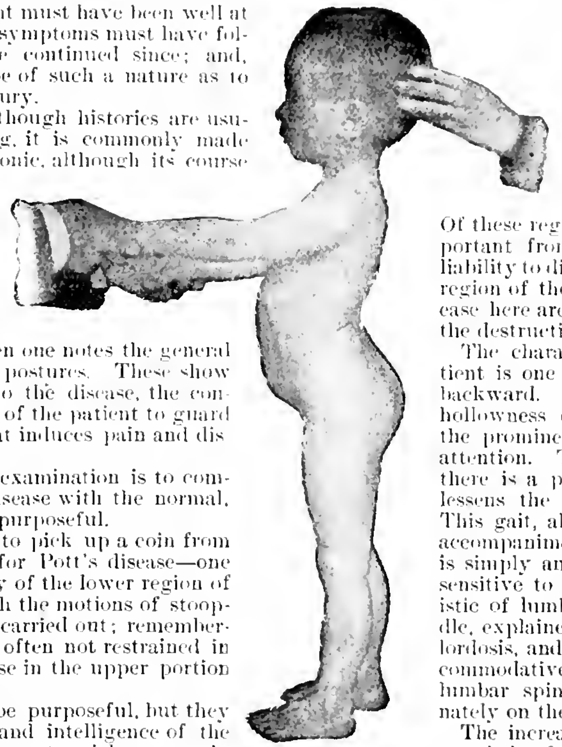

FIG. 4128.—Pott's Disease in the Lower Dorsal Region, showing Compensatory Lordosis.

The Lower Region.—As has been stated, the spine should be divided into regions according to varying function. Of these regions the lower is the most important from the standpoint of relative liability to disease, and, as it is the movable region of the spine, the symptoms of disease here are usually evident long before the destructive stage.

The characteristic attitude of the patient is one in which the body is swayed backward. Often there is an increased hollowness (lordosis) of the back; thus, the prominent abdomen may first attract attention. The walk is careful, and often there is a peculiar tiptoeing step, which lessens the jar on the sensitive spine. This gait, although most common as an accompaniment of disease of this region, is simply an evidence that the spine is sensitive to slight jars. More characteristic of lumbar disease is a peculiar waddle, explained in part by the exaggerated lordosis, and in part by the loss of the accommodative balancing motion of the lumbar spine, as the weight falls alternately on the legs in walking.

The increased lumbar lordosis so characteristic of the early stage of the disease is capable of several explanations. It is partly voluntary, the backward inclination relieving the pressure upon the diseased vertebræ. It is partly involuntary, caused by the contraction of the large muscular masses on the posterior aspect of the spine. It is in part compensatory, as the slight psoas contraction which is often present has a tendency to tilt the pelvis forward, necessitating a greater compensatory backward inclination of the body.

As the disease progresses, the lumbar section becomes straighter, and finally it may project backward in the characteristic angular deformity. Yet even after the lordosis has been changed to a kyphosis the backward inclination of the body still continues as a compensation for the reversal of the lumbar curve.

Slight psoas contraction simply increases the lordosis, but when the contraction is more extreme and persistent, the erect attitude is no longer possible. The limbs are drawn toward the body and the body is inclined forward to relax the tension. This greater contraction, which is usually symptomatic of abscess formation, is most often limited to one side. Thus the patient inclines the body somewhat forward and toward the flexed leg, "favors it," and the resulting limp is usually mistaken for a sign of hip disease. Unilateral psoas contraction of this character is, in fact, so often present when the patient is first brought for treatment, that a limp and the accompanying inclination of the body may be considered as characteristic of more advanced disease of the lumbar region.

The location of the pain depends upon the distribution of the nerves that supply the diseased vertebræ, or that

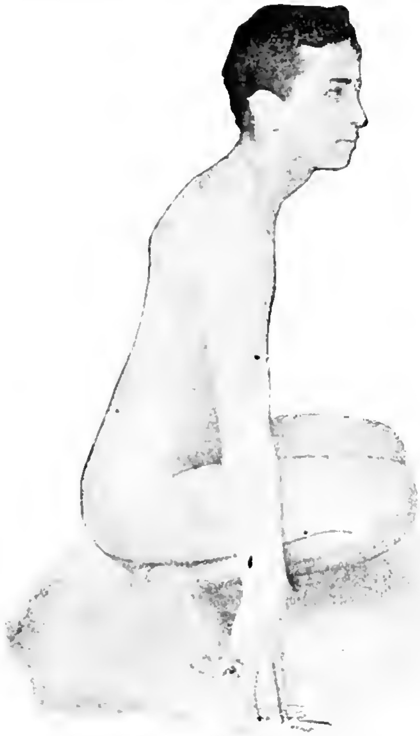

FIG. 4429.—Pott's Disease of the Lower Region before the Appearance of Deformity, illustrating the Manner of Picking up an Object from the Floor.

pass in its vicinity. It may radiate over the inguinal region or backward to the loins or buttocks, or down the front or back of the legs to the knees. Painful cramp is not infrequently a symptom, the thigh is spasmodically drawn toward the body, and the patient seizing it with both hands shrieks with pain.

Lateral inclination of the body is often present. Commonly it indicates unilateral psoas contraction, or at a later stage it may be caused by collapse or destruction of one side of a vertebral body. In other instances it is simply adaptation to weakness or pain, an attitude similar to that caused by persistent sciatica.

The effects of the stiffness, weakness, and pain are usually sufficiently apparent. For example, the child may be unable to turn in bed. If the disease is at all active, the standing is more comfortable than the sitting posture, in which more weight is thrown upon the sensitive vertebral bodies. When seated, particularly when riding in a carriage or street car, the patient often sits upon the edge of the seat, the shoulders only touching the back, while the hands rest instinctively on the seat, partially supporting the weight and steadying the spine.

Stooping, a posture that increases the pressure in the diseased vertebral bodies and which necessitates muscular tension and strain in regaining the erect position, is particularly difficult, and it is always avoided by the patient if the disease is at all acute. For example, when the child is asked to pick up an object from the floor, it either refuses or it squats on the heels or drops upon the knees instead of flexing the spine as in health. Young children having seized the object upon the floor, regain the erect attitude by pushing the body up by the pressure of the hands upon the thighs. If the child is placed upon the floor it will, if possible, seize the mother's dress, or will crawl to a chair or other object, upon which the body may be drawn up by the arms, so that the discomfort caused by muscular contraction of the back muscles may be avoided.

After this preliminary observation and examination the patient should be placed at full length, face downward, on a table, and the range of extension and of lateral motion is then to be tested by lifting the legs and swaying the body gently from side to side. One should always test for psoas contraction by holding the pelvis firmly against the table with one hand while the leg in the line of the body is gently lifted by the other. As tested in this manner the normal range of extension should allow the knees to be lifted two or three inches from the table. Slight restriction of extension of both thighs, indicating a slight degree of psoas contraction, is very common in Pott's disease, but when the restriction is marked, and especially if it be unilateral, a deep abscess may be expected. Such unilateral psoas contraction may be more clearly demonstrated by placing the child on the back, allowing the limbs to hang over the table, when the unaffected thigh will drop below its fellow.

As has been stated, in many instances the lordosis is increased, and in all cases flexion of the lumbar spine is much more restricted in the early stages of the disease than is extension. This rigidity and fixation may be demonstrated by placing the child on its hands and knees and lifting it from the floor, the trunk, instead of bending over the supporting hands, retaining almost its original contour.

Although in many instances no noticeable deformity is present, still one can almost always detect a slight fulness about the spinous processes or a slight irregularity in their line, indicating the exact seat of the disease. Strong pressure upon the spinous processes at this point may induce discomfort, and sometimes greater elasticity at the diseased area is apparent. This is, however, a test of comparatively little value.

Abscess is very commonly a complication of disease in this region of the spine, and it may be suspected when persistent unilateral psoas contraction is present in marked degree. In such cases the patient may be turned upon the side, and by deep pressure one may often detect an elastic tumor in the loin or pelvic fossa.

The diagnosis of Pott's disease, even in the early stage, is comparatively easy on careful and systematic physical examination. It is most often mistaken for some one of the following affections:

FIG. 4430.—Showing the Altitude of Over-erectness Caused by Compensation for Deformity; also abscess presenting itself in the inguinal region.

Lumbago.—This is an acute affection, usually of adult life, of sudden onset, characterized by local pain and by sensitiveness of the muscles themselves.

Strain of the back has as a rule a well-defined cause.

Like lumbago, its onset is sudden. The pain is usually localized at the point of injury and it is relieved by rest. In Pott's disease the pain is neuralgic, it is often worse at night, and the stiffness due to reflex muscular spasm is quite different from that caused by strain.

FIG. 4431.—Pott's Disease in Infancy, showing the Early Indication of Deformity.

Sciatica.—The pain of sciatica is most often unilateral; it is usually confined to the distributions of this nerve. The pain of Pott's disease, if it is referred to the legs, is usually bilateral. In sciatica movements of the limb often aggravate the pain, while motion of the spine is free or but slightly restricted. The reverse is true of Pott's disease. In persistent sciatica of long standing, lateral deviation and even rigidity of the lumbar spine are sometimes observed; but if the latter symptom is marked, the diagnosis may be regarded as open to question.

Sacro-iliac disease is far more likely to be mistaken for disease of the hip-joint than of the spine. The pain and sensitiveness are usually localized about the seat of disease, and the motions of the spine are but slightly restricted.

The attitude characteristic of Pott's disease of this region—viz., the hollow back, the prominent abdomen, combined with the waddling gait—may be simulated by bilateral congenital dislocation of the hip and by certain forms of nervous disease in which the muscles of the back are weak, as, for example, progressive muscular atrophy, or pseudohypertrophic muscular paralysis. In these affections the characteristic symptoms of bone disease are of course lacking.

Hip Disease.—When psoas contraction is present in lumbar Pott's disease it induces a limp, and not infrequently the patient complains of pain in the affected limb. These symptoms are usually mistaken for those of hip disease. The limp of Pott's disease is caused simply by flexion of the leg; when, therefore, in the physical examination the tension of the contracted ilio-psoas muscle is relieved by flexing the thigh still further, the other movements of the hip—flexion, rotation, and the like—may be shown to be free. In hip disease all motions are restrained in equal degree by muscular spasm.

Hip Disease in Infancy.—In infancy sympathetic spasm of the lumbar muscles is often present in hip disease, and a similar spasm of the muscles about the hip may accompany disease of the lower part of the spine. In doubtful cases of this character the application of a temporary support to the back and limbs, as, for example, a plaster spica bandage which will relieve the secondary spasm, is an aid in diagnosis.

Secondary Hip Disease.—An infected abscess in the neighborhood of the hip-joint may finally set up secondary disease of its structure, and in the presence of discharging sinuses that involve the tissues about the hip it is not always possible to decide whether or not the joint is actually diseased.

Pelvic Abscess.—As abscess is a common complication of Pott's disease it will be necessary to consider abscesses of other origin within the pelvis or in the neighborhood of the spine that may induce symptoms resembling somewhat those of Pott's disease. The most common abscesses other than those resulting from disease of bone are the perinephritic and appendicular. As a rule these are of sudden onset, and are attended by local pain and by constitutional symptoms. There is of course no deformity of the spine.

Chronic abscess in the pelvis, of other than spinal origin, may be the result of disease of the pelvic bones, or of the sacro-iliac articulations, or of the hip-joint. It may be caused by the breaking down of lymphatic glands, or it may have its origin in inflammation about the uterine appendages, and cases of so-called idiopathic inflammation and suppuration of the ilio-psoas muscle have been described. In childhood chronic abscesses in this locality are almost always tuberculous in character, and are caused by disease of bone, either of the spine or of the pelvis. Disease of the spine can be determined usually by the methods already indicated, but, if the abscess is of other origin, its exact cause can be decided in many instances only by an operative exploration.

Abscesses of this character, of slow and apparently painless formation, may finally cause a swelling in the inguinal region or about the saphenous opening, that in the adult is not infrequently mistaken for hernia. In practically all cases, however, the tumor of the abscess may be made out on palpation within the pelvis, while the swelling, although its contents may be in part forced into the abdominal cavity, feels very differently from that of an ordinary hernia, which may usually be completely reduced. In addition, some sign of the disease of the spine or pelvis, of which the abscess is a result, is almost always present.

Pott's Disease in Infancy.—Attention has been called to the great importance of carefully observing the movements and postures of the patient, and of noting the contour of the spine when the patient is in the erect attitude. In Pott's disease of infancy such observations are of course not possible. As a rule at this age the muscular spasm is more intense and its extent is greater. The child screams when it is moved or lifted. There is usually no difficulty in determining the presence of disease from the evidence of rigidity and pain, but, as has been stated, it is sometimes difficult to decide whether the lumbar spine or one of the hip-joints is involved. Slight

FIG. 4432.—Illustrating the Change from the Normal Contour, made Evident when the Patient Bends Forward.

irregularity of the spinous processes, indicating the position of the destructive process, is often evident at an early stage and early abscess is not unusual.

Pott's disease of infancy and early childhood is most often mistaken for *rachitic deformity*, or, rather, this deformity is often mistaken for that of Pott's disease.

The diagnosis from Pott's disease should be made without difficulty. The characteristic deformity of rachitis is a rounded projection of the middle and lower part of the spine. It is simply an exaggeration of the contour of the sitting posture which the rachitic child habitually assumes, a posture that would be painful if actual disease were present in this situation.

If the patient be placed in the prone posture the projection may be reduced in great part by raising the thighs while gentle pressure is exerted upon the kyphosis; and although the spine is somewhat rigid, and although such extension and pressure may be resisted by the patient, yet there is complete absence of the muscular spasm characteristic of Pott's disease.

Disease of the Middle Region.—As motion in the thoracic region of the spine is limited, the early symptoms of disease are far less marked than in the region below. On the other hand, a slight exaggeration of the normal dorsal kyphosis causes noticeable deformity. Thus it is that deformity may be the first symptom that attracts attention.

The effect of the disease upon the attitudes varies. If the disease involves the lower part of the thoracic segment, and if it be at all acute, they are similar to those of disease of the lumbar region, namely, erectness, the peculiar cautious intoeing step, and the disinclination to bend the body forward.

In disease of the upper dorsal region there is usually a slight forward inclination of the body while the head is tilted backward or inclines toward one side. A peculiar shrugging squareness and elevation of the shoulders is often noticed, due in great part to the lowering of the head and forward inclination of the neck resulting from the deformity. Another effect is pigeon-chest. As the deformity progresses the sternum is thrust forward and the antero-posterior diameter of the chest is increased at the expense of its height. This deformity of the chest may be the first symptom to attract the attention of the parents.

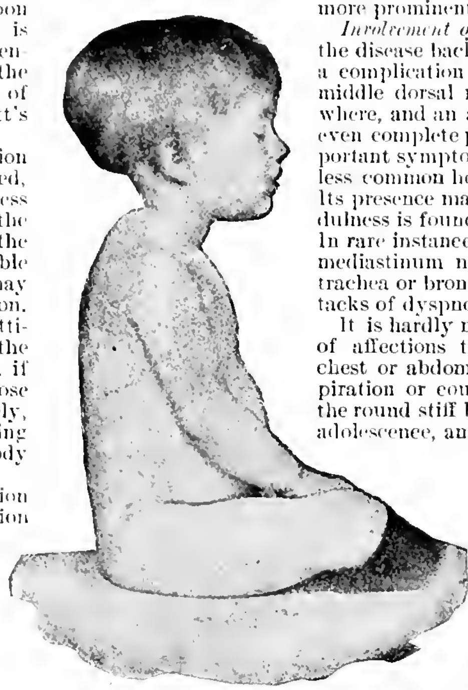

FIG. 4433.—Pott's Disease at the Cervico-dorsal Junction, showing the Effect of the Deformity in Thrusting the Neck Forward.

Of the early symptoms of dorsal disease pain and labored or "grunting" respiration are the most characteristic.

Pain referred to the abdomen and to the front and sides of the chest is usually an early and often a constant symptom. Thus, persistent "stomachache" in a child should always lead the physician to make an examination of the spine. A "spasm of pain" is sometimes excited by lateral compression of its chest, as when the child is lifted suddenly by the parent.

Of still greater importance is the labored respiration, which, indeed, is almost pathognomonic of Pott's disease. The "grunting" is caused by the interference with respiration, more particularly with the normal rhythmical movements of the ribs. The restraint is in part due to muscular spasm and in part to the voluntary efforts of the patient. The inspiration is quick and shallow, in great degree diaphragmatic, and expiration is accompanied by a sigh or grunt. This is apparently caused by a momentary closure of the larynx to resist the escape of air and thus sudden motion of the chest wall. Grunting respiration is of course an evidence of the more acute type of disease, but even in mild cases it is usually present when the patient is fatigued or during play. An irritating aimless cough is often a symptom of disease of the upper dorsal region, and spasmodic attacks resembling asthma are not uncommon.

When symptoms have existed for any length of time the characteristic angular kyphosis is usually apparent on physical examination, or at least the significant break in the contour of the spine when the patient is inclined forward.

In tracing the neuralgic pain to its origin, the sharp downward inclination of the ribs must be borne in mind: thus the cause of pain in the "stomach" must be looked for between the shoulder blades.

As in the lumbar region, slight lateral deviation of the spine is not uncommon, and it may be accompanied by a slight twist or rotation, so that the ribs on one side are more prominent.

Involvement of the cord from extension of the disease backward is far more commonly a complication of disease of the upper and middle dorsal region than of disease elsewhere, and an awkward stumbling gait or even complete paralysis may be the first important symptom of the disease. Abscess is less common here than in the lower region. Its presence may be suspected if an area of dulness is found by the side of the kyphosis. In rare instances an abscess in the posterior mediastinum may press directly upon the trachea or bronchi and cause spasmodic attacks of dyspnœa resembling asthma.

It is hardly necessary to mention the list of affections that may cause pain in the chest or abdomen, or induce a labored respiration or cough. As regards deformity the round stiff back, a postural deformity of adolescence, and the rachitic kyphosis may be excluded without much difficulty. Spondylitis deformans, the typhoid spine, and the like differ essentially in history and symptoms. Acute or chronic affections within the chest may cause pain and even deformity of the spine. Such disease, however, could hardly be mistaken for Pott's disease. The abscess of Pott's disease in this region, as has been mentioned, causes dulness or flatness on percussion of the chest, and within this area friction sounds and râles may be heard. If the diagnosis of Pott's disease had not been made, or if the presence of the abscess had not been determined by the previous physical examination, it might be mistaken, during an acute exacerbation of the disease or constitutional disturbance from other cause, for pleurisy or empyema, and at other times for phthisis. The tuberculous fluid may remain indefinitely in the posterior mediastinum, and the area of flatness may extend beyond the axillary line, yet it may give rise to no symptoms.

In all cases a careful examination of the chest should be made from time to time in order that the presence or absence of abscess may be recorded.

The Upper Region.—The upper region of the spine, which includes the cervical and two of the dorsal vertebræ, is a region of free movement. This movement is in part true joint motion; thus it is necessary to consider disease of this portion apart from that of the remainder of the upper section. Occipito-axoid disease is comparatively rare, and relatively more frequent in adult life than in childhood. It is especially dangerous because the displacement or fracture at this point may cause sudden death by pressure on the vital centres. In a typical case the symptoms are neuralgic pain radiating over the back and sides of the head, following the distribution of the auricular and occipital nerves. The head is usually inclined forward and rotated slightly to one or the other side of the median line. There is usually thickening of the tissues on the posterior and lateral aspects of the neck, and there is in most instances sensitiveness to deep pressure. As a rule motion in these joints is absolutely restricted, as is shown when one attempts to move the head up or down or from side to side.

In disease of this region if an abscess appears it usually presents itself on the posterior or lateral aspect of the neck, but in some instances it forces its way forward as a retro-pharyngeal abscess. In such cases the symptoms may be characteristic of obstruction, such as snoring, change in the quality of the voice, difficulty in swallowing, and sometimes spasmodic attacks of so-called croup.

When an abscess is present, and when the disease is at all acute, the reclining posture often increases the symptoms.

The symptoms of disease of the middle cervical region are similar to those of the upper dorsal section. There is usually a backward inclination of the head if deformity is present. In other instances the head may be turned to one or the other side, so-called false torticollis. Deformity at the upper extremity of the spine straightens the natural anterior curvature in the cervical region, and as a result there is compensatory flattening of the back; thus a short neck and a flat back are often the most prominent physical signs of disease of this region.

The distortion of the head symptomatic of Pott's disease is sometimes mistaken for torticollis. From chronic torticollis it may be easily distinguished, because in this distortion there is limitation of motion only in the direction opposed to the contraction and there are no accompanying symptoms. From so-called acute torticollis caused by enlarged or suppurating glands, or following irritation of the nose or pharynx, the diagnosis may be more difficult; but in this affection, if the head be inclined toward the contracted muscles, motion in other

FIG. 4434.—Atlo-axoid Disease, showing the Characteristic Attitude.

directions will be unrestricted, whereas in Pott's disease all movements are checked by muscular spasm. It may be stated also that the distortion of Pott's disease is often irregular, and there is no evident contraction of certain muscular groups, such as is usually present in simple torticollis.

Injury.—Injury of the upper segment of the spine may cause pain and stiffness and deformity, symptoms that could not be distinguished from those of Pott's disease but for the history of the case.

Weakness of the posterior muscles following diphtheria may cause a forward droop of the head. Spasm of the posterior muscles is sometimes seen incidental to meningitis and even as a less serious symptom in weakly children, but such deformities can hardly be mistaken for Pott's disease.

Abscess may cause symptoms of obstruction in the throat which might be mistaken for that due to adenoid growths or enlarged tonsils. It may be mentioned also that the seventh cervical vertebra often forms a noticeable projection at the base of the neck. In hysterical or hyperæsthetic individuals these symptoms are sometimes mistaken for those due to disease.

Forms of organic diseases of the spine other than tuberculous are described elsewhere.

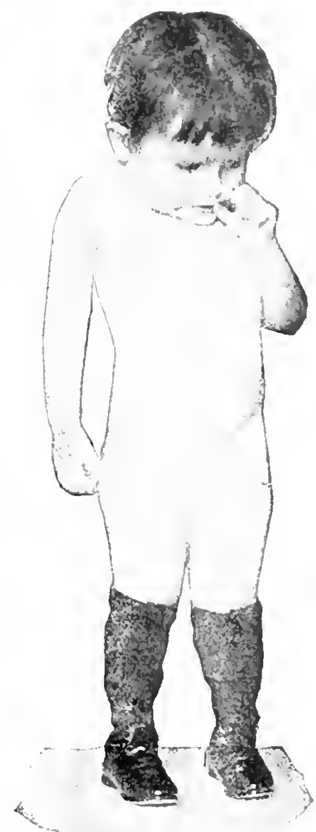

FIG. 4435.—Pott's Disease of the Upper Cervical Region, showing the Characteristic Deformity in an Untreated Case.

The diagnosis having been established, an accurate record of the case should be made. This should include the general condition of the patient, the character of the disease, whether acute or quiescent, and the presence or absence of complications. The position and character of the deformity should be recorded by means of a tracing of the entire length of the spine, such a tracing being made by means of a strip of lead or tin while the patient is lying extended in the prone position.

TREATMENT.—Pott's disease is the most important of the tuberculous affections of bone, and the importance of proper surroundings, nourishing food, open air, and sunlight can hardly be exaggerated.

Special orthopedic treatment is essentially mechanical; its object is to resist the natural tendency of the disease toward deformity.

Under normal conditions the weight of the head and of the thoracic and abdominal organs tends to bend the spine forward. If the support is weakened by the direct destruction of the weight bearing portion of the spine this tendency is greatly increased. It is evident, therefore, that the force of gravity is a very important factor in the production of deformity. Flexion of the spine compresses the vertebral bodies; extension of the spine relieves this pressure and transfers it in part to the articular processes.

The object of a brace or other support in the treatment of Pott's disease is to hold the spine in the extended position and to prevent motion at the seat of disease. The effectiveness of any splint depends upon the accuracy of its adjustment, and it is apparent that such adjustment is more difficult in certain regions of the spine than in others. For example, if the disease involves the lower thoracic region the splint is likely to be effective because its two extremities attached to the pelvis and to the shoulders are equally distant from the point to be supported; but if the upper thoracic region is affected, it is difficult to fix the spine because of the insufficient leverage of the supporting appliance. Even if the brace is accurately adjusted it cannot remove entirely the jar and strain incidental to the upright posture. It is evident, therefore, that complete rest can be assured only in the attitude of recumbency.

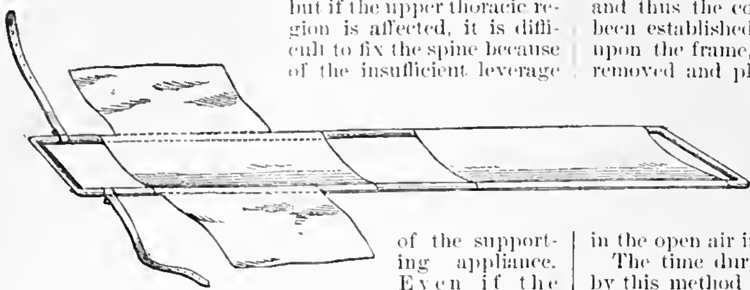

FIG. 4436.—The Bradford Frame.

Treatment by Horizontal Fixation.—A number of appliances to assure horizontal fixation are in use, but the most effective and convenient support is the Bradford frame or stretcher. This is a rectangular frame of ordinary gas pipe, a few inches longer and a little wider than the patient's body, covered with canvas or cotton cloth, except for an interval in the centre, as shown in the illustration (Fig. 4436.).

This appliance may be modified with advantage in the following particulars: it should be made slightly narrower than the patient's body, its width corresponding to the distance between the articulating surfaces of the shoulder-joints. The cover should be made of strong canvas in one piece so that it may be drawn tight by means of straps and corset lacings (Fig. 4437.). The centre should be covered by rubber cloth. Upon the canvas cover opposite the seat of disease should be sewed two pads of felt about six inches long, one inch wide, and half an inch thick. These should be parallel to one another and about one inch apart. They protect the spinous processes from pressure, and aid in fixing the spine. The patient, in most instances a young child, wearing simply a shirt and diapers, is then placed upon the frame, and is fixed to it by means of a front piece of canvas, as shown in the illustration. If the disease is of the upper region, the head should be fixed by an appliance similar to the ordinary jury-mast; if it is in the lower region the movement of the limbs should be restrained by means of a swath or by traction straps. When the frame has been adjusted the child's clothing is put on, having been made sufficiently large to include it and the frame. This illustrates the advantage of making the appliance as narrow as possible. When the patient has become accustomed to the restraint the frame is gradually bent backward until at the end of a few weeks the spine is forced, if possible, into an attitude of extreme overextension. (Fig. 4438.)

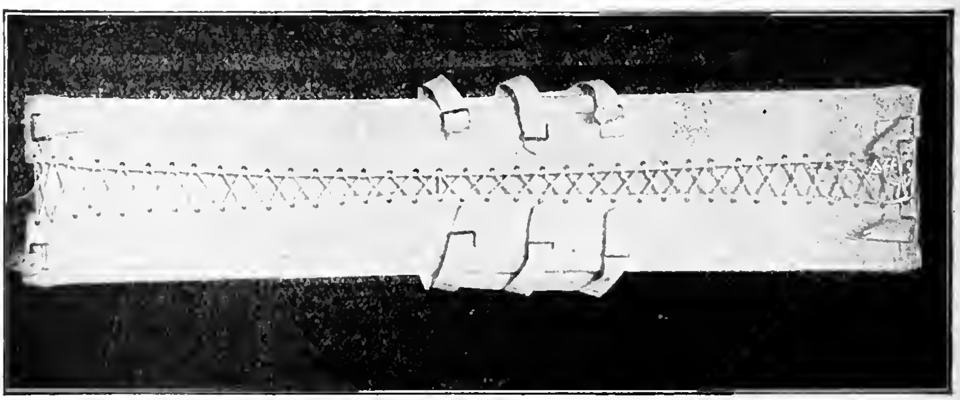

FIG. 4437. The Modified Stretcher or Bradford Frame, showing the Covering.

In favorable cases treated in this manner the deformity may be entirely obliterated, and as it is evident that the diseased vertebral bodies have been separated from one another, friction and pressure must have been removed and thus the conditions most favorable for repair have been established. The patient is kept constantly fixed upon the frame, except that once a day he is carefully removed and placed face downward on a pillow. The back is then rubbed with alcohol and powdered, the frame cover is cleansed, and the child is then replaced upon it. As has been stated, the child wears diapers, and a dust-pan serves as a convenient form of bedpan. As much of the time as possible is passed in the open air in the ordinary baby carriage.

The time during which the patient should be treated by this method varies with the severity of the disease. As a rule it is from six to eighteen months. The indications for its discontinuance are the subsidence of the symptoms and the behavior of the patient. A child suffering from active disease almost instantly recognizes the benefit of treatment and dislikes to be removed from the frame; but when repair is advanced he becomes impatient at the restraint, and when he begins to crawl about with the frame on his back and to attempt to stand, it is evident that the necessity for this mode of treatment is passed.

Although there is a strong prejudice against this form of treatment, I have never noticed ill effects from it, even when it has been long continued. The patient usually gains in weight and often grows rapidly, more rapidly in fact than those who are allowed to go about.

It is apparent that this form of recumbent treatment, although by far the most efficacious, is limited practically, as a routine practice at least, to early childhood, that is, to patients of four years or less, who can be carried about in arms. As a treatment for special cases, or to meet special indications, it has, however, no limit of age. For older patients the cover should be made in two parts, as in the original Bradford frame, to allow for the use of the bedpan.

Horizontal fixation must be supplemented of course by a support for the weakened spine when the erect posture is again assumed, and ambulatory treatment by such means is in the majority of cases the only one that is employed. These supports are either in the form of metallic braces applied along the spine or as circular supports, of which the plaster jacket is the common form. The object of every form of appliance is to remove as far as possible the weight from the weakened vertebral bodies by holding the trunk in the extended position, and to prevent motion at the seat of disease.

The Back Brace.—The most efficient spinal brace consists essentially of two steel bars that are applied on either side of the spinous processes from the top to the bottom of the spine (Fig. 4439.). The attachment at the lower end is made by means of a pelvic band of sheet steel (gauge 18) from one and a half to two inches in width, long enough to reach from one iliac spine to the other. It is placed as low as possible on the pelvis—in other words, just above the upper extremities of the trochanters. To this the uprights are firmly attached at an interval of from one and a quarter to one and three-quarter inches from one another, so that the spinous processes may pass between them while pressure is made on the lateral masses of the vertebræ. The uprights are made of varying strength according to the age of the patient, usually about one-half an inch in width (of gauges 8 to 12), and of such quality of steel that although unyielding to the strain of use it may be readily bent by wrenches and thus accurately adjusted to the back. The uprights reach to the root of the neck, or to about the level of the second dorsal vertebra. From this point two short arms of metal project forward and outward on either side of the neck, reaching to about the middle of the clavicles. To these are attached padded shoulder straps, which pass under the arms to a crossbar on the back brace; thus downward pressure on the shoulders is avoided and increased leverage is assured.

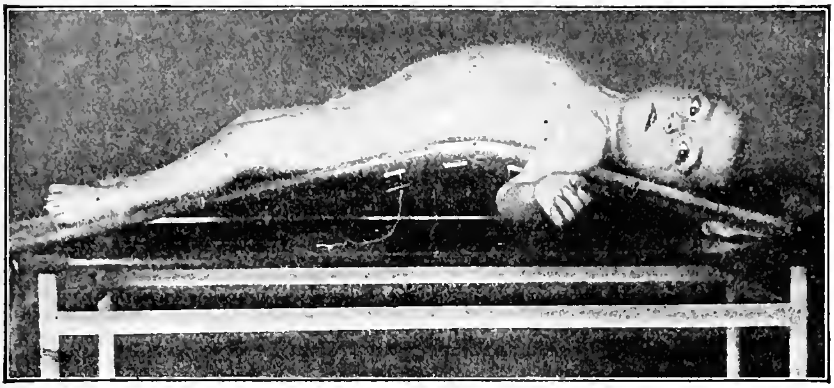

FIG. 4438.—The Stretcher Frame, showing the Attitude of Overextension.

FIG. 4439.—Whitman's Shoulder Brace; side view.

Opposite the point of disease two strips of this steel, about three-quarters of an inch in length, are fixed. These are slightly wider than the uprights, and are perforated for the attachment of the pressure pads, made of layers of Canton flannel or felt, or of unyielding material, such as leather or hard rubber if this is preferred.

The pads should project from a quarter to a half inch in front of the uprights in order that firm and constant pressure, to the extent that the skin will tolerate, may be made at the seat of disease.

In measuring for this brace the patient is placed in the prone posture and a tracing of the outline of the back, beside the spinous processes, is made by means of the lead tape. This outline may be cut in card-board and fitted to the back; in fact, if the mechanic is unfamiliar with the work, each part of the brace, uprights, pelvic band, etc., may be cut in card-board and attached to one another to serve as a model. Before the brace is finished it should be applied to the back, and should be carefully adjusted by means of wrenches. The pelvic band is then padded and the parts that come in direct contact with the skin are usually covered with leather, or, in the treatment of young children, with rubber plaster and Canton flannel, to prevent rusting.

If the brace is applied before the stage of deformity, it should follow the exact shape of the normal spine; but if deformity is already present, particularly in disease of the thoracic region, it should be made somewhat straighter than the compensatory curves above and below the projection, in order to permit a gradual straightening of the compensatory lordosis in the lumbar region, and for increased leverage above the deformity. As has been stated, a certain amount of recession of deformity can be obtained by rest in the horizontal position; and if practicable this improved contour should be attained before the brace is applied. The apparatus is held in place by an "apron," which covers the chest and abdomen, and to which straps are attached. Ordinarily this is made of strong linen or cotton cloth, but a canvas front, shaped accurately to the body and strengthened with whalebone as is a corset, is a much more comfortable and efficient support (Fig 4440.). In applying the brace with the patient in the recumbent posture the pelvic band is first attached to the apron, then the straps in order from below upward, and finally the shoulder straps. Each strap is then tightened until the brace is firmly fixed in proper position. When a brace is properly applied and properly fitted, it holds its place by friction; but in certain cases when the disease is low in the back, it is sometimes of advantage to apply perineal straps to hold the pelvic band firmly in its place.

FIG. 4440.—Whitman's Brace, with Chin-piece Applied.

At first the brace is removed once a day in order to wash and powder the back, the same care being observed in moving the child as in the treatment by the frame; but when the back has become accustomed to the pressure, the brace should be removed only at infrequent intervals, and thus, if need be, only under the supervision of the surgeon.

This description indicates the essential qualities of the back brace. It has been modified in various ways. For example, Dr. Taylor, its inventor, finally discarded the straight pelvic band in favor of one of a **U** shape, as shown in the illustration (Fig. 4441). This makes the brace somewhat lighter and relieves the sacrum from the pressure of the pelvic band, but it does not add to its effectiveness. The efficiency may be increased, however, by improving the attachment at its upper extremity. Taylor has accomplished this by placing two triangular pads against the chest. If, however, the disease is of the upper and middle segment of the thoracic region, more efficient support is of advantage; for in such cases the upper part of the chest is flattened, the inclination of the ribs is increased, and the shoulders incline forward, carrying with them the scapulæ. Thus the weight and the strain of the motion and use of the arms tend to increase the deformity.

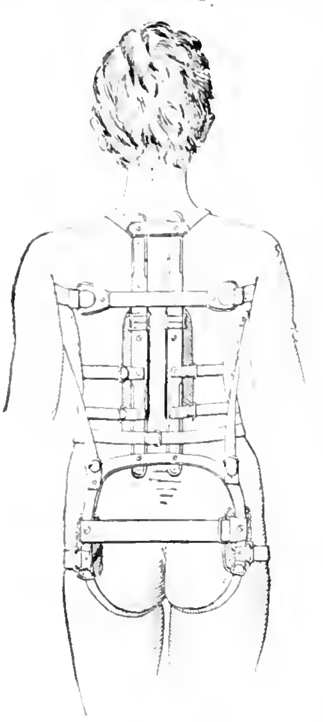

FIG. 4441. The Taylor Back Brace.

In health direct forward or reaching movements of the arms are always accompanied by an increase in the posterior curvature of the dorsal spine. On the other hand, if the shoulders are drawn backward and held in this attitude, the curvature of the spine is lessened and the chest is elevated and expanded.

In the treatment of disease of the upper dorsal region it should be the aim, in the application of a brace, to follow this indication and to apply pressure directly upon the extremity of the shoulders, to assure the greatest possible fixation of the spine, and to restrain the movements of the arms that tend to increase the deformity.

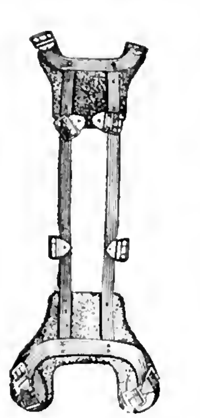

FIG. 4442. Modified Taylor Spinal Brace.

The accompanying diagrams show how such support should be applied (Figs. 4443 and 4444). Two saucer-shaped plates of hard rubber or padded metal cover the heads of the humeri, and are joined by a rigid bar of steel which passes across, but does not touch, the chest. On the back brace are placed two triangular pads of similar construction, which cover and press upon the scapulæ. These pads are, however, not essential, and are often omitted. The back brace is applied, the shoulders are then drawn backward, and the shoulder cups are firmly attached by straps to the neck bars of the brace above and below by axillary bands in the usual manner. By this means the thorax is elevated and the spine more effectively fixed, while direct movement of the arms forward is made impossible. It would seem that such restraint would be irksome to the patient, but in an extended use of the apparatus I have never heard this complained of. In many instances, even when the disease is as low as the tenth dorsal vertebra, this form of brace may be used with advantage, but it is especially indicated when the disease is in the neighborhood of the seventh dorsal vertebra. In connection with the shoulder brace it is usually advisable to apply a support beneath the chin to prevent the forward inclination of the neck and to tilt the head somewhat backward.

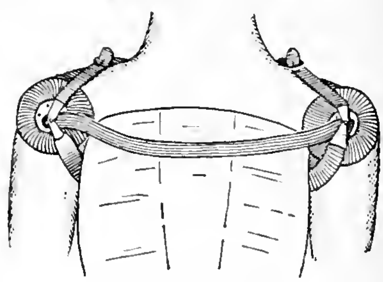

FIG. 4443.—Whitman's Brace; front view.

A very simple and inoffensive support of this character is a loop of steel surrounding the neck and attached by screws to a back bar on the brace (Fig. 4445). If a more efficient brace is required, as when the disease is of the upper dorsal or cervical regions, the Taylor head support should be used (Fig. 4446). This is an oval ring of steel, which may be clasped about the neck by means of a lateral hinge. On the front a cup of hard rubber supports the chin, and behind the ring fits upon an upright pivot, that may be raised or lowered upon a crossbar on the upper part of the brace. Free lateral motion is allowed, or it may be checked by means of a screw.

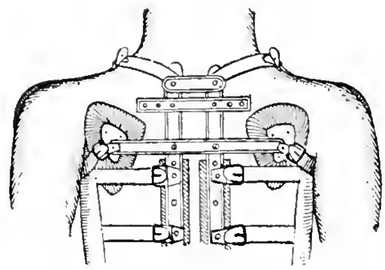

FIG. 4444.—Whitman's Brace; rear view.

If absolute fixation of the head is indicated, as in disease at or near the occipito-axoid region, two steel uprights are attached to the back of the ring, and are bent to fit the posterior and lateral aspect of the head closely. If necessary, a band of webbing is passed from one upright to the other and about the forehead.

In applying the support the chin should always be slightly tilted upward in order to throw the weight of the head backward.

The adjustment of the head support is made easier if the pivot is attached to the upright by means of a ball-and-socket joint (Shaffer) that may be regulated by a screw and key. This arrangement is of service when the head is distorted, but it is by no means necessary.

When the Taylor head support and similar appliances are used, the greater part of the pressure is sustained by the chin, which may after a time undergo an unsightly recession. It may be of advantage therefore in certain cases, particularly when restraint of the motion of the neck is desirable, to transfer this pressure to the forehead by means of a strap attached behind to light bars of metal shaped to the occiput and attached to the upper extremity of the brace (Figs. 4448 and 4449).

FIG. 4445.—Chin-piece to Whitman's Brace.

A jury-mast may be used to support the head also. Its adjustment will be described in connection with the plaster jacket, with which it is usually associated.

The Plaster Jacket.—It was at one time claimed that a plaster jacket applied while the body was partially suspended would actually relieve the weakened area of superincumbent weight by holding the diseased surfaces apart; but it is now generally conceded that the jacket supports the spine, as does the brace, by holding it in the erect or extended position. One is a circular and the other a posterior splint. There is this difference, however: the brace fits the spine accurately and holds its place by pressure and friction. The jacket is held in place by the support of the projecting pelvic bones. It lacks the accuracy of adjustment of the brace at the seat of disease; but, on the other hand, it provides a solid support on the front and sides of the body that may be even more effective.

FIG. 4446.—Whitman's Anterior Shoulder Brace Applied with the Taylor Brace and Head Support.

Each appliance has advantages and disadvantages that become apparent in the treatment of certain phases of the disease or conditions of the patient.

The plaster bandage is a simple support whose efficiency depends upon the accuracy of its adjustment to the irregularities of the body, and upon the leverage that it exerts above and below the point of disease. It should be applied while the body is held in the best possible position. Its inner surface should be smooth, and the bony prominences that are susceptible to friction and pressure should be protected. A seamless shirt should be worn. These are made in several sizes and are sold by the yard at a low price. The shirt should fit the body closely and should be long enough to reach to the knees. The patient is then placed upon a stool and the halter of the suspension apparatus is carefully adjusted. The arms are extended over the head and the hands clasp the straps or rings; thus the chest is expanded to its full limit. Sufficient tension is made upon the rope partially to suspend the body and to draw the spine into the best possible attitude. In most instances the heels should be slightly lifted from the stool.

FIG. 4447.—Whitman's Shoulder Support with the Taylor Brace.

Dr. Sayre, to whom we are indebted for the exposition of this valuable means of treatment, insists that the sensations of the patient should be the guide, and that traction should be made only to the point of comfort. This is a valuable indication in the treatment of the adult, but it is not often of service in childhood.

Before the plaster bandage is applied pieces of piano felting or Canton flannel of sufficient size should be placed about the anterior pelvic spines and over the upper part of the sternum. A thin strip of the same material may also be used to cover the spinous processes. Finally, long strips of saddler's felt, or other material of sufficient thickness, are applied on either side of the prominent spines to protect them from friction, and to provide greater pressure and fixation at the seat of disease. The "dinner pad" is now very rarely used, except in the treatment of adults and in certain cases of deformity in which the abdomen is retracted. In childhood the abdomen is usually prominent, and as the jacket expands somewhat no extra space is required. The pad, which is supposed to represent the space required after a full meal,

FIG. 4448.—An Appliance for fixing the Head, used with the Plaster Jacket.

is made by folding a napkin in the shape of a sandwich. To this a bandage is attached, and is placed beneath the shirt just below the ensiform cartilage. When the jacket is hard it is drawn out. Another long bandage is placed beneath the shirt, to remain permanently for the purpose of cleaning the skin beneath the jacket. The bandages should be freshly prepared of dental plaster, which should be rubbed into strips of crinoline from three to five inches in width and about six yards in length. From three to six of these are required according to the size of the child. As ordinarily applied by means of the swing the surgeon sits behind the patient, grasping the child's legs between his knees to prevent swaying of the body; and during the application of the bandages the layers of plaster should be constantly rubbed in order that the support should fit the body accurately. At the same time gentle pressure may be exerted with the aim of straightening or overextending the spine. It is well to make the first turn about the waist and use the first bandage about the pelvis, as this is the base of support. The bandages should also be applied with especial care across the upper portion of the chest, as this is the most important point for counter-pressure. When the jacket is nearly firm it should be trimmed, if practicable, while the patient is in the swing. As a rule, the front of the jacket

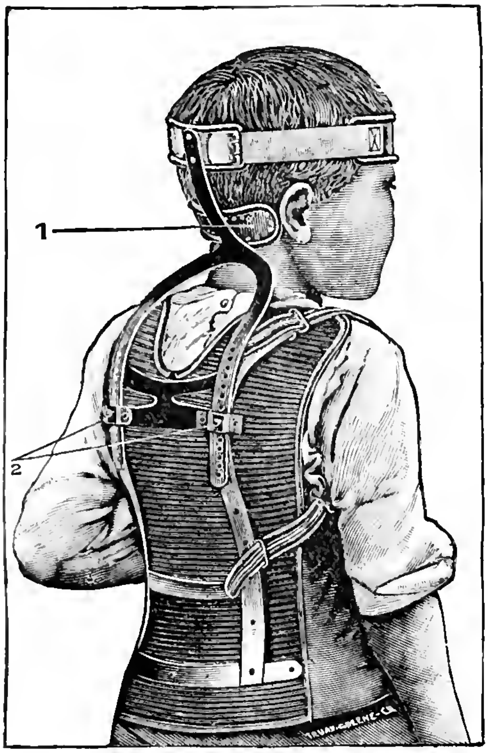

FIG. 4449.—Blanchard's Brace.

should extend from the top of the sternum to the pubes; behind, from the spines of the scapulæ to the gluteal fold. Laterally, it should be cut away sufficiently to prevent chafing of the arms, and below, too, in order to allow flexion of the thighs in the sitting posture. When properly applied, the jacket need not exceed a thickness of from one-eighth to one-quarter of an inch. The shirt is then drawn up over the jacket and sewed to the upper border, and the two ends of the bandage or skin rubber are tied together.

In the treatment of children by this means a protective bib should be worn to prevent crumbs from falling under the jacket, and at morning and night the skin should be vigorously rubbed by means of the bandage. In many instances the anterior shoulder brace, already described, may be used with advantage. This may be attached to buckles incorporated in the back of the jacket.

If the disease is of the upper or middle region of the spine a head support is required (Fig. 4452). For this purpose a jury-mast is most often employed. This should be of tempered steel, and its base should be incorporated firmly in the jacket below the seat of disease. When it is properly applied the head should be tilted and drawn somewhat backward with so much tension as can be tolerated.

In place of the jury-mast a fixed support may be used, as shown in (Fig. 4448). Fixed supports of this character have an advantage over the jury-mast in the matter of security, for although the latter appliance is effective when properly adjusted, it is of no value when the straps are allowed to hang loosely about the head, as is the case in so many instances.

The Application of the Jacket in the Recumbent Posture.—For young children who have been treated on the frame a very satisfactory method is the following: The patient is suspended face downward by two assistants, one holding the arms and the other the thighs. Thus a certain amount of traction is exerted while the trunk is in the overextended position. The jacket is applied, and before it has hardened the patient is replaced upon the frame, and the spine becomes fixed in the habitual attitude. The jacket may be applied in the supine posture by means of the appliance devised by Goldthwait. The body is supported at the seat of disease by means of an upright, on which are placed two pads like those used in the Taylor back brace. The two extremities of the spine are then allowed to sink downward with the aim of extending the spine at the point of disease. The jacket is then applied about the central support, and when it is firm the patient is lifted from it, the two adjustable pads remaining within the jacket (Fig. 4453).

As a rule a jacket may be worn for three months, although in hospital practice six months is not unusual.

In the stage of recovery the jacket may be replaced by a corset. This is constructed as follows: A jacket applied in the manner described is cut through the centre and removed from the body. It is then thoroughly dried and trimmed, and strips of leather with hooks having been sewed in front, it may be laced like an ordinary corset. The corset should always be removed and reapplied with the patient in the suspended or recumbent posture. It should not be used during the active stage of disease.

In contrasting the two ambulatory supports that are in common use, the jacket and the metallic brace, it may be stated that the jacket has the great advantage in that the treatment is in the hands of the surgeon. It is inferior to the brace when the disease is in the lower lumbar region. The brace is to be preferred also when the disease is in the upper region, as in such a case the jacket serves only as a base for the head appliance.

FIG. 4450.—A Plaster Jacket Applied to Support the Abdomen, showing also the Method of Fastening the Shirt about the Neck. (From Whitman's "Orthopedic Surgery.")

In certain instances when the disease is in this situation, the jacket is carried over the shoulders and is made to include the head. This is an effective treatment, but rather cumbersome.

If the disease is seated in the lower region of the spine, and if it is accompanied by contractions of the thighs, the limbs may be encased by means of the spica jacket. As a rule, however, cases of this character are best treated by recumbency.

In certain instances the Thomas collar may be used. This is of especial service in atlo-axoid disease, where it may be used with or without the jury-mast. The shape is shown in Figs. 4454, 4455, 4456 and 4457). It is made of a piece of thin sheet metal, wide enough to reach from the sternum to the chin and from the back of the neck to the base of the occiput. The edges are turned out and the whole properly covered with pieces of felt and fitted. One may improvise a support of this character by making a thick muff-like appliance of absorbent cotton, which may be stiffened by layers of adhesive plaster on the exterior. The original form of collar is shown in the illustration.

Prognosis and Treatment as Influenced by the Situation of the Disease. The Lower Region.—The prognosis as regards deformity is favorable. The part may be easily supported. The cases are often seen before the deformity is extreme; and, as a rule, one may predict recovery without noticeable distortion. In most cases the trunk is somewhat shortened and a peculiar erect attitude persists. The most troublesome complications of disease in this region are psoas contraction and the abscess with which it is often combined. Slight psoas contraction usually disappears after the application of effective support. If it persists it is well to provide the patient with crutches. If it is a symptom of progressive disease and is accompanied by pain, the patient should be placed in bed, where, if necessary, the deformity may be reduced by traction. In confirmed cases in which the distortion has become fixed by secondary contraction of the muscles and fascia, operative treatment is occasionally required to overcome the deformity. In this region of the spine the plaster jacket or the spinal brace may be used, the former means being perhaps preferable. The most troublesome complication is abscess, which is present in about fifty per cent. of the cases.

FIG. 4451.—The Plaster Jacket from Behind. (From Whitman's "Orthopedic Surgery.")

Disease of the Middle and Upper Dorsal Region. — Disease of this region of the spine is not often acute in its onset, and in most instances deformity is advanced before treatment is begun. It is the region most unfavorable for treatment from the standpoint of prevention of deformity, for the reasons that have been stated.

Whenever possible the patient should be treated by recumbency in the overextended position until the progress of the disease has been checked. Support must be employed for many years because there is a tendency toward increase of the deformity even after the cure of the disease. The Taylor brace assures better fixation than does the jacket. In most instances the anterior shoulder brace should be employed for better support, and to prevent the forward movement of the arms; and whenever the disease is above the eighth dorsal vertebra a head support should be applied. In this region of the spine paralysis is the most important complication. This occurs in about ten per cent. of the cases.

Disease of the Cervical Region.—In disease of the cervical region the prognosis is good, the most noticeable

FIG. 4452.—The Anterior Shoulder Brace Applied with the Plaster Jacket and Jury-Mast.

deformity being the shortened neck and the forward thrust of the head.

Disease of the occipito-axoid region is uncommon. The tendency is toward fixation of the head in the attitude of flexion. This may be prevented by the use of apparatus. The jury-mast when properly applied is a thoroughly efficient support, but fixation of the head by means of the Taylor support or posterior splint insures better control of the patient when he is not under observation.

The Complications of Pott's Disease. Abscess.—It may be assumed that a limited collection of tuberculous fluid accompanies practically every case of Pott's disease; but unless it can be demonstrated by palpation or unless it

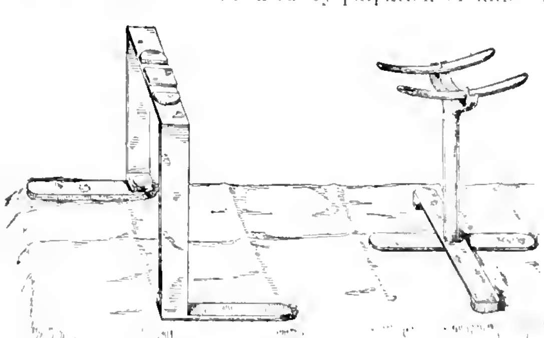

FIG. 4453.—The Goldthwait Frame as used with the Short Uprights in applying the Plaster Jacket.

appears upon the surface of the body it is not as a rule detected. Abscess as a complication in this sense is present in about twenty-five per cent. of the cases. It is far less common in the upper than in the lower region of the spine. This is accounted for in part by the fact that abscesses find their way downward, and in part because the large size of the vertebral bodies in the lumbar region offers better opportunity for their formation.

An abscess may appear without noticeable symptoms, but in many instances it is preceded by pain or discomfort, which indicates apparently tension at the seat of disease.

Abscesses are not as a rule accompanied by increase of bodily temperature, but when they are of large size and are approaching the surface, and especially when the skin covering them is reddened, there is usually a rise in temperature that implies apparently secondary infection of a mild type.

The Course of Abscesses in the Different Regions of the Spine.—Abscess accompanying disease of the occipito-

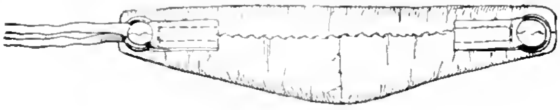

FIG. 4454. The Thomas Collar.

axoid region may force its way forward and appear in the throat as retropharyngeal abscess. More often it finds its way backward, distends the suboccipital triangle, and then passes forward to the region of the mastoid process. Abscesses from the middle cervical region pass outward and appear usually in the interval between the trapezius and the sterno-mastoid muscles.

In the thoracic region the abscess in the posterior mediastinum usually passes outward to perforate the intercostal muscles and appear on the posterior or lateral aspect of the chest. Or it may pass downward through the openings in the diaphragm and become an iliac abscess. Abscesses that originate in the lumbar region, or that have come from above, may follow various paths. Some perforate the sheath of the quadratus lumborum muscle and become a lumbar abscess, distending the skin between the twelfth rib and the crest of the ilium. Others pass downward on the surface of the iliac fascia and form a tumor at the outer extremity of Poupart's ligament or escape into the thigh. Psoas abscess burrows in the sheath of the psoas muscle and appears on the inner aspect of the thigh. Occasionally the fluid may escape from the greater sacro-sciatic foramen and appear as a gluteal abscess. In rare instances abscesses may take other courses. They may find their way into the spinal canal or break into the lung or into the intestines.

In most instances abscesses cause no direct symptoms, but occasionally from their size or situation they may

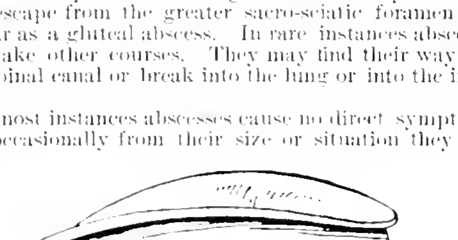

FIG. 4455. The Thomas Collar.

cause dangerous complications. The retropharyngeal abscess may interfere with breathing or swallowing. An abscess in the posterior mediastinum may press upon the trachea and cause attacks of inspiratory dyspnœa resembling asthma. Psoas contraction, which so often accompanies lumbar abscess, has been described already.

Treatment of Abscesses.—Abscesses that cause direct symptoms may require immediate treatment. The retropharyngeal abscess in case of emergency may be opened by direct incision in the throat. As a rule, however, a lateral opening in front of or behind the sterno-mastoid muscle is preferable. Obstruction due to mediastinal abscess is uncommon, and in such cases the abscess should be evacuated. An incision is made at the point of deformity over the articulation between the transverse process and rib. A portion of the latter is removed and

FIG. 4456.—The Thomas Collar Applied.

the abscess is exposed, lying as a rule directly in front of the spine. Care should be taken to follow the spine as closely as possible in order not to wound the pleura.

All infected abscesses should be opened and drained, but quiescent abscesses that cause no discomfort need not be disturbed, as a collection of tuberculous fluid is simply an incident of the original disease of the bone.

If an abscess is of large size, as, for example, when it distends the lumbar region or iliac fossa, the fluid may be evacuated by simple incision. The contents having been removed, the cavity is thoroughly flushed with hot salt solution in order to remove the shreds of necrotic tissue, and the wound may be then closed by layers of sutures. Drainage should be employed if the abscess is infected, or if the surroundings are such that subsequent infection may be avoided. It must be borne in mind that the danger of a tuberculous abscess is an indirect one, and this danger is from secondary infection, which does not often occur until a communication with the exterior has been established either by operation or by spontaneous evacuation. It is on this account that one hesitates to open abscesses when their source cannot be removed.

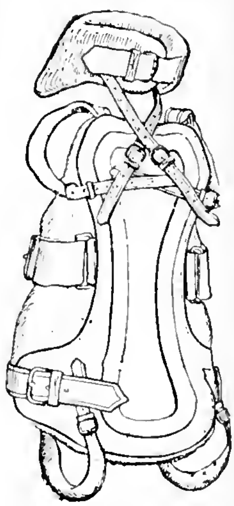

FIG. 4457. The Thomas Spinal Cuirass, with Collar.

Aspiration.—Aspiration serves a useful purpose in removing the thinner fluid and thus preventing the extension of the abscess. The injection of iodoform emulsion is sometimes employed after aspiration, although it is less in favor than in past time. The action of the iodoform is that of a local irritant, and it may be supposed to lessen the infectious quality of the tuberculous fluid. The ordinary form is a ten-per-cent. emulsion of iodoform in sterilized oil. A quantity varying from 4 to 30 gm., according to the size of the abscess, is injected at intervals of from two to four weeks.

In many instances abscesses disappear spontaneously by absorption, and after natural evacuation there is apparently no more danger from infection than after operative intervention, if cleanliness is assured.

It is apparent that the treatment of abscesses must be governed by the conditions in the individual case.

PARALYSIS.—The tuberculous process in the vertebral bodies may find its way backward into the epidural space, press upon the spinal cord, and thus cause paresis or paralysis of the parts below. In most instances the pressure is due to the inflammatory thickening of the coverings of the cord. Thus, in addition to direct pressure, there is often an interference with the blood supply and with the lymphatic circulation. As a result there are, after a time, an increase of the interstitial connective tissue and atrophy of the nervous elements, which may go on to partial or complete sclerosis. As a rule, however, but little permanent damage results, even from long-continued pressure and paralysis.

Occasionally paralysis is due to the pressure of an abscess; and when it is of sudden onset it may be caused by a breaking down of a vertebral body, which allows pressure of the thickened tissues upon the cord. In cases of this character the paralysis is at once relieved by straightening the spine.

The calibre of the spinal canal is not lessened by the characteristic angular deformity; in fact, paralysis more often accompanies slight than extreme distortion.

Paralysis not infrequently complicates disease in the upper and middle dorsal regions of the spine, occurring in about ten per cent. of the cases. It is an unusual complication of disease of other regions of the spine.

Symptoms.—The early symptoms, as noted by the patient or his friends, are weakness and an awkward shambling gait. The symptoms usually increase rapidly until paralysis of motion is complete. The extent of paralysis depends upon the situation of the pressure; thus the paralysis is most evident in the legs. There is an increase of the reflexes; and although when the patient is quiet the limbs appear limp, when he is moved, or when the reflexes are stimulated, the peculiar spastic rigidity appears. As a rule, the rigidity increases with the duration of the disease, and in cases of long-standing flexion contraction becomes permanent. This indicates irretrievable damage to the cord. Sensation is retained in the ordinary cases, but in those of the more severe type it may be impaired or lost.

When the paralysis is incomplete, control of the bladder is retained; but usually there is incontinence. As the bladder fills, the reflex centre is excited and it empties itself. The control of the sphincter ani is less noticeably impaired.

If the pressure on the cord is in the cervical region the arms are involved in the paralysis. If it is in the lower portion of the spine the symptoms are weakness and impaired sensation. The reflexes are not exaggerated.

Time of Onset.—Occasionally paralysis may precede deformity, but as a rule it is a late symptom, appearing more often from one to two years after the beginning of the disease.

Duration.—In exceptional cases in which the paralysis is caused by temporary pressure or disturbance of the circulation, it may be relieved at once by straightening and supporting the spinal column. If, however, the paralysis is complete, as it is in most instances, it persists usually for at least six months, and not infrequently for a year or longer, recovery being dependent upon the organization of the tuberculous granulations or disappearance of the abscess that causes pressure.

Prognosis.—In properly treated cases the prognosis is very favorable. In about seventy-five per cent. of the cases practically complete recovery occurs; absolute and permanent paralysis is unusual. Recurrence of the paralysis after an apparent cure is not uncommon, being dependent of course upon the persistence of the local disease.

Treatment.—The treatment of the paralysis is in great degree included in the treatment of the disease of which it is a symptom. If possible, rest on the stretcher frame in the position of overextension should be employed. If the disease is in the upper region of the spine traction upon the head is of value. In many instances the additional fixation secured by a plaster jacket should be used also.

If there is persistent contraction of the lower limbs restraint and traction should be applied. Counter irritation, such as the local application of the actual cautery, is thought by some to exert a favorable influence upon the disease. Iodide of potassium in large doses may aid in bringing about the absorption of the granulation tissue.

The first indication of improvement is a lessening of the muscular rigidity; then there is a gradual return of voluntary motion.

The exaggerated reflexes persist long after the disappearance of the paralysis.

Operative Treatment.—Operative treatment may be required in exceptional cases. If the presence of an abscess in the posterior mediastinum can be demonstrated it is well to evacuate it before opening the spinal canal, because the pressure may be due to the collection of fluid. If after persistent mechanical treatment there is no improvement in the paralysis, the operation of laminectomy may be undertaken. Eighteen months has been suggested as the limit of time which should have tested the efficacy of mechanical treatment.

The usual method of operating is as follows. A long incision is made parallel to and close by the side of the spinous processes. The muscles are drawn to one side, the spinous processes of several of the vertebræ at the seat of disease are cut through at their bases, and with the attached tissues are drawn to the opposite side. The laminæ are then removed with cutting forceps, exposing the dura mater. The thickened tuberculous tissue is usually found by the sides and in front of the cord. As much of this should be removed as is practicable. The wound is then closed and the spine is supported by a plaster jacket or other appliance.

Forcible Correction of the Deformity of Pott's Disease. Calot's Operation.—In 1896 the ancient operation of forcible straightening of the deformity of Pott's disease was revived by Calot of Berck-sur-Mer, and for several years the proceeding was in favor; but it has now been practically abandoned, at least as a measure of routine. Experience proved that in the milder cases the deformity might be overcome by rest upon the back, or even by the application of corrective jackets, while in the cases in which the destruction of bone was extensive, the recurrence of deformity after correction was practically inevitable. At the present time the operation is restricted to cases in which the deformity is of recent onset, and in which, it may be assumed, the disease is limited in extent. Forcible straightening of the spine separates the vertebral bodies at the seat of disease, and thus places the spine in a position favorable for repair; but, unfortunately, there appears to be but slight power in the spine to throw out new tissue to fill the interval that is made. If, then, forcible correction of the spine is employed, one should be prepared to fix the spine in the over-corrected position for at least a year. This necessitates, as a rule, rest in the horizontal position.

As the operation is ordinarily performed the patient, having been prepared as for the application of a plaster jacket, is anæsthetized, and is then suspended face downward, manual traction being exerted upon the arms and legs, and also upon the head. The deformity is then overcome by the application of gradual direct pressure upon the kyphosis. Thick pads are placed on either side of the spine. A large so-called "dinner pad" is inserted under the shirt and a strong jacket is applied. The patient is then placed in bed upon a pillow, or else upon the stretcher frame.

Great care should be taken to prevent pressure upon sensitive points, and as a rule, if much pressure has been applied, the plaster should be cut away to allow inspection at the seat of disease. As has been stated, cases in which the disease is of long standing should not be subjected to this operation, nor should cases complicated by abscess. On the other hand, paralysis is rather an indication for the operation than against it. In suitable cases the procedure is practically without danger.

Duration of the Treatment of Pott's Disease.—The duration of treatment must depend upon the extent and the severity of the disease. It may be divided into two stages, one in which the disease is active, when absolute fixation is indicated, and a stage of recovery in which supervision is required. Tuberculosis of the spine is slow in progress and recovery is insecure. The course of the disease is shortest in the cervical region, but even here brace treatment will be required for at least two years. In the lumbar region twice this time may be assigned to this period, and in the upper and middle dorsal regions, where the deformity may increase long after the cure of the disease, support may be required indefinitely.

Indications of Recovery.—As pain is almost always relieved by efficient treatment, its absence is no indication of cure. Muscular spasm usually persists as long as the disease is active; it is therefore a valuable indication in prognosis. The appearance of the kyphosis has some significance. In the early stage of disease the area of the destructive process is not defined; but when consolidation has taken place, its extent is shown by the rigid vertebræ that stand out from the remainder of the spine separated from it by a well marked depression, deeper below than above. In all cases removal of support must be gradual and its effect must be watched. When the disease is cured massage of the muscles, breathing exercises, and mild gymnastics may be employed with advantage. It may be noted that abscess or even paralysis may appear many years after the apparent cure of disease.

If recovery from Pott's disease has been complete, and if the deformity is slight, the individual may be to all intents normal; but if the deformity is great, his condition is abnormal, and he is unfitted for ordinary occupations. Such individuals usually suffer from neuralgic pain about the weakened spine, and in most instances some form of light support must be worn.

Royal Whitman.

SPIROMETER. See *Respiration.*

SPLEEN.—In the following description of the spleen the physiological is blended with the anatomical, for in the present state of our knowledge of the subject it is practically impossible to separate them. Throughout the article the description begins with the coarser structures and gradually passes to the finer ones, in order to point out more definitely that this organ is composed of a multitude of histological units. It will be apparent to the reader that our knowledge of the structure of the spleen is much more satisfactory than that of the function, but it is usually in this order that anatomy and physiology progress.

Framework of the Spleen.—If pieces of a fresh spleen are gently crushed between the palms of the hands in a stream of water, the pulp is soon washed out, leaving only the coarser network of fibres, or trabeculæ, the capsule, and the blood-vessels. When these are examined with the low power of the microscope, it is found that the trabeculæ are of uniform size and encircle spaces, each of which is about 1 mm. in diameter. This rough method of demonstration may be aided by macerating pieces of the spleen in water or in a solution of potassium hydrate, or by digesting them in a solution of pancreatin; but the specimens thus obtained are not much more instructive than those made by the simple water method. After repeated tests I finally invented a method by which the trabecular system of the spleen is demonstrated clearly and definitely.

The spleen is removed from the body with a portion of its mesentery, care being taken not to tear the capsule. It is kept completely covered with water at ordinary room temperature for a week or more, until the pulp is soft, the water being changed from time to time in order to prevent excessive putrefaction. When the pulp is soft the tip of the spleen is cut off and the pulp stripped out. The spleen is then filled with water and washed until the trabecular system and capsule is perfectly clear and clean. By repeated washings the framework of the spleen is finally clean, and it can now be strained, blown up, and dried. After the trabecular framework is purified in this way, it can be digested, stained, or treated with various reagents in order to determine the nature of the fibres of which it is formed.

The capsule and trabecular system being perfectly clean, it is to be stained with acid fuchsin and then thoroughly washed with alcohol. A tube is now tied into the cut end of the spleen and the specimen is kept distended with compressed air. After it is dry the mesenteric border and adjacent capsule are removed with a forceps and scissors, thus giving a most magnificent preparation. Fig. 4458 is from a section of dog's spleen prepared in this way.

Structure of the Capsule.—It is easy to show that the capsule of the spleen is composed of both white fibrous and yellow elastic tissues. A strip of the capsule boiled in dilute KOH will show the one, while digesting with pancreatin and further microscopic study will show the other. After the capsule of the spleen, the trabeculæ, and a piece of tendon have been digested in pancreatin for eighteen hours to remove all the elastic tissue, boiling them in HCl 0.5 per cent. or KOH 0.5 per cent. will dissolve the tendon in five minutes, the capsule in about twenty minutes, and the trabeculæ in about one hour. In each test a control section of the lymphatic gland shows that its reticulum is less resistant than are the fibrils of the capsule of the spleen. These tests, the value of which will be discussed later on, show that the capsule of the spleen contains, besides yellow elastic tissue, also white fibrous and reticulated. The white fibres can easily be recog-

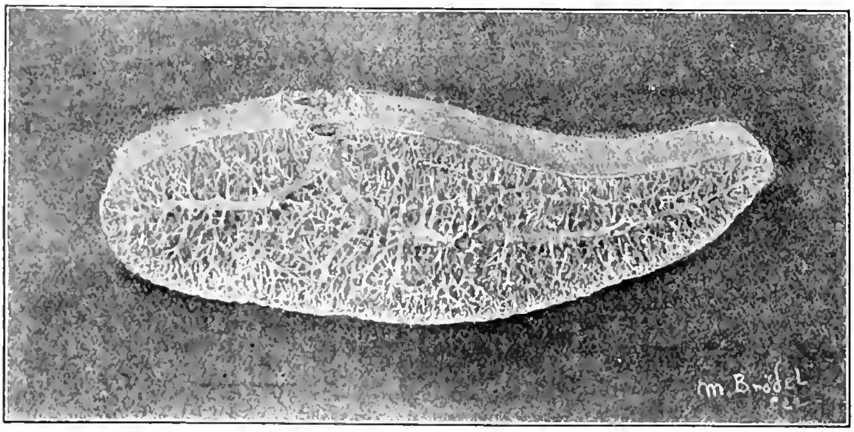

Fig. 4458.—Transverse Section of the Framework of the Spleen. Natural size. It shows the relation of the vein and the artery.

nized with the microscope by their wavy appearance and by their color, as well as by the great amount of gelatin which can be obtained from them when boiled. That it takes as much time to dissolve the capsule in boiling KOH or HCl as it does to dissolve a section of a lymphatic gland indicates that both are made up of the same tissues. That these two tissues are at least histologically unlike tendons is shown by their appearance under the microscope and by the fact that they will resist boiling acid and alkali at least four times as long as tendon does. From these observations I must conclude that the capsule of the spleen is composed of elastic, white fibrous, and reticulated tissues.

In the spleen of an ox macerated in water, digested in pancreatin, blown up and dried, the capsule is easily split into two layers—an outer which is composed in great part of white fibrous tissue, and an inner which appears to be of the same constitution as is the trabecular network. Between these two layers the lymphatics are located.

If a portion of the capsule of the spleen is first treated with hot dilute KOH, or is digested in pancreatin, and then stained and mounted in Canada balsam, it is found that the fibrils radiate toward centres from which the trabeculæ arise. Such a specimen is pictured in Fig. 4459. In case the preparation is treated with KOH the specimen thus obtained is composed of yellow elastic tissue, while if it is obtained through pancreatic digestion it is composed of white fibrous tissue and reticulum fibrils.

The three groups of fibrils forming the capsule of the spleen are all arranged after the same plan. When the white fibres and reticulum fibres are first removed by boiling the capsule in dilute KOH, leaving only the elastic tissue, a specimen is obtained which could easily be mistaken for the tissues destroyed, were it not for the chemical and color reactions, as well as the high refractive index of the elastic fibres.

Frozen sections of the spleen, which have first been macerated in water or in ten-per-cent. NaCl solution and then stained in hæmatoxylin, show the capsule and trabeculæ intensely stained, as all the non-striated muscle cells and elastic tissue are still present in them. This method is not suited to determine the character of the tissues constituting the capsule and trabeculæ, as the presence of all obscures the individual. When, however, the sections are first digested with pancreatin, it is found that the capsule is composed of delicate and wavy fibres, which in turn are arranged in heavier bundles; from these arise fine fibrils and anastomosing fibrils. That a number of white fibres are in the capsule is shown by the large quantity of gelatin easily obtained from it and by the bundles of wavy fibrils seen with the microscope. These bundles lie in great part immediately below the peritoneum, radiate toward the trabeculæ, and are continued into them. That the capsule also contains reticulated tissue is shown by the number of anastomosing fibrils present in teased specimens, as well as by the great resistance of the capsule shown when it is boiled in dilute KOH or HCl after all the cells and elastic tissue fibres have been removed by digestion with pancreatin. When boiled with dilute acid or alkali, as shown in Table I., the capsule proves to be much more resistant than is either a section of the lymphatic gland or a bundle of fibres from the tendo Achillis.

The conclusion to be drawn from these tests is that the boiling first removes the white fibres and leaves only the reticulated tissue, which finally falls into pieces. Although these tests are not absolutely definite, they at least make it highly probable that reticulated tissue exists in the capsule of the spleen. The fact that the fine anastomosing fibrils can be seen with the microscope in digested specimens is an additional argument in favor of this view. This question will not be completely solved until an extensive chemical study is made on these fibres obtained from different organs in addition to the invention of a satisfactory differential stain.

The group of the three kinds of connective-tissue fibrils then radiates toward centres, as shown in Fig. 4459. From these centres the trabeculæ arise and penetrate the spleen at right angles to the capsule. In general from four to six trabeculæ surround small masses of spleen

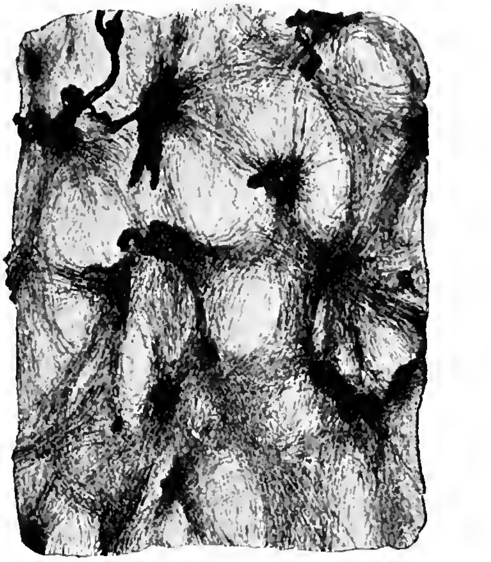

FIG. 4459.—Capsule of the Dog's Spleen Stripped Off Fresh and Digested in Pancreatin. Thoroughly washed in water and spread on a glass slide and allowed to dry. Stained with acid fuchsin and partly decolorized with picric acid. Enlarged 30 diameters. The trabeculæ are torn off at their capsular origin.

tissue, about 1 mm. in diameter. These masses I have termed the typical lobules or anatomical unit of the spleen.[1] They are well seen on the surface of fresh contracted spleens as slight elevations about as large as pins' heads. The great number of muscle cells within the trabeculæ makes the lobules immediately below the capsule protrude when they contract.

TABLE I.—FRESH TENDO ACHILLIS, SECTIONS FROM LYMPHATIC GLAND, CAPSULE OF SPLEEN AND TRABECULÆ FROM THE DOG DIGESTED IN STRONG PANCREATIN FOR EIGHTEEN HOURS. THEN THOROUGHLY WASHED AND BOILED IN KOH ONE-HALF PER CENT. AND IN HCL ONE-HALF PER CENT.

Treated with One-Half Per Cent. KOH Solution.

Time boiled. Minutes.	Tendon.	Lymphatic gland.	Spleen capsule.	Trabeculæ.
1	×	×	×	×
4	+	×	×	×
30	+	+	×	×
75	+	+	+	×
90	+	+	+	+

Treated with One-Half Per Cent. HCl Solution.

Time boiled. Minutes.	Tendon.	Lymphatic gland.	Spleen capsule.	Trabeculæ.
1	×	×	×	×
7	+	×	×	×
15	+	+	×	×
30	+	+	+	×
90	+	+	+	+

× = swollen; + = dissolved.

STRUCTURE AND ARRANGEMENT OF THE TRABECULÆ.—The trabeculæ in the capsule are composed of elastic, white fibrous and reticulated tissues, as well as great quantities of non-striated muscle cells.

The elastic fibres may be demonstrated by boiling the isolated trabeculæ with dilute KOH, but this is not a satisfactory method, for the elastic fibres separate and are easily lost. Henle's method[2] of treatment with cold dilute KOH and afterward washing with water is only fairly satisfactory, for it does not destroy completely the reticulum and fibrous tissue. To be sure, the elastic tissue prepared by Henle's method is easily recognized under the microscope by its high refractive index. Furthermore, the great destruction of the elements in isolating the elastic fibres by Henle's method makes it difficult to locate the part of the spleen from which the fibres have been obtained.

As regards the distribution of elastic tissue in the spleen, a decided step in advance has been made recently by Hoehl[3] in using Spalteholz's method of staining elastic tissue. By this method it is shown that there are numerous elastic fibres not only in the trabeculæ, but that they extend somewhat into the spleen tissue between the pulp cells. Sections in which the elastic fibres have been stained black by Spalteholz's method and the reticulum red with picrocarmine show that the finest elastic fibres never communicate with the reticulum.

After the cells and elastic fibres are removed from the trabeculæ, the reticulum and white fibrous tissues alone remain. To separate these two definitely again becomes the stumbling-block in connective-tissue study. That reticulum is present is shown by the fact that the fibres anastomose and by the great resistance of this tissue toward boiling KOH and HCl, as shown in the above tables. It takes more than twenty-two times as long to dissolve the trabeculæ than the tendo Achillis in one-half-per-cent. KOH, and six times as long in one-half-per-cent. HCl. To prove the presence of fibrous tissue is by no means as easy, for whatever reagent is used to dissolve the reticulum dissolves also the white fibrous tissue. Teased trabeculæ occasionally show bundles of wavy fibres which have all of the appearance of white fibrous

FIG. 4460.—Section of the Spleen Treated as that from which Fig. 4458 was Drawn. The vein had been injected with Prussian blue. Enlarged 8 diameters.

tissue. In case it is finally proved that reticulated tissue does not yield gelatin when boiled, the presence of gelatin will indicate the presence of white fibrous tissue.

Hoehl[4] has shown that the non-striated muscle fibres are embedded in a mass of most delicate connective-tissue fibrils, which, if I may judge from specimens he has sent me, appear to be reticulum fibrils. I have investigated non-striated muscle from the stomach, intestine, and uterus, and can fully confirm Hoehl's observation. It appears to me that the reticulum of the trabeculæ of the spleen may be considered as a sheath to the muscle, as is the case of non-striated muscles in other parts of the body. It is a very resistant reticulum, more so than that of the lymph follicle, and much more so than that of the pulp of the spleen.

All of the connective tissues and muscles which constitute the trabeculæ form the main skeleton of the spleen. From a number of estimations I find that there are from fifteen thousand to twenty-five thousand trabeculæ, each from 0.05 to 0.1 mm. in diameter, arising from the capsule of the dog's spleen to pass at right angles into the pulp. These many beautiful muscle strands outlining about twenty-five thousand subcapsular lobules pass into the depth of the spleen, anastomose and subdivide, and finally attach themselves to the walls of the veins as well as to the trabeculæ arising from the opposite side of the spleen.

The trabecular system of the spleen appears to be irregular in arrangement, but when examined closely it is shown that it surrounds distinct areas, about 1 mm. in diameter. Not only are these areas shown in the picture when the capsule has been removed, but they also appear as rounded elevations immediately below the capsule. This mottled appearance on the surface of the spleen is seen still better in the fresh spleen, as the contraction of the muscles causes the pulp between the trabeculæ to protrude under the capsule. When the artery of the fresh spleen is injected with an aqueous solution of Prussian blue, it will be noticed that the centres of these elevations are first injected, making the spleen mottled. The blue centres of these elevations gradually extend as the injection is continued, and finally flow together, when it is found that the fluid has entered the veins.

By comparing the specimens thus obtained, it is seen that we are dealing with an orderly arrangement of the spleen tissue which can easily be recognized with the naked eye. It is practically identical with the arrangement of that of the liver, and I shall speak of these anatomical units as the lobules of the spleen. *The anatomical unit of the spleen is a mass of pulp about one millimetre in diameter, with the main veins and muscle on its periphery and the artery in its centre.*

In turn the lobule is broken up into histological units, which I shall consider when discussing the termination of the arteries. If the pulp of the spleen is removed by washing it out and the trabecular system distended and dried, the lobules are seen outlined beautifully when the specimen is viewed as a transparent object. They appear five- or six-cornered, with darker points at about three of the corners, as is the case in the liver. These darker corners represent the position of the more important veins which encircle the lobule. But in addition to the trabeculæ which encircle the lobule, as shown in Fig. 4460, there are many other trabeculæ around the lobule, and a number of them penetrate it, although the greater number of the trabeculæ are on the periphery. The illustrations of the corroded spleen, as shown in Fig. 4458, do not show the lobules as well as Fig. 4460 does, for the former was drawn from a specimen in which the veins were not injected, while the latter is from a specimen in which they were injected. In case the veins are not injected but are only distended by the general distention of the whole organ, the tips of the veins blend with the trabeculæ and thus partly obliterate the sharpness of the lobule. In case the veins are partly injected, as in Fig. 4460, the lobule is outlined by the veins, while the trabeculæ which penetrate the lobule are also shown. Stained sections of injected spleens also bring out this point. Fig. 4460 shows beautifully the deep lobules as well as the ones immediately below the capsules. While there are from fifteen thousand to twenty-five thousand subcapsular lobules in the dog's spleen, there are from fifty thousand to one hundred thousand deep lobules, making the sum total of lobules between sixty-five thousand and one hundred and twenty-five thousand, or an average of eighty thousand. Lobules in any portion of the spleen can be seen very well in corroded specimens, either injected or uninjected, but they are somewhat obscure in an ordinary section, because the lobules are perforated by a number of trabeculæ. Yet if only the coarser arteries and veins are injected, the peripheries of lobules are outlined by the veins, while the main arterioles mark the centres of them.

We can therefore classify the trabeculæ as well as the veins as interlobular and intralobular; the interlobular veins and trabeculæ are closely related, while the intralobular veins and trabeculæ are not related.

With the naked eye the different kinds of trabeculæ cannot be observed (Fig. 4458) unless the veins are exceedingly well shown, but with a slight magnification the various kinds of trabeculæ are easily seen. Fig. 4460 shows this beautifully. The interlobular trabeculæ are here seen to surround in part the terminal or interlobular veins, a portion of them lie between the veins, while another portion of them perforate the lobule. Those which lie between the lobules together with the veins make the greater part of the network of the spleen, as shown in Fig. 4458. In Fig. 4460 the lobule is outlined by interlobular trabeculæ and veins, while the interior of the lobule is cut up into compartments by the intralobular trabeculæ. These intralobular trabeculæ communicate with one another to form a group of meshes within the lobule, each 0.2 to 0.3 mm. in diameter. So the lobule, which is about 1 c.mm. in volume, is subdivided into about ten parts by the intralobular trabeculæ. Within each of these subdivisions there is a fine venous plexus which extends in all planes throughout the lobule. Each of the meshes formed by the venous plexus is 0.05 mm. in diameter, and there are about six thousand of them within each lobule, or about five hundred million for the whole spleen. In a number of specimens the estimation of the histological units obtained by dividing the volume of the spleen by the cube of the diameter of the histological unit gave in each instance about five hundred million. The meshes formed by the venous plexus of the lobule are occupied by the spleen pulp, within the centre of which the terminal arteries end. This small mass of spleen tissue encircled by a vein with the terminal arteriole in its centre forms the histological unit of the spleen.

Reticulum of the Spleen.—I have shown above that the trabeculæ are composed in great part of a very resistant reticulum placed between the muscle cells. That this should be the case is not very remarkable, since Hoehl has shown that the non-striated muscle fibres in other parts of the body are enveloped in a most delicate and extensive network of reticulum fibrils. I have tested Hoehl's work and can confirm it in every respect as regards the sheath of non-striated muscle fibres. This envelopment certainly has the greatest meaning in aiding those cells to perform their function. Were they simply stuck together by a cement substance, it is very difficult to conceive how they could act so very delicately and also with so much power without pulling apart. But as it is, each cell lies within a basket of delicate reticulum fibrils, which acts as ligaments passing in all directions.

The reticulum fibrils in the trabeculæ must be viewed as the sheath of their muscle cells. It aids to tie them together. Since the trabeculæ are in strands the fibrils are also in strands, in order to give them their best support. The reticulum fibrils of the trabeculæ are more resistant when boiled in dilute HCl or dilute KOH than

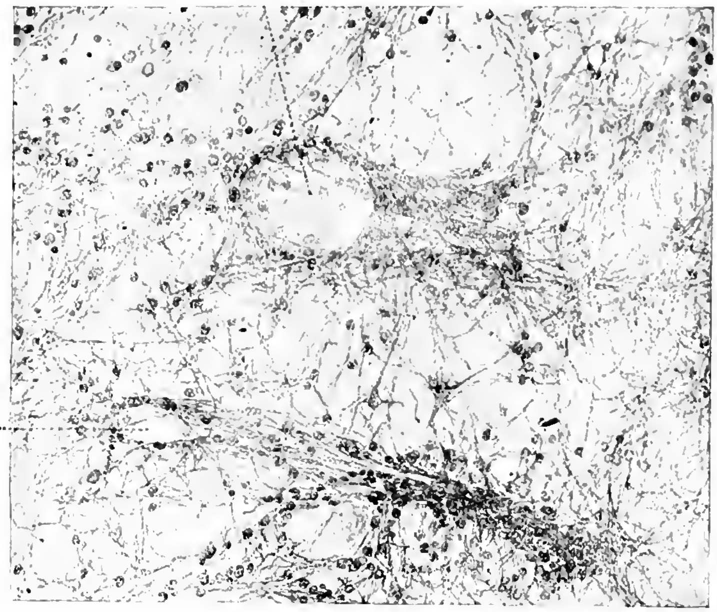

Fig. 4461.—Frozen Section of a Spleen made Œdematous by Injecting it with Colorless Gelatin. The section was then washed in warm water, which removed the gelatin and most of the cells, leaving the reticulum. Stained with gentian violet and mounted in glycerin. Enlarged 250 diameters.

are those of the capsule of the spleen or those of the lymph gland, as Tables I. and II. show. It is therefore a very tough reticulum.

In addition to this resistant reticulum of the trabeculæ, the lobule itself is filled with a very delicate reticulum, which is very easily destroyed and therefore hard to demonstrate by ordinary methods. I have noted in my earlier communication on reticulum that by the ordinary methods it was impossible to demonstrate the presence of reticulum between the trabeculæ within the spleen. At the same time Oppel[5] showed by using Golgi's method that the Malpighian corpuscle of the spleen and the tissue surrounding it was literally filled with a network of fibrils, which he termed *Gitterfasern*. Their appearance and arrangement at once showed that they must be reticular fibrils, but I was never able to isolate them by means of pancreatic digestion. In addition to Oppel's observation, we are all familiar with the reticulum of the spleen as seen in fresh as well as in hardened specimens. Hoehl has also shown us that when small pieces of spleen are washed for days in flowing water the cells are all washed out, leaving a beautiful network of fibrils, which he describes as reticulum. A frozen section of the spleen can also be washed out in flowing water, but the method is not satisfactory, as the section becomes matted together or is very liable to fall into pieces. When, however, a spleen is made œdematous by injecting it with gelatin, it can easily be cut by the freezing method, and the sections thus obtained are well suited for further study. The gelatin separates the tissue and holds everything in place. Such sections can be fixed with formalin and stained, or can be shaken out by simply placing them in warm water to dissolve the gelatin. They can be used for further tests with acid and alkali, or they can be digested with pancreatin.

When a frozen section of spleen made œdematous with gelatin is passed through formalin, it becomes well fixed and the gelatin can no longer be dissolved by heating or by digesting. Such a section stained with hæmatoxylin carmine, or a dilute aniline, gives most instructive pictures. The fibrils of reticulum are widely separated, upon them lie the fixed cells, and between them pass the blood-vessels. Within the gelatin itself are numerous free cells, and red blood corpuscles, proving conclusively that they are not within the blood-vessels. If, instead of hardening the section in formalin, it is placed in warm water to dissolve the gelatin, it is seen that the section becomes smaller in area, showing that the reticulum is elastic, but in so doing the gelatin carries out all of the free cells, leaving almost a pure reticulum. Such a section can be coaxed upon a glass slide, stained under the cover glass with acid fuchsin or with gentian violet, differentiated with picric acid, and preserved in glycerin (Fig. 4461). Such specimens are easily made, and they show perfectly the reticulum as demonstrated by Oppel and by Hoehl.

Further tests with pancreatin show that the reticulum of the spleen lobule is easily digested in it. The same is true if sections or blocks either of fresh or of hardened spleen are digested in pancreatin. In all cases the reticulum of the lobule is dissolved, but that of the trabeculæ remains. In pancreatin, then, this reticulum, as elastic tissue, dissolves. When, however, sections of reticulum are treated with dilute KOH, dilute HCl, or acetic acid, it at once swells, becomes transparent, while the elastic fibres show their usual reactions. With these reagents the reticulum shows its usual reactions. The reticulum of the spleen lobule is about as delicate as fibrin and at times I have thought that it is fibrin, but its distinct anatomical relation to other structures within the lobule proves that it must be constantly present.

The difference between the reticulum of the lobule and that of the trabeculæ is certainly most marked; that of the lobule is the least resistant reticulum known, while that of the trabeculæ is the most resistant. It only shows that there are a variety of reticula, and here we encounter side by side the two extremes. An analogous condition is found in fibrin. Newly formed fibrin is very easily digested, while fibrin from old fibrinous deposits is most resistant, not being digested in pepsin or pancreatin nor dissolved in strong acids. It is also not possible that the two reticula found in the spleen could be two varieties of the same thing, as it is impossible to conceive of the reticulum of the lobule shifting to become the reticulum of the trabeculæ.[6]

The main reactions of the connective-tissue fibrils are expressed in the following table:

TABLE II.

	Yellow elastic.	White fibrous.	Reticulum ordinary.	Reticulum from lobule of the spleen.
Boiling dilute HCl or KOH	0	+	+	+
Pepsin digestion	+	+	+	+
Pancreatic digestion	+	0	0	+
Maceration	+ (?)	0	0	+
Gelatin	0	+	+(?)	(?)
Reticulin	0	0	+	(?)

0 = not changed or no.
+ = dissolved or yes.

THE ARTERIES OF THE SPLEEN.—The arterial system of the spleen is arranged, as in all other organs, in such a manner that equal parts of it will receive equal quantities of blood during a given period of time. So definite is this adjustment that in studying organs we must always look for terminal branches which supply the final units of tissue, as is the case in the villus of the intestine. These tissue units are piled upon one another in the solid organs much like the grapes in a bunch, but in turn they may be clustered around centres as are the bunches of grapes upon a vine, which again may be repeated many times like the vines in a vineyard. This is the arrangement in the spleen, and when it is studied embryologically as well as physiologically it is found that it could not well be otherwise.

Without discussing the question extensively I allude to the many researches of Ludwig and his pupils as well as to the brilliant studies of Thoma bearing upon this question. Ludwig has shown us that in the circulation through an organ no part of the organ is favored more than another, while Thoma has demonstrated the conditions which regulate the size of the arteries not only in the embryo but also in the adult. Ignoring the causes which produce the first growth of the capillaries, Thoma's work establishes the fact that in a given vessel there is a relation between its lumen and the circulation through it. Any factor which makes the blood flow more rapidly will cause the vessel to enlarge, while anything which diminishes the circulation will make the vessel become smaller. This law is constantly at work not only in increasing the number and size of the blood-vessels in the growth of an organ, but also in diminishing and reducing them. It follows that in a finished organ the arteries are beautifully distributed according to system throughout it and that the forces which produced this relation are ever ready to correct little difficulties which are constantly arising.

The main trunk of the splenic artery gives off a number of branches, which, according to their size, are distributed to proportionately large parts of the spleen. In general, throughout the spleen the arteries are separated as far as possible from their corresponding veins, but at their points of entrance a number of the arteries are located close to the veins. This must be due to a secondary shifting of the large vessels in their development, as is also the case in the lung and the liver.

After the arteries enter the spleen their main trunks remain on the proximal side of the veins, as Fig. 4458 shows. In general, they lie midway between the larger veins and the capsule. These primary branches in turn give rise to branches of the second order, which pass directly toward the capsule, there passing to the proximal side of the spleen, crossing the large veins, but keeping away from them as far as possible, and give rise to all of the lobular arteries of the spleen.

The spleen of an animal killed by bleeding is found to be contracted and relatively pale after having been exposed to the air for a very short time. Its surface is rough, due to a protrusion of the lobules immediately below the capsule. If the artery of a spleen which shows these characteristics is injected with aqueous Prussian blue, it will be found that the centres of the lobules below the capsule first turn blue, thus showing conclusively the relation of the artery in the lobule. From these many blue points in the centres of the lobule the blue spreads as the injection is continued until their peripheries are reached. At this time the blue lobules coalesce and the Prussian blue appears in the veins. As soon as the blue has once entered the veins, secondary injections take place through the veins in distant portions of the spleen, giving pictures the reverse of the ones just described.

The lymphatic tissue encircles the arteries, increases at points into marked follicles, and accompanies them until they reach the histological units, where they form the splenic ellipsoids. The thickness of this lymphatic sheath varies very much in different spleens, and often in different portions of the same spleen. Whether these variations are transient or permanent in a given spleen is difficult to determine, but it is certain that in all cases the lymphatic follicles, cords, and ellipsoids lie around the artery and in the centres of the lobules and pulp cords. The relation of the artery and the vein to the lymphatic tissue in the spleen is identical with that of the lymphatic gland, as recently shown by Calvert.[7] The spleen structure differs, however, from the lymphatic gland in that its lobule contains no lymphatic channels like the follicle, but in their stead there is a marked and peculiar plexus of veins, which surround the lymphatic tissue of the arteries to complete the spleen lobule. In other words, the spleen can be viewed as a modified lymphatic gland without lymphatic channels.

It is appropriate at this place to speak of the lymphatic channels of the spleen, because in their true sense—*i.e.*,

FIG. 4462.—Section of a Spleen in which the Veins had been Injected with Aqueous Prussian Blue. Canada balsam preparation. Enlarged 30 diameters.

in their relation to the Malpighian follicles—they do not exist. Although nearly every text-book on histology states that the lymphatic channels exist in the spleen, I must assert that the books are wrong. Nor can I find any proof of their existence in reliable literature, nor by hundreds of injections of many kinds made by me. To be sure, the capsule of the spleen of the ox, pig, and horse contain large lymphatic channels which enter the spleen along the trabeculæ, but I could not trace them back to the lobule. In the dog a few lymphatic channels are occasionally seen at the hilum of the organ, but these do not penetrate the spleen, much less do they meet the Malpighian follicle. Moreover, most careful analysis of the lobule of the dog's spleen never shows their presence, unless we consider the intestinal spaces lymphatic radicals which never collect into efferent vessels but enter the veins at once.[5]

THE VEINS.—The spleens of most dogs have eight large veins emerging at the hilum, although frequently there is a tendency for two or three of them to unite within the substance of the large end of the spleen before they pass out of the organ. These eight main trunks pass deep into the splenic tissue and ramify on the distal side of the artery in all directions, as the section pictured in Fig. 4458 shows.

The first group of branches, those of the first order, are all distributed in the flat plane of the spleen. The veins of the second order arise at right angles from this first group and pass directly toward the capsule. The terminal branches of the second group become the interlobular veins (Fig. 4460).

As the large veins enter the spleen its capsule accompanies them and in a measure helps to form their walls. The walls gradually thicken and from them arise numerous trabeculæ which are directly continuous with the general trabecular network of the spleen. As the vein divides and subdivides, the trabeculæ attaching themselves to them increase in number, so that by the time the interlobular veins are reached the small size of the veins makes it appear as if they ran within the trabeculæ.

Thus the veins show a definite relation to the trabeculæ throughout the spleen until the lobule is reached. The intralobular veins not having a muscular wall must communicate with the interlobular veins through numerous openings in their thick sheaths, as is shown by the opening pictured in Fig. 4462. The larger veins, *i.e.*, veins of the second order, also receive collecting veins directly from the intralobular plexus. All the systems of the veins are shown in Fig. 4463. In this figure the veins of the first order are cut transversely; those of the second order give rise to the interlobular veins; the intralobular venous plexus is shown opposite, at *L*, while the intralobular collecting veins are shown at *L'*. The relation of the trabeculæ to the veins is such that when the veins and trabeculæ are stretched the larger veins are distended, as a number of the figures show.

This arrangement must be of the utmost physiological importance, for increasing the tension of the pulp of the

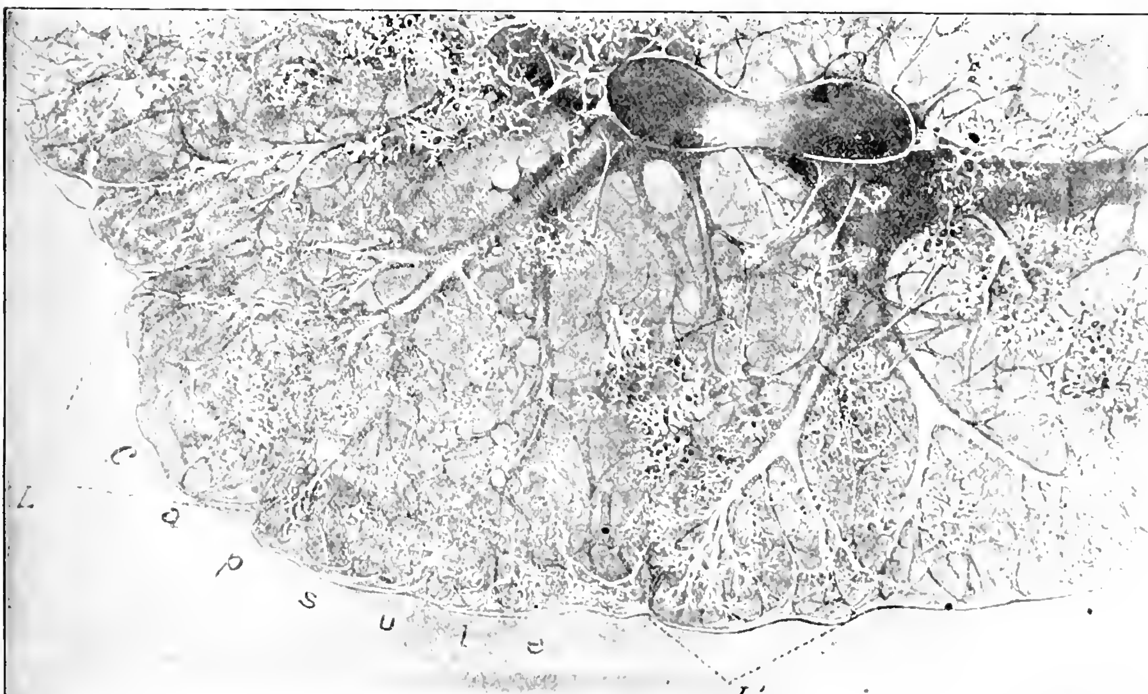

FIG. 4463. Section of a Spleen in which the Vein had been Injected with Celloidin Colored with Prussian Blue. The whole spleen was macerated for weeks in water, then digested in pancreatin, washed, stained, distended, and dried. The dried spleen was next sectioned and mounted in Canada balsam. Enlarged 16 diameters.

spleen, either through an increased quantity of fluid within the pulp or through a contraction of the trabeculæ and capsule, will favor the flow of blood toward the vein and into it.

Preparations of the spleen made by maceration, cleansing, distention, and drying show the general arrangement of the trabeculæ to the veins. With the naked eye the veins can be followed to the interlobular spaces. Low powers show this relation of the veins to the lobule bet-

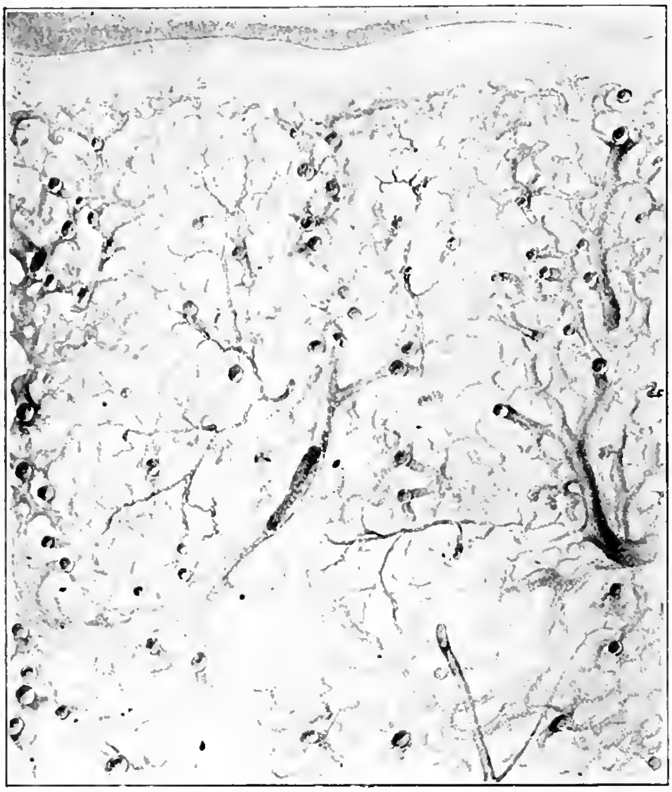

FIG. 4464.—Double Injection of the Spleen with Prussian Blue into the Vein and Carmine Gelatin into the Artery. At many points the injection of the artery is more complete than is shown in the figure, the entire field being tinged red. Enlarged 10 diameters.

ter (Fig. 4460), yet it is impossible by this method to follow with certainty the smaller veins between the lobules to the capsule. At the main junctions of the trabeculæ with the veins the tissues are more or less matted together, and an attempt to separate them without special methods always leads to some confusion. Ordinary injections of the spleen do not give better specimens, and for a long time I had to rely on sections of hardened spleen which had been injected by the ordinary method. Such specimens do not lead to good results, as the great quantity of colored veins in a thick specimen obscures the larger vessels, for at no time do any number of them lie in the same place. Finally, however, I obtained most definite specimens by macerating spleens after the veins had been injected with either colored celloidin or agar-agar. Both of these substances will not dissolve when the tissue is macerated or when it is digested in pancreatin. The agar can easily be forced throughout the whole venous system, and, if too much pressure is applied, into the tissues, while the celloidin flows with difficulty and under no condition will fill completely the venous plexus of the lobule.

Fig. 4463 is from a specimen injected with celloidin colored with Prussian blue digested with pancreatin, washed, and slightly tinged with acid fuchsin. It was next injected and dried, then cut into sections and mounted in Canada balsam. It shows most beautifully the interlobular veins and the intralobular venous plexus. Only at exceptional points is this plexus injected, and in numerous sections the larger veins, the interlobular veins, and the trabecular system alone are shown. In sections parallel with and immediately below the capsule the lobules form a beautiful honeycomb arrangement with the larger interlobular veins at the point of junction of several lobules. The veins now leave the trabeculæ and enter the lobule to form the intralobular venous plexus (Fig. 4464). The main venous branches upon entering the lobule give rise to numerous smaller branches, which anastomose with one another to form the intralobular venous plexus.

Specimens obtained by digesting with pancreatin a spleen in which the veins have been injected with colored celloidin outline most beautifully the spleen lobules. They are about as regular in shape and arrangement as those of the liver, and each is encircled by about three terminal interlobular veins, which are set equidistant from one another and lie within trabeculæ. The walls of the branches which arise from the interlobular veins to penetrate the lobule are formed by a delicate network of reticulum fibrils lined by a layer of peculiar spindle-shaped endothelium cells.

The spleen shows much more beautifully than any other organ the value of fibrils in the construction of a skeleton in which the various structures are suspended. This skeleton not only acts as framework for the larger veins, lobules, and muscles, but is also most delicately adjusted to the structures of the lobule. The arrangement of the whole skeleton is such that a contraction of the muscles (trabeculæ) will compress the lobule (pulp), at the same time pulling open the larger veins. When the contraction of the trabeculæ and capsule is at a maximum the larger veins are also compressed. This mechanism thus aids the circulation from the pulp to the smaller veins and from them to the larger ones. Within the lobule the elastic network of reticulum not only empties the intralobular plexus, but also aids to force the red blood corpuscles and plasma which have escaped into the interstitial spaces back into the veins.

If a portion of a spleen is made partly œdematous by injecting neutral gelatin into a few of its arteries, most instructive specimens are obtained by further injecting the whole venous system with a weak solution of nitrate of silver. A successful specimen made in this way shows the cells lining the veins, outlined and stained, throughout the whole organ. In the contracted portion of the spleen the veins are shown in a collapsed state, while in the œdematous portion they are shown distended. From specimens made in this way I find that the whole venous tree, up into the lobule, is lined by a complete layer of endothelium cells. From this portion of the venous tree no extravasation of blood can take place, as repeated injections have shown. When, however, the endothelial lining is followed into the lobule, it is soon seen that the walls of the veins are not by any means complete, but there are numerous stomata between endothelial cells which are greatly increased in size when the lobule is distended. A given vein followed from an interlobular vein into the lobule soon loses its sharp endothelial lining. At first, in the interlobular collecting veins, the outlines of the cells are sharp and line the whole vein, in either collapsed or distended condition, but as the vein breaks up into the venous plexus the cells no longer line the whole vein. The transition from the complete endothelial wall to an incomplete one takes place in the collecting veins of the lobule, and no complete walls are found within the intralobular plexus.

With the change from a complete endothelial wall to an incomplete one the forms of the cells change also. When the wall is complete the endothelial cells have the usual and well-known form, but as the wall becomes broken the cells at first are irregular, flat protoplasmic masses, sometimes sharply outlined on the side toward the complete wall, but usually irregular in all directions. Soon, however, the cells change their form into a long spindle-shaped mass with rounded ends, with the nucleus protruding on one side of its body, as is well pictured in Henle's "Anatomy." These have been described as muscle cells, and when isolated look much more like them than those pictured by Henle. Yet their position and relation to the perfect endothelial walls lining the collecting veins show definitely that they are endothelium. These long spindle-shaped endothelial cells do not overlap at all in lining the veins of the intralobular plexus. Sometimes two nuclei are seen side by side, but in thin sections of organs made œdematous with gelatin, frozen, cut, and hardened in formalin, they are found to be fairly numerous. The spaces between them in distended organs are considerably larger than the diameter of their nuclei, large enough to allow cinnabar granules to pass into the tissue with ease when injected into the veins, but too small to allow many ultramarine blue granules to escape.

The Lobule of the Spleen.—It has been shown above in the study of the arteries, veins, and trabeculæ that each of these systems is ultimately related to a portion of spleen substance, always of about the same volume, which I have termed the anatomical unit or the lobule of the spleen. These units are outlined only by the larger trabeculæ with their enclosed veins, and not by a membranous layer of connective tissue, as is the case in the lobule of the pig's liver. So in sections it is almost impossible to detect the lobule because in the mass of splenic tissue there are seen only sections of the scattered trabeculæ, some of which are within the lobule.

With care and some imagination the lobule may be outlined in a thin section of spleen after the veins have been injected. Especially is this true if the section is immediately below and parallel with the capsule. In specimens so made the lobules are cut transversely and are outlined by the larger veins and trabeculæ. Yet a number of fairly large veins and smaller trabeculæ enter the lobule, and their section aids to obliterate it. When, however, the veins are injected with coarse granules which do not enter the smaller veins easily, thick sections show the lobules very clearly. Such a section is given in Fig. 4464. In this specimen the lobules, both peripheral and deep, are shown throughout the spleen. This method of preparation permits of the study of the lobules themselves more carefully than do the common specimens, the latter, however, giving more clearly the outlines of the lobules and their relation to one another.

The study of the artery also aids to define the lobule, as its main terminal branches always lie in the centre of it. The arterial injections always show the lobules best when the tissues have first been well distended with a fluid. In the specimen from which Fig. 4464 is taken this was done by means of the diffusion of the gelatin throughout the tissue after having been injected into the vein. The same result was accomplished in the second specimen by ligating the splenic vein in an animal half an hour before killing it. By so doing the lobules are all distended with blood and the main structures within them are spread apart. After this the artery was next injected and thick sections of the fresh spleen were placed in ten-per-cent. NaCl to extract the blood. Specimens made in this way show the distribution of the artery in the lobule most beautifully.

Not only does the artery mark the lobule by passing in through its centre, but it is especially well defined where the arterial sheath of lymphatic tissue becomes enlarged to a Malpighian follicle. These follicles usually lie at the point where the artery enters the lobule, but in rare instances they may extend well into the lobule or they may be so large that at the point of their location the whole lobule is not only filled but distended. This is especially the case in spleens which are empty and collapsed.

With thick sections of injected spleens the lobule is again well defined, confirming in every respect the results obtained from corrosion specimens. That this is so is of the utmost importance in outlining the lobules, because the tissues of neighboring lobules run together, and because the main trabeculæ, veins, and arteries undergo further branching over and into the lobules. A similar branching takes place among the interlobular veins, bile ducts, and arteries of the liver. At the middle of the lobule of the liver there are on an average three interlobular veins, while at the distal end or tip of the lobule there are six. Furthermore, the architecture of the liver lobule is by no means as simple as it is usually pictured; in fact, its very existence was not fully established until nearly two hundred years after it was described by Malpighi.

Were it not that the section of the bile duct is so characteristic, we would have as much trouble in locating the liver lobule in most animals as we have in locating the spleen lobule.

Throughout the lobule there is a beautiful venous plexus which is suspended in a coarse network of trabeculæ penetrating the lobule. These trabeculæ are solid, having no veins within them but toward the periphery of the lobule they usually accompany the collecting veins arising from the venous plexus. On an average there are nine of these intralobular collecting veins in each lobule. The distances between them are equal and they divide the lobule into nine pyramidal parts, within the centre of each of which parts there is a branch of the lobular artery. In a measure this arrangement is shown in Fig. 4464. If the subdivisions of the lobule marked by the intralobular veins were more definite, I would be inclined to consider them the lobules of the spleen, as they possess all the characteristics of lobules. But the extreme difficulty in demonstrating their presence by the different methods at our disposal, as well as the fact that the greater masses or lobules always exist and can be demonstrated with much greater ease, is the reason why I consider the larger the units, and the smaller ones the subdivisions of the units.

But if we did consider the subdivisions to be the lobular units, we should still not be at the end of our difficulty, for they are again cut up into compartments by branches of the intralobular collecting veins which finally arise from the venous plexus. The venous plexus, however, is definite and constant. This last surrounds small masses of spleen tissue, in the centre of which is the final arteriole. This mass, with the end of the artery in its centre and the venous plexus around it, I shall term the histological unit. Within it lies the whole mystery of the spleen.

The spleen is composed of many histological units which are arranged in great clusters within the anatomical units or lobules. The lobules are repeated a sufficient number of times to form the whole spleen.

The Histological Unit or Pulp Cords.—The histological units occupy all the space of the spleen with the exception of that occupied by the Malpighian corpuscles and their extension into the lymphatic tissue which accompanies the arteries. The boundaries of the units being outlined by the veins of the intralobular plexus, which pass in all planes, are not separated from one another any more than are the holes in a sponge, although these are outlined by the sponge substance. The units together, as well as the veins, form a ramifying network, the two together filling all the available space.

Fig. 4463 is a low-power drawing of the network of veins within the lobule, *L*, the meshes of which are filled with the histological units or pulp cords. In Fig. 4462 the veins and units are shown with a higher power. As the veins are emphasized in this drawing, the units appear as islands, but it is easy to imagine them communi cating with one another between the meshes of the vein plexus lying in a deeper plane. Fig. 4464, which is still more highly magnified, shows the units as a plexus of the spleen pulp marked by the sections of the intralobular veins. When the boundary lines of the units are emphasized by examining with low powers thick sections which have been stained intensely, the veins are seen to outline the histological units as distinct islands. Thinner sections with higher powers, however, show that the units communicate with one another very freely and are also outlined by the sections of the veins of the intralobular vein plexus, as shown in Fig. 4465. The separation of the histological units and their relation to one another is a repetition on a smaller scale of the relation of the anatomical units or of the lobules.

Fig. 4462 is from a specimen in which the veins had been filled by an interstitial injection of aqueous solution of Prussian blue. In all specimens made in this way the blue fluid passes directly into the intralobular vein plexus and outlines the histological units. Interstitial injections of other organs usually fill the lymphatic channels, in case they exist, and in the spleen the anatomical arrangement of the venous plexus is similar to that of the lymphatics in other organs. This fact is remarkable, and although it may suggest ideas regarding the circulation through the spleen, it does not help us much regarding its anatomy, because we do not know the anatomy of the lymph radicals. When the veins of the spleen are filled either by means of interstitial injection or by injection into the main veins, the fluid never passes over into the arteries. This has been observed repeatedly by many investigators and appears to show conclusively that there is no direct connection between the arteries and veins.

The specimen from which Fig. 4465 was drawn was made by injecting chrome yellow suspended in gelatin into the vein until the spleen was distended to its maximum, and then an aqueous solution of Prussian blue was injected into the artery. In specimens made in this way the spleen is distended to its maximum with gelatin, with yellow granules in the veins and a blue precipitate in the artery. In the portion of the section drawn the arterial injection did not pass beyond the terminal arteries, but in many other portions of the specimen it did.

By this method of procedure there can be no doubt whatever in determining arteries from veins. In case the whole injection is made with a colored fluid into the artery, it is usually very difficult to determine whether or not a certain vessel is an artery or a vein, and in case it is a vein whether or not it had been injected through an artery in the immediate neighborhood. To illustrate: If an ordinary spleen, hyperæmic at points, is injected with Prussian blue through the artery, it is found that when the injection is complete there is usually much extravasation of fluid. Arising from these extravasations there are many injected veins, from which neighboring veins, including the intralobular plexuses, are injected. Of course, the arteries in portions of the spleen with secondary venous injections are also filled with fluid of the same color, and thus false conclusions are often drawn. Such specimens must be viewed as double injections with fluid of the same color, and are of little value in studying the relations of the blood-vessels of an organ, especially of the spleen.

To mark definitely the veins of the intralobular plexus, it is desirable to employ substances which will fill these veins and go no further. Ultramarine blue is an excellent substance for this purpose, as few of its granules will pass over into the tissues. Yet for purposes of double injection the color is wrong, for in all instances aqueous Prussian blue is the best for the artery. On this account I used most frequently chrome yellow granules in gelatin for the veins and Prussian blue for the arteries. After the spleen has had its veins all filled with the yellow granules suspended in gelatin, the gelatin passes over into the tissue, leaving the granules in the vein, for its walls act like a sieve. If the arteries of a specimen prepared in the above-described manner are injected with a solution of Prussian blue, but little of it enters the veins; nor can secondary injections of the spleen take place through the veins, as all of them have been plugged by the chrome-yellow.

A spleen having been made œdematous by the extravasation of the gelatin, by injecting it as described above, is easily cut into thin sections on the freezing microtome, either fresh or after it has been hardened in formalin. Such sections may be treated in various ways and are most instructive. They always have their veins decidedly marked with the yellow granules, which is of greatest importance in studying sections of the spleen. Repeated tests have shown that veins are very characteristic and need not be confounded with the *capillaries* or *ampullæ*, as I shall show presently.

Sections of the intralobular venous plexus are shown in Figs. 4461 and 4465, which are from specimens prepared in various ways. The figures show sufficiently the nature of the walls, the intralobular veins, venous sinuses, or spleen sinuses, as they have been termed. By injecting dilute solutions of nitrate of silver into the veins, endothelium cells are sharply outlined throughout the interlobular veins and fairly well in the intralobular collecting veins. From now on throughout the intralobular venous plexus the cells lining the veins no longer make a continuous layer. They become spindle-shaped with rounded ends, their nuclei protruding at their sides, as described by Henle. When the veins are collapsed these cells come in contact with one another, and in sections look much like non-striated muscle fibres. With the veins distended, however, the cells separate, leaving wide openings between them, which are large enough to allow cinnabar granules to pass through them with ease, but not large enough to allow ultramarine-blue granules to pass through freely. Although the blue granules are smaller than red blood corpuscles, they have sharp edges which certainly do not favor their passage through the openings in the walls of the veins, which are considerably larger than the diameter of the granules. The openings between the endothelial cells in the veins may be also shown by ligating the splenic vein in the living animal (Thoma). At first the spleen becomes hyperæmic, and sections at this stage show that all the blood is lodged in the veins and but very little in the tissues. After a greater length of time the veins become enormously distended, and then the blood begins to pass from the veins over into the tissues of the spleen pulp or the histological units. This experiment in itself is a strong argument in favor of a closed circulation through the spleen, for were it otherwise the blood would begin to accumulate in the tissues long before the veins are distended to their maximum. The pictures obtained after tying the veins all speak most strongly in favor of the idea that the blood in the spleen pulp extravasated from the veins and not from the arteries.

At any rate, both experiments and specimens show that the endothelial lining of the venous plexus is very incomplete, having openings between them large enough to allow the passage of red blood corpuscles with ease, and of course blood plasma with the greatest freedom. These openings are the largest when the spleen is distended to its maximum, and smallest when it is completely contracted. The two pictures obtained by examining distended and contracted spleens are so different that it is difficult to recognize that both are from the same organ. We are all familiar with sections of contracted spleens, but the sections obtained from a distended spleen are certainly a great surprise to one who has not seen them before. The most instructive specimens are made by injecting the veins of a portion of the spleen with ultramarine-blue gelatin, leaving the remaining portion uninjected. In the injected portion the tissues of the histological units are distended with the gelatin, while the blue granules remain in the veins. At the junction of the injected portion with the uninjected all gradations may be seen, which when put together give the idea that the cells have been washed out of the part distended. This interpretation is out of the question in this case, as the spleen substance has simply been distended with gelatin and all of its tissues have been held fast and fixed by the hardened gelatin.

Henle washed out the spleen by a long-continued artificial circulation of a solution of sulphate of soda through the artery. If the circulation is continued for half an hour or longer, the spleen loses its red color, becomes pale, distended, and very œdematous. The first fluid which comes from the veins has in it many red corpuscles, but as the spleen becomes paler and paler they gradually diminish in number. This experiment appears to prove that the blood-vessel system of the spleen is open and that the circulation passes through the spaces in the pulp. For a long time this argument seemed incontestable to me, and it, with another and apparently contradictory experiment, showed that the mystery had not been fully solved. Ten years ago I found that when cinnabar gelatin is injected into the artery with a pulsating pressure for a long-continued time, most of the cinnabar passed over into the intralobular venous plexus and not into the tissues of the pulp, as it should were the circulation through the spleen open. While Henle's experiment speaks for an open circulation, this experiment calls for a closed one.

I have repeated Henle's experiment many times, and am now fully convinced that he never washed out the pulp cells at all, but only washed out the cells and red discs which were lodged in the veins. In addition to this, he made the spleen œdematous, which in all cases appears "washed out." After the artificial circulation has been carried on through the spleen for hours, the pulp spaces of the histological units have within them just as many cells as are present when the œdema is produced by a simple injection of gelatin into the veins. In the latter instance the cells certainly were not washed out, as the gelatin simply passed into the tissues and after hardening held everything in place. Furthermore, in numerous tests I have never succeeded in removing the cells from the pulp by means of artificial circulation. Fig. 4461 is from a frozen section of a spleen made œdematous by injecting gelatin into the vein. The section was then placed in warm water to dissolve the gelatin, and then shaken a short time. Most of the cells have been removed. Further shaking would destroy the section entirely.

Reticulum of the Histological Unit.—That the framework of the pulp is made up of anastomosing fibrils which must be viewed as a variety of reticulum has been shown sufficiently above. At present I shall consider the arrangement of this reticulum within the lobule. In the description of the delicate reticulum fibrils of the lobule the terms reticulum of the lobule or of the pulp are used, while the tougher and more resistant reticulum of the capsule and trabeculæ is referred to as the reticulum of the trabeculæ.

The reticulum of the lobule forms a delicate network throughout the lobule, which in turn is suspended within the meshes of the network formed by the trabeculæ. The main strands of the fibrils accompany the vein plexus as pictured by Oppel. When sections of a fresh œdematous spleen are washed in water to remove most of the cells and then tinged with picric acid, the same picture is seen as that gotten by Oppel by using Golgi's method. The main strands of the reticulum accompany the interlobular venous plexus, while a more delicate network with more open meshes extends throughout the histological unit. In the centre of the unit the network becomes more dense again, which marks the position of the terminal artery with its accompanying ellipsoid lymphatic tissue.

Within the meshes of the reticulum are located all the cells known as pulp cells, *i.e.*, free cells including all the elements of the blood, giant cells, pigmented cells, and the fixed cells, which are more or less spindle-shaped. Many of the multipolar cells are only such in appearance, as their prolongations are the reticulum fibrils upon which they lie. Fig. 4461 is from a spleen partly washed out; it shows only the cells which are more firmly attached to the reticulum.

The reticulum fibrils are very extensible as well as elastic. The fibres may be stretched at least to twice their former length and when liberated will immediately rebound to the position they occupied before stretching. If a spleen is distended to its maximum by injecting it full of gelatin, it is found that all of the dimensions of the spleen have been doubled, as the spleen has increased its volume eight times. After the gelatin has hardened the spleen can be cut into sections on the freezing microtome and further experiments made upon them. When the section is placed in warm water to dissolve the gelatin, it is found that all its dimensions shrink to one-half. In other words, removing the gelatin allows the section to take the form it possessed before the spleen was injected. The reticulum is under no tension when the spleen is contracted to its maximum. When the spleen is distended the least its reticulum is stretched.

That the shortening of the section, when treated with warm water as described above, is due to the elasticity of the reticulum of the pulp and not to that of the structures of the trabeculæ, is proved by the fact that all the trabeculæ have been cut into small blocks in the sections. The small blocks of trabeculæ can no longer influence the dimensions of the section, for all of their main attachments have been broken. The trabecular network and capsule of the spleen are, however, very elastic, but the experiments with the œdematous section exclude these factors.

Fig. 4461 is from a section of œdematous spleen, the gelatin having been removed with warm water. The bundles of fibrils have taken on their natural shape, leaving a considerable lumen to the vein. Any further reduction of the meshes of the reticulum could be brought about only by external force, such as contraction of the trabeculæ in the living spleen. At any rate, it appears as if any marked distention of the spleen lobule can be brought about only by stretching the reticulum fibrils, and that these in turn are constantly pressing upon the fluids and elements within the meshes. In so doing the only outlet for them is through the vein, and this is favored by the openings in the vein walls. If the lobule is further distended the reticulum is stretched still more, and the veins, as well as the openings within their walls, are made larger. Everything, then, seems to favor the flow of fluid and cells from the spleen pulp into the veins when the pulp has become distended.

Henle has described spiral fibrils around the smaller veins in the spleen. In searching for them I have used his method over and over again, and occasionally I have obtained specimens which confirm his observations. It appears to me that the spiral fibrils which he describes are the reticulum fibrils around the larger veins, for only at these points have I been able to find them in specimens treated with KOH. I have already stated on a previous occasion that dilute HCl and KOH solutions do not cause white fibrous nor reticulated tissues to become transparent and swell when they are under tension. At the point where the larger veins (intralobular collecting veins) leave the lobule, the opportunity to stretch the reticulum surrounding them is extremely good while the specimen is being treated with KOH, because a pressure upon the cover slip will cause the trabeculæ to separate. These collecting veins are then stretched, as they are frequently located at the junction of two trabeculæ. Although, according to Hoehl, some elastic fibres leave the trabeculæ to enter the pulp, I do not think that Henle's spirals are anything but reticulum. If it were not difficult to obtain pictures like Henle's, the question could be easily settled.

The reticulum of the histological unit not only encircles the vein but extends to the artery, and in so doing passes through the lymphatic tissue surrounding it. If the reticulum is followed into the lymph follicle, it is found that the fibrils of the pulp are directly continuous with those of the follicle. Whether or not the reticulum of the follicle of the spleen gives the same reactions as that of the pulp cord, I have not been able to determine.

The Arteries Within the Lobule.—After the artery of the spleen has divided and subdivided a number of times, a final branch enters the base of each lobule, passes through its centre, and gives off numerous branches which radiate toward the periphery of the lobule (Figs. 4464 and 4466). In all there are eighty thousand lob-

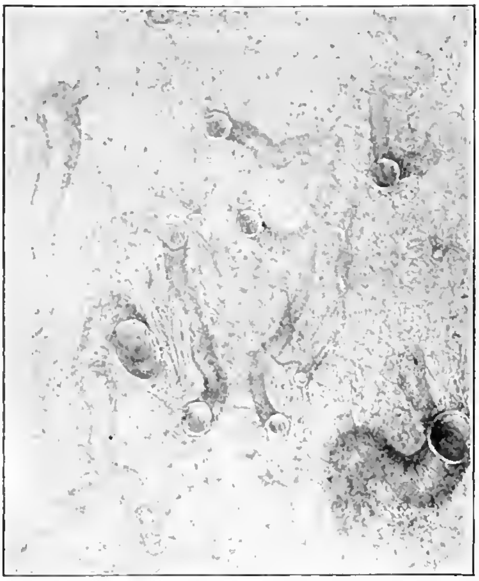

FIG. 4465. Section of a Spleen the Veins of which had First been Injected with Chrome Yellow Suspended in Gelatin. The gelatin formed an œdema and the yellow granules remained in the vein. The artery was next injected with an aqueous solution of Prussian blue. Enlarged 80 diameters. At the point from which the drawing was taken the injection in the artery did not reach the vein.

ules, which are piled upon one another in such a manner that their bases point toward the nearest main trunk of the artery. The term base is arbitrary, not being the largest side of the lobule; in the case of the deep lobules the "base" is as large as any other side; while in the subcapsular lobules it is, in fact, the smallest side. In spite of this, however, it is well to consider the base the side of the lobule, the side that is most firmly attached in case they are separated from one another. In other words, as in the liver, in the lung, or in the intestine, the base is the proximal side of the anatomical unit. Within the lobule the long slender artery gives rise to about ten main branches, which are located in the centres of each of the subdivisions of the lobule outlined by the intralobular collecting veins. Finally, the smaller branches run in the centre of the pulp cords and each artery terminates in the centre of the histological unit, as shown in Fig. 4466. As the subdivisions of the central artery of the lobule pass to their destination, they are seen to curl under and over the veins of the intralobular venous plexus, remaining as far as possible from the veins. Their course in the pulp cords is the same as that of arteries of the lymph cord of a lymphatic gland.[9] The relation of the final artery to the intralobular veins surrounding the pulp cords is again identical with the relation of the artery to the vein in the lymphatic gland, as described recently by Calvert.[10]

The artery of the spleen and all of its branches are long and slender throughout their course, and they are surrounded by a sheath of lymphatic tissue, which accumulates into the Malpighian follicles at the origin of the central artery of the lobule and continues to the ends of the arteries as the ellipsoid sheath. The central artery of the lobule gives rise to ten main branches, each of which in turn gives rise to about six hundred terminal branches. The final branches lie in the centre of the histological unit, and in a distended spleen the distance between them and the vein plexus is about 20 μ.

When the artery of the spleen is injected with fluids, *e.g.*, gelatin, an extravasation takes place as soon as the injection enters the lobule; it is most intense around the periphery of the lymph follicle, around the arteries toward their termination, and throughout the histological units or pulp; it never takes place within the lymph follicle. When the injection of the spleen is incomplete it is found that the veins are injected only at the points of extravasation. The various authors who advocate an open circulation through the spleen base their conclusions upon the above tests, while those who advocate a closed circulation have occasionally observed a direct communication between the artery and vein. It matters little which opinion is correct, for in any case an extravasation invariably takes place when the artery is injected with a fluid, showing that a similar thing may take place in the living spleen. And since this takes place in part at least, we must admit that there is constantly a stream of blood plasma passing out of the artery into the pulp, which again must flow into the vein and not into the lymphatic channels, for they are not present. When, however, the spleen is distended to its maximum by tying the splenic vein, as well as its anastomoses with the gastric, half an hour before killing the animal, a subsequent injection of the artery with an aqueous solution of Prussian blue gives specimens which are most instructive. The spleen pulp is so distended with blood that there is no further space for the Prussian blue in it and it must take the course of the least resistance. This naturally is over toward the vein for before injecting the artery of the spleen the veins were opened to relieve the tension in them. If then there is any direct connection between the artery and vein it must be injected by this method. Fig. 4467 is from a specimen made by this method. It is seen that the terminal artery suddenly widens, passes toward the vein, and then communicates with it. In every respect this confirms Thoma's description of the termination of the artery within the spleen.[11] For a long time I have been obtaining specimens from time to time, which show that there is a communication between the artery and vein, but until recently I was unable to obtain complete injections in every specimen until I invented this method; for with ordinary methods the injections may be complete in one specimen while the next specimen treated in the identical way has a diffuse injection, barely showing the terminal arteries. I finally found that these ampullæ are very marked if an œdematous or a hemorrhagic spleen is injected with aqueous Prussian blue, a fluid which precipitates very easily. I have never been able to demonstrate them with carmine gelatin as it diffuses with the greatest ease. There are then marked channels, or the ampullæ of Thoma, connecting the arteries with the veins, which can be demonstrated by certain methods. From time to time it appeared to me that the ampullæ marked artificial channels, but their constancy, their direction and their arrangement being always so characteristic, as well as the fact that they are present in uninjected specimens, are sufficient evidence against this view. The fact that

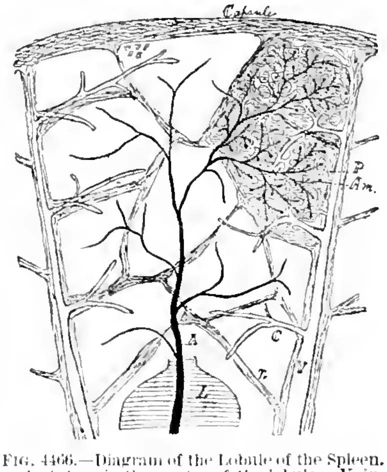

FIG. 4466.—Diagram of the Lobule of the Spleen. *A*, Artery in the centre of the lobule; *V*, interlobular vein within the interlobular trabeculæ; *Tr*, intralobular trabeculæ; *L*, Malpighian follicle; *C*, intralobular collecting vein; *P*, intralobular vein plexus which surrounds the pulp cords or histological units; *Am*, ampulla of Thoma.

they are easily injected only when the rest of the spleen is filled with fluid appears to indicate that they may be reserve channels through which the circulation can pass only when the spleen is hyperæmic, as it is during digestion.

The arterial end of the ampulla is much more easily injected than the venous end, and apparently for this reason Thoma divides the communication between the artery and the vein into two parts, the ampulla or the arterial end, and the *Zwischenstück* or the venous end. There is no sharp line of demarcation between the ampulla and the Zwischenstück, for the one passes directly over into the other. This division I find very artificial, and in describing the different portions of the ampulla I shall divide it into thirds, numbering them from the artery to the vein.

The first third of the ampulla is a marked space lined with spindle-shaped cells, which are a continuation of the endothelial cells of the artery.

In the second third the ampulla has a tendency to divide the subdivisions in such a way that some of them communicate with the divisions from neighboring ampullæ. The anastomoses of ampullæ pass along the middle of the pulp cord, and if care is not taken it may be mistaken for the vein. However, double injections with granules in the veins excludes this source of error. The last third is much more difficult to demonstrate than the first two thirds. Thoma has already emphasized this point in stating that the ampulla appears to communicate with the vein when viewed with a low power of the microscope; that with the high power, however, it is shown that the ampulla passes over and under the vein, but not into it. This description applies to what I have called the first two thirds of the ampulla. Successful injections leave no doubt whatever about the ampullæ communicating directly with the vein, as shown in Fig. 4467. To be sure, it may be asserted that the spleen pulp in this specimen was so gorged with blood that the Prussian blue injected was forced to take the direct course through the tissues into the vein. To settle this question further I made rapid injections with Prussian blue into the artery of a spleen which had been distended, but not to its maximum, by injecting chrome yellow suspended in gelatin into the vein. The gelatin passed over into the tissues and the yellow remained in the vein. The smaller quantity of blue injected into the artery extravasated as usual at numerous points and flowed into the veins in the immediate neighborhood. Where the injection was not so intense spots were found in which the blue from the artery passed directly over into the vein. In such specimens the extravasation of the blue takes place along the artery as much as it does in any portion of the ampulla, and it appears from this that the walls of the last third of the ampulla are fairly complete, otherwise the injection would have passed into the pulp spaces immediately surrounding it.

By studying numerous successful injections of the last third of the ampulla I find that its communication with the vein is not wide, but is cut up by bridges of tissue passing across its lumen before it connects with the vein. This is so extensive that in uninjected specimens it has been impossible for me to show that the ampulla communicates with the vein. That the ampulla can never be injected from the vein is an additional argument for the idea that there is an obstruction near its connection with the vein.

If the artery of the spleen is injected with gelatin in which cinnabar granules are suspended it is found that the granules are forced over into the veins only under special conditions. Ordinarily the granules pass to the origin of the ampullæ and then can be forced no farther, nor can they be forced through the walls of any of the arteries. When, however, the cinnabar is driven into the artery with a high pulsating force for a long-continued time, it is found that the granules pass beyond the ends of the arteries and the gelatin diffuses, thus causing an artificial œdema. Many of the granules enter the pulp spaces, but by all odds the greater number of them pass over into the veins. Often so many of the granules pass over into the veins that it appears as if the veins had been injected by them. The extravasation of granules into the pulp spaces is most intense around the lymph follicles, which is also true in the case of other injections. It appears as if in the neighborhood of the lymph follicles the walls of the ampullæ are most porous.

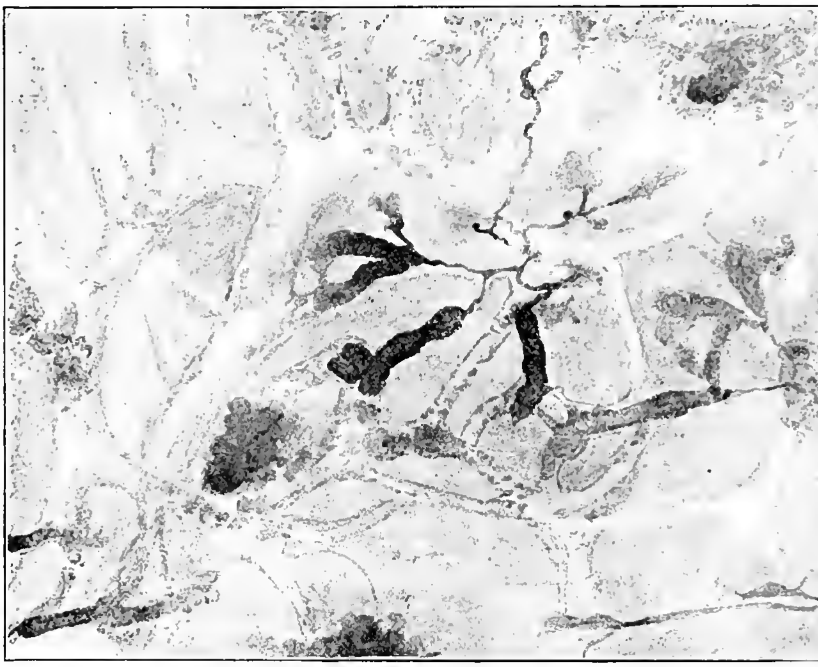

FIG. 4467.—Section of a Spleen Distended to its Maximum by Tying the Vein One Hour before Killing the Animal. The artery was then injected with aqueous Prussian blue. Enlarged 60 diameters. The ampullæ communicate with one another and also directly with the intralobular venous plexus.

In all of the specimens in which the artery had been injected with cinnabar the ampullæ are not sharply outlined. All granules which enter them are carried over into the veins at once. This result corresponds fully with natural injections made by ligating the veins. In any case there must be some mechanism which empties the ampullæ, as they are never found distended with cinnabar granules or with red blood discs.

Whether the course of the granules is from the ampullæ directly to the veins, or indirectly through the pulp is another question. Were it through the pulp we would expect to find the tissue first filled with granules or blood, as the case might be, before they entered the veins. Instead of this we find that in the natural injections the blood first fills the veins and then the pulp spaces, and when the pulp spaces are overdistended with blood, the corpuscles do not return to the veins after the pressure in them has been removed. If there were a constant circulation from the ampullæ through the tissues into the vein, the blood discs in the pulp spaces should be forced into the veins in the above experiment. Furthermore, if the muscle of the spleen is paralyzed by cutting its nerves, a great quantity of blood passes over into the pulp spaces causing a hemorrhagic infarction, which shows that the elasticity of the reticulum alone is not sufficient to keep the blood out of the pulp spaces. If all the circulation of blood were through the pulp spaces, and if the contraction of the muscle of the capsule and trabeculæ forces the corpuscles from them into the veins, then the pulp spaces should remain empty after the obstruction of the veins which produced an infarction has been removed. These experiments are considered now only to the extent in which they relate to the walls of the ampullæ. Their bearings are of such great physiological significance that they will be discussed more extensively presently.

The walls of the arteries are surrounded with a sheath of lymphatic tissue throughout its whole course. The layer of round cells is greatly reduced around the first third of the ampulla, but it often increases again at the end of it, thus aiding to separate the first third from the second. From the end of the first third of the ampulla to the vein there are no marked walls, not more than the increased number of reticulum fibrils (Fig. 4461). Injections with solutions of nitrate of silver outline the first third of the ampulla extremely well, and show that the sharp endothelial lining of the artery reaches nearly to the ampulla. Then the cells become irregular in shape and finally are represented as long spindle cells which lie upon a framework of reticulum. Throughout the second third the walls of the ampulla are still faintly marked by spindle and multipolar cells, but I have been unable to demonstrate any distinct cell walls in the last third. In sections of uninjected specimens this third appears to communicate as freely with the pulp spaces as with the veins.

The sections and injections show (1) that the walls of the ampulla become more and more porous as the vein is approached; (2) that the walls of the whole venous plexus of the lobule, especially in the distended spleen, are also very porous; and (3) that at the point of junction between the ampulla and the vein there is no marked blood-vessel wall other than a dense network of reticular fibrils.

The experiments show that if the muscle is paralyzed the blood discs enter the pulp spaces, thus causing a hemorrhagic infarction, and that under normal conditions all the tissues are bathed in plasma while the solid elements of the blood pass directly from the ampullæ into the veins.

Experiments on the Circulation through the Spleen.—The experiments here recorded were made to test what influence the contraction of the trabeculæ and capsule may have upon the circulation through the spleen. It is well known that at certain times the spleen is very hyperæmic and dilated, while at other times it is anæmic and contracted. In addition to this periodic change in volume its muscle is also constantly contracting rhythmically. Since the arteries are very long and slender and end in so many branches it is evident that the resistance in them must be very great. Their muscle walls are also so powerful that it is practically impossible to inject them completely in a contracted spleen. If artificial circulation is carried on through a spleen in which the muscle is alive and contracted, it is found that the spleen must be distended considerably before any fluid comes out of the vein. This usually takes a number of minutes after the artificial circulation is started, and from it we must conclude that the circulation through a distended spleen is much easier than through a contracted one.

I have been unable to obtain this result in the living animal with the normal circulation unbroken, for all the operations which I performed upon the veins always caused the hyperæmic spleen to contract. A number of experiments, however, gave some good data regarding the venous outflow in a spleen fairly well contracted, as usually seen in the living animal. With all the arterial anastomoses ligated the quantity of blood which flowed from the vein was usually 25 c.c. every five minutes, or about two drops per second in dogs weighing 10 kgm. When we consider the five hundred million arterial endings in the spleen we realize how very slow the circulation must be through them. In the intestine of the same animal there are not over five million arterial terminations and the blood simply rushes through the superior mesenteric vein. I have never been able to measure the quantity of blood which passes through splenic veins when the spleen is hyperæmic, but it is very free when artificial circulation is carried on through the distended organ. If the spleen is made very hyperæmic by ligating the veins in a living animal there is a great gush of blood from the vein in case it is opened; but accompanying this there is a corresponding contraction of the organ, showing that in addition to the natural circulation through the spleen the blood lodged within it is also pressed out by the contraction of its intrinsic muscles.

When a spleen, which is physiologically hyperæmic, is irritated either directly or through its nerves, it is found that the contraction which follows forces the blood contained in it through the vein and then it becomes pale. The same result is observed when an hyperæmic spleen is completely removed from the body; it gradually contracts and forces the blood contained in it through the vein. These observations indicate that when the blood is once within the venous plexus and large veins of the spleen a contraction of the muscles forces the blood out through the vein, thus aiding in the circulation through the organ, as is the case in the intestine. The presence of valves at the point where the veins leave the spleen prevents the blood when once forced out from returning to the organ again when its muscle relaxes. To test this point I made a number of experiments, measuring the pressure within the vein, after it had been tied, while the spleen is contracting. Unfortunately the activity of the muscle of the spleen varies very much in different animals, and I have been unable to control this factor. In some experiments the spleen simply continued to distend after ligating the vein without any perceptible increase of pressure in the vein. At other times the spleen responded beautifully when irritated. In one experiment the venous pressure was 15 mm. Hg. before closing the vein; after closing, it rose to 180 mm. Hg. After it had reached this height ligating the artery further irritated the spleen muscle, causing the venous pressure to rise to 190. In another animal the venous pressure in the spleen with the vein closed registered every five minutes as follows: 20, 70, 106, 60, 140, 90 mm. Hg. At no time could I observe any contraction of the organ. The maximum pressures of 106 and 140 mm. were in each case accompanied by great struggling of the animal. In another spleen the venous pressure registered constantly at 7 mm. Hg. after closing the splenic veins, and the organ was gradually becoming hyperæmic. Irritation of the nerves about the artery caused the venous pressure to rise to 20 mm., but this would soon fall again to 7 mm. All other irritants, like hot water or closing the artery, did not cause the spleen to contract nor the venous pressure to rise.

These experiments, although incomplete, show that the contraction of the spleen causes the pressure in the splenic vein to rise, and from what has been said above regarding the anatomy of the spleen this is to be expected. Therefore it is highly probable that the physiological rhythmic contraction of the spleen, acting partly upon the veins, is a great factor in the circulation through the organ.

While we can cause contraction of the muscle of the spleen, and observe its effect upon the venous blood pressure, we can also make the opposite experiment by paralyzing the muscle. Jaschkowitz[12] has shown by cutting the nerves around the splenic artery that an extreme hemorrhage into the pulp spaces follows. I have repeated Jaschkowitz's experiment a number of times and obtained his results in each case. In making the experiment I isolated the artery and vein completely with a probe and passed a double ligature around all the tissues about these vessels. After tying both ligatures I cut between them, thus excluding every possibility of an error. In certain experiments an individual nerve or the nerves around one branch of the artery were not cut, thus making the control experiment at the same time. At the end of twenty-four hours the animals were killed, and in each case there was an extensive hemorrhagic infarction of the spleen; if all the nerves had been cut the hemorrhage was throughout the whole spleen, while if certain nerve branches were not cut, the spleen tissue innervated by these branches remained unchanged. Before killing the animals, first the vein and then the artery was opened, showing that there was no obstruction in either of them due to the operation. Irritation of the spleen with hot water caused no contraction in case all the nerves had been cut, while if some nerves remained uncut, the portion of the spleen innervated by them would respond to irritants. The border line between the normal and hemorrhagic, which was very hyperæmic, would respond to irritants. This last test undoubtedly shows that within every portion of the spleen there is an overlapping of the nerves, as is the case in many other portions of the body.

Since irritation of the splenic nerves causes contraction of the spleen, and since cutting the nerves causes paralysis of the muscle of the spleen, it is probable that the results upon the circulation following these two experiments are due to the excessive or diminished activity of the muscle. On the one hand, the contraction presses blood out of the spleen, while on the other hand the removal of this force allows the blood to accumulate in the spleen. Sections of spleens made hemorrhagic by cutting the nerves show that whenever the tissues are filled with blood the veins are likewise filled, but in numerous places the veins are full and the pulp spaces empty, corresponding with the results obtained by Thoma after tying the splenic vein. It therefore seems that the pulp spaces are in all cases filled with blood through the openings in the walls of the veins. Yet I am unwilling to accept this explanation until further arguments are made to support it, but am rather inclined to the idea that the pulp is filled with blood through the openings in the walls of the ampullæ.

The reasons why I believe that the escape of blood corpuscles is through the walls of the ampullæ to produce the hemorrhagic infarction after cutting the nerves are: (1) the anatomy of the ampulla; (2) the fact that granules injected into the artery pass mostly into the veins and partly into the tissues; and (3) hemorrhagic infarction produced in other organs takes place mostly through the capillary walls.

I have shown sufficiently above the characteristics of the walls of the ampullæ. That as soon as they begin the endothelial cells of the artery become spindle-shaped and are separated, and that a distinct cell wall cannot be followed to the vein. Furthermore any fluid injected into the artery will invariably pass immediately over into the pulp, thus causing an artificial œdema. When this is complete the fluid then flows from the veins. The extent of this œdema in the spleen under normal conditions would depend upon the tone of the muscles of the trabeculæ. It does not appear that the natural elasticity of the reticulum of the pulp and of the elastic tissue of the trabeculæ and capsule are sufficient to prevent this, as shown by artificial circulation through the isolated spleen as well as by producing paralysis of the muscle in the living animal by cutting the splenic nerves.

Long-continued circulation with cinnabar granules suspended in gelatin through the isolated spleen shows that the bulk of the granules pass directly into the vein while a considerable number of them enter the pulp spaces. When such an injection is continued long enough the granules passing into the pulp will naturally accumulate, as does the blood when the nerves are cut. The few red discs which normally pass out into the tissues will probably remain there until destroyed by the various migrating cells, then to be carried into the veins by them. Sections of a spleen which has been distended with gelatin, as well as the relative number of red and white blood discs within the vein under normal conditions, suggest this. Furthermore, the veins have the largest openings in their walls nearest the lymph follicles.

Numerous experiments, made by Welch and myself, upon the blood-vessels of the intestine have shown that hemorrhagic infarction takes place only with considerable blood pressure within the arteries and capillaries. When the vein only is tied or when the venous pressure is greatly increased, with the artery closed, the expulsion of red discs through the thin capillary walls is easily understood. When, however, the artery is tied and the vein left open, as is the case when an embolus lodges in the superior mesenteric artery, the cause of the following diapedesis throughout the mucosa of the intestine is not easily understood. Many experiments have shown that it is not necrosis of the capillary walls and venous regurgitation, for after the whole intestine has been deprived of its circulation for twenty-four hours, re-establishing it does not produce an infarction nor hasten it. An infarction of the intestine takes place after ligature of the superior mesenteric artery just as rapidly with the mesenteric vein cut open as it does under the normal portal pressure of 7 mm. Hg.

All the usual explanations of hemorrhagic infarction, as printed in the pathologies, are incorrect when applied to the intestine. The superior mesenteric artery with its branches suspended in a membrane is eminently adapted to experiments to test this question. The pressure in the vessels can be increased and gradually modified in different portions of the intestine, and it is found that when the arterial pressure is reduced to one-third its normal with the vein either intact or cut open, an infarction invariably follows. Cutting off all the anastomoses and partly closing the main artery with clamps until the pressure in the distal end is about 40 mm. Hg. produce an infarction. It does not appear, however, that the infarction is due to the reduction of the arterial pressure to 40 mm. Hg., but rather to the lack of a pulse wave, which is almost completely cut off at this pressure.

The experiments of von Frey[13] with artificial circulation through isolated organs have shown that the lack of a pulse wave in the artery always causes them to clog with red blood discs, while the presence of a pulse prevents this by not permitting the red discs to stick together, for it constantly tears them apart. When they stick together they gradually block the capillaries, and then the lateral (lymphatic) circulation drags with it the straggling red discs, thus choking up the tissue to produce hemorrhagic infarction. The result obtained by von Frey in an isolated organ in which artificial circulation is carried on without a pulse wave has also been found in the living intestine when the artery is closed sufficiently to break the pulse in its distal end. The infarction produced by long-continued circulation through the artery under constant pressure is due to a condition which blocks the capillaries, but still leaves the blood within them under considerable pressure. The important factor is stagnation, due to the absence of a pulse in case the artery is tied, while if the stagnation is produced by ligating the vein the presence of a pulse only hastens the infarction. In one case there is a pulse, in the other there is not, while in both the result is the same.

I have given then a brief summary of some unpublished work in order to discuss the infarction within the spleen following division of the nerves. The great sectional area of the ampullæ as well as the great number of them (at least five hundred million), together with the long, slender arteries, must cut down the pulse in the ampullæ enormously. Hence with the normal circulation through the spleen we have present most favorable conditions for diapedesis. Not only is the circulation slow and the pulse wave insignificant, but the walls of the ampullæ (capillaries) are incomplete. So, therefore, without the rhythmic contraction of the spleen to aid the circulation a hemorrhagic infarction takes place. The quantity of discs which normally passes from the ampulla into the pulp spaces is increased while a share of the blood still passes over into the veins, just as is the case in the intestine when infarction is taking place after ligature of the superior mesenteric artery. With the spleen pulse present, however, the constant pressure upon the pulp produced by the elasticity of the connective tissues and the tone of the muscle are sufficient to drive the blood discs through the channels of the least resistance, as is the case when a distended spleen is injected (Fig. 4467).

The balance between the arterial pulse, ampullæ, and spleen pulse is so delicate that when it is proper the blood discs will "creep single file" over into the vein, while the least overthrow of it will drag an increased number of corpuscles with the normal flow of plasma over into the pulp spaces to make a pathological condition—hemorrhagic infarction.

The Nerves of the Spleen.—The nerves of the spleen accompany the artery and are composed mostly of non-medullated fibres.[14] It is quite easy to separate them by the ordinary methods of dissection and to follow them far into the spleen. With the aid of the dissecting microscope Kölliker was able to follow them to the Malpighian corpuscles, while with the aid of Golgi's method Retzius followed them to their terminations in the spleen substance. Rich plexuses of fine nerves surround all of the arteries which supply the muscle fibres of the media. A second group of nerves go to the muscle fibres of the trabeculæ. This distribution explains the physiological experiments: (1) Irritation of the splenic artery causes contraction of the whole spleen; and (2) cutting these nerves causes paralysis of these muscles followed by hyperæmia and hemorrhagic infarction. According to Kölliker the presence of some medullated nerve fibres in the spleen accounts for the pain felt in this organ at times. It is impossible to determine with certainty by the method of Golgi whether or not the nerve fibres leave the trabeculæ and walls of the arteries to enter the substance of the pulp, for the precipitation of the silver often outlines the reticulum fibrils also.

The Spleen Pulp.—The red substance of the spleen, the true spleen pulp, is arranged in bands which anastomose in all planes, inasmuch as it fills all of the space between the capillary veins, similar to the arrangement between the cells and capillaries of the liver. The framework of the pulp is composed of reticulum, the nature of which has been already discussed. There appear to be some elastic fibres encircling the veins, and also within the Malpighian corpuscles, as is the case in all lymph glands.

The small mononuclear lymphocytes, which form the main mass of the Malpighian corpuscles, are found scattered throughout the pulp substance, except along the arteries, where they form a kind of a sheath to the outside of the muscle wall.

The large leucocytes are in general more numerous, and they are also numerous in the centres of Malpighian corpuscles. They are partly unicellular and partly multicellular, and in addition there are granular forms, some of which are intensely stained with eosin (eosinophile cells). The large brown cells (phagocytes) which contain much blood pigment must also be recorded with the leucocytes. They are found scattered in an irregular fashion throughout the pulp of the spleen. The contents of the phagocytes are also found free in the pulp. Red blood corpuscles lie scattered singly and in groups within the meshes of the reticulum of the pulp. As a rule giant cells and nucleated red blood cells are not found in the pulp of the adult spleen, but there are cells present which cannot for the present be arranged with certainty in the series of leucocytes or the series of erythrocytes. These cells are pretty large and have a very fine granular protoplasm which stains more intensely with eosin than does the protoplasm of leucocytes. The nucleus is round or oval, seldom constricted, and never lobulated, and often contains marked nucleoli. In preparations made from tissue hardened in sublimate the nuclei of these cells resemble those of the reticulum, but unlike them lie free within its meshes. Large giant cells, similar to those in bone marrow and in the liver of the embryo, are also found. Their nuclei are large and lobulated, or are pressed together into a heap. In order to differentiate them from the giant cells with many nuclei they are called megacarocytes. It has been found by Kölliker that they are present in the spleen of embryos and of young animals and occasionally in the spleen of the adult—the mouse for instance. There are also constantly present in the spleen of young animals very small granules which can be found in very large numbers in teased preparations. They resemble very much blood platelets, but are more resistant, for they can be preserved for a very long time in salt solution. They also have a tendency to take on irregular shapes and to form clumps.

The question is naturally asked, Is the spleen a blood-producing organ? The more the question is studied the less probable it becomes that the spleen plays any rôle in the production of blood. The coarse counts of the number of white and red cells in the artery and in the vein or the increased number of white cells in leucocythæmia are of little value when examined critically and experimentally. According to Ehrlich,[15] to whom we owe much regarding our knowledge of the blood, the leucocytes are greatly increased in number after extirpation of the spleen, which is accompanied with a marked hypertrophy of the lymph glands of the body. Extensive experiments were carried on in Ehrlich's laboratory by Kurloff, from which the following conclusion is drawn: That the spleen of the guinea-pig plays an insignificant rôle in the formation of the white blood corpuscles.

It is also very apparent that the relation of the spleen to the formation of red blood corpuscles varies much in different animals and at different periods in the development of the same animal. In lower vertebrates the spleen is a great factor in the production of red blood corpuscles. In mammals, however, it generally plays no rôle whatever in their production. Nucleated red corpuscles are found in relatively large numbers in the mouse's spleen; in smaller number in the spleen of the rabbit; in that of the dog during the anæmia following hemorrhage; and in the human spleen only during leukæmia.

It appears as if the spleen of higher animals is a place for the destruction of blood corpuscles, especially those which have been partly destroyed. So Ponfick has found that in the destruction of red corpuscles the spleen takes up a part of the "shadows" of the red cells and produces a spleen tumor, and Ehrlich has found that the enlarged spleen in many infectious diseases is produced by the products of disintegrated leucocytes which are there accumulated. *Franklin P. Mall.*

Literature.

[1] Mall: The Johns Hopkins Hospital Bulletin, 1898, p. 218.
[2] Henle: Anatomie, ii., 575.
[3] Hoehl: His' Archiv, 1897, 138.
[4] Hoehl: Anat. Anz., xiv., 253.
[5] Oppel: Anat. Anz., vi.
[6] Mall: Amer. Jour. of Anatomy, vol. i.
[7] Calvert: Anat. Anz., xiii.
[8] W. Müller: Bau der Milz, 1865, S. 112.—Also Mall: American Journal of Anatomy, vol. ii.
[9] His: Zeit. für wiss. Zoologie, Bd. xi.
[10] Calvert: Anat. Anz., Bd. xiii.
[11] Thoma: Dorpater Naturforscher-Gesellschaft, Jahrg. 18; Verhandl. der anat. Gesellschaft, 1895.—Golz: Untersuchungen über die Blutgefässe der Milz. Diss., Dorpat, 1893.
[12] Jaschkowitz: Virch. Arch., xi.
[13] von Frey: Archiv für Physiologie, 1885, 539.
[14] Kölliker: Handbuch der Gewebelehre.
[15] Ehrlich: Die Anaemie, Vienna, 1898.

SPLEEN, DISEASES OF THE.—General Considerations.—Developmentally, the spleen belongs to the mesoblastic tissues. It is derived from the mesogastrium, and in its origin is closely related to the pancreas, but has none of the hypoblastic elements which enter into the formation of the latter. It first appears during the second month of fœtal life and develops slowly, so that it is not complete until nearly the end of that period.

Structurally, and, as will be seen later, to some extent physiologically, the spleen is closely allied to the lymphatic nodes or glands. The framework of the spleen is connective tissue, which is massed especially in the capsule, giving the general form of the organ; in the trabeculæ, which are processes running from the capsule into the substance of the viscus, and dividing it into smaller parts; and, finally, in a fine meshwork which fills these parts and divides them into minute spaces, the so-called pulp spaces of the organ. Connected with this fine connective-tissue meshwork are many stellate branching cells. The walls of the pulp spaces are lined with small or large endothelial cells. In the meshes of the connective tissue framework, that is in the pulp spaces, are great numbers of small round cells or lymphocytes. The blood supply is the splenic artery, whose main divisions run along the trabeculæ of the organ, then, subdividing into smaller branches, pass into the so-called pulp. Upon the walls of, or around, the smaller arterioles are clustered here and there masses of lymphoid cells which constitute the Malpighian bodies of the spleen. These bodies correspond in a general way with the lymph follicles of the lymph nodes, and the pulp spaces of the spleen correspond to the lymph sinuses of the nodes. The pulp spaces constitute the beginnings of the venous radicles of the organ, which gather up the blood to pass it on to the splenic vein. The nerves of the organ are derived from the cœliac plexus and the right vagus, and to some extent they accompany the branches of the splenic artery.

The size and weight of the spleen vary considerably even in conditions of health. During the first year of life it weighs from 15 to 20 gm., in adult life from 140 to 200 gm.

Anatomically the spleen stands in close contact with the stomach, and the blood supplies of the two are closely related. In some of its functions also it is associated with the stomach and liver. It is therefore not uncommon to find it classified as belonging to the digestive system.

From what has already been said with regard to the structure of the spleen, its close kinship to the lymphatic apparatus, and its anatomical relations to the digestive organs, we may expect that it will but rarely become the seat of primary disease, but that it will participate largely in systemic disorders and in local disturbances, especially those involving obstruction to the circulation in the portal system. In fact, apart from the extremely rare cases of primary malignant disease of the spleen, there are but two affections in which it appears to play the primary or chief rôle. These are the splenic form of leukæmia, and the disease or group of diseases which has lately been designated as splenic anæmia. It is, however, still an open question whether in either of these the rôle of the spleen is primary. We can only say that in some at least of the cases included in these categories such seems to be the case.

Abnormalities.—Absence of the spleen is met with in some cases of acephalic monsters and in premature fœtuses with imperfect development of the skull. Litten records two cases in which no spleen could be found in bodies otherwise perfect, but as one of them dates back to the sixteenth century, the condition must be an exceedingly rare one. Supernumerary spleens, on the other hand, are extremely common, being found in about one body in four. In number they vary from one or two up to forty. They are found near the hilus of the spleen, in the gastrosplenic omentum, in the great omentum, and even in the pancreas. In size they are usually small, 0.5 to 1 cm. in diameter, but they may reach considerable proportions. The absence of the usual symptoms after splenectomy in some instances has been explained on the basis of the presence of supernumerary organs.

A recent study by Parsons shows that there is great variation as to the number and arrangement of the notches and fissures of the spleen. On the anterior border he found that some spleens had no notch, while, when they were present, they varied from one to eight in number. About one-third of the specimens examined showed notches on the posterior border and one-fifth had fissures on the parietal surface.

Abnormal Placement.—Congenital abnormalities in the position of the spleen are observed in rare instances. The most interesting of these is the placement of the spleen in the right hypochondrium in cases of transposition of the viscera. The spleen may be found outside the usual limits of the abdomen in cases of large umbilical hernia, and has even been found in the left thorax in connection with defect of the diaphragm. Von Löwenwald records a case in which the spleen was found attached upon the spinal column.

Movable or Wandering Spleen.—The spleen is normally in position in the left hypochondrium, touching the ninth, tenth, and eleventh ribs, its long axis almost in the line of direction of the tenth rib, its upper and posterior end being about 2 cm. from the vertebral column and its anterior and lower extremity being about 3 cm. from the margin of the ribs in front. It is suspended by several folds of peritoneum, one passing from the greater curvature of the stomach to the hilus, another from the upper end of the spleen to the diaphragm, and a third from the diaphragm to the splenic flexure of the colon. The last of these suspends the spleen as in a sling and is its chief support.

The normal spleen enjoys a certain amount of mobility and may be depressed from above by effusions in the left thorax, emphysema, etc., or may be displaced upward by fluid in the abdomen or by distention of the colon with gas or fæces. In the condition of movable or wandering spleen, however, all the suspensory ligaments are lengthened or relaxed and the spleen is displaced downward into either the abdomen or the pelvis.

Etiology.—The condition may be one of the features of a general splanchnoptosis produced by trauma, such as sudden falls, or by lifting heavy weights, but is most commonly a result of the persistent dragging of an enlarged and heavy spleen upon its attachments, especially likely to be seen in such affections as malaria, leukæmia, or splenic anæmia.

Morbid Anatomy.—The spleen itself may present any one of the various types of chronic enlargement, or in rare instances it may be normal. The ligaments are all stretched, and with them the splenic artery and vein. The latter may be dilated to enormous size. The tail of the pancreas and the greater curvature of the stomach are dragged down with the spleen and deformity or dilatation of the latter organ may result. The pedicle of the spleen may become twisted upon itself with secondary atrophy of the organ, or even, in case of complete obstruction of the circulation, with gangrene.

Symptoms.—There may be no symptoms whatever, and the displaced viscus may be discovered by accident. There may be pain due to the weight and pressure of the spleen in an abnormal location, or dragging pain due to the stretching of the ligaments. In many instances the patients are neurasthenics and present characteristic symptoms of that disorder.

Diagnosis.—This rests upon two points: First, the recognition of a solid tumor in the abdomen or pelvis as the spleen; and, secondly, the demonstration of the absence of the spleen from its normal situation. The first is usually easy, if the possibility be present to the mind, the smooth, hard, rounded external surface, the sharp anterior border with its notch or notches and the rounded ends being characteristic. The second point depends upon the absence of splenic dulness in the left hypochondrium. Litten suggests the observation of the colon when distended with fluid, and then again evacuated as an aid to diagnosis, but this is not usually required

Treatment.—An abdominal bandage or binder may be sufficient to retain the spleen in its normal place; if not, operative measures are called for. A number of instances are on record of successful suturing of the spleen in its proper bed, but splenectomy seems to be the preferable operation.

Acute Hyperplasia of the Spleen; Acute Splenic Tumor; Acute Splenitis.—*Etiology.*—In all the acute infectious diseases an acute enlargement of the spleen may be met with, especially in malaria, typhoid, pyæmia, pneumonia, and the exanthemata. The exact significance of this change in the spleen has not yet been clearly determined. That in all cases of bacterial invasion of the blood the spleen plays the part of a filter is well known, and also that even in cases in which the bacteria are but rarely found in the blood, such as typhoid fever, they nevertheless abound in the spleen. We also know that in these cases there is always a more or less active hæmolysis going on in the spleen. So much is clear. The interpretation of these facts and many kindred ones developed by experimentation has furnished a difficult problem. Metschnikoff and his followers regard the spleen as a centre for the manufacture of phagocytes, and therefore as an active agent in the protection of the body against microbic invasions. Extensive experiments have been conducted upon normal and splenectomized animals to test the part played by the spleen in this relation. The results of such investigations as those of Kanthack, Tizzoni and Cattani, Blumreich and Jacoby, have been entirely indecisive of this question. Jawein has recently published the results of a long series of experiments, from which he concludes that the essential function of the spleen is one of hæmolysis, that its enlargement in the acute infectious diseases is in exact proportion to the extent of the hæmolysis occurring in each particular case, and that in the cases in which no hæmolysis occurs there is no splenic enlargement. After full consideration of all these data Rolleston concludes that the spleen in fact is and behaves like a lymphatic gland broken up and embedded in erectile tissue. The Malpighian bodies and adenoid tissue play much the same part that lymphatic glands do elsewhere, while the open, loose, vascular tissue of the organ serves rather as a filter in which various bodies are deposited by the blood, perhaps to remain, perhaps to undergo subsequent changes.

Morbid Anatomy or Pathology.—The spleen is regularly swollen, the capsule stretched, and in many instances it shows patches of thickening. The organ is usually soft, but may be even firmer than normal. On section the pulp is usually found to be deep red and soft, or even diffluent. In some instances the Malpighian bodies show more prominently than usual and the cut section at first sight looks as though studded with miliary tubercles; in other cases these bodies are quite obscured by the swelling and congestion of the pulp. Microscopical examination shows the enlargement to be due to congestion and swelling of the pulp or the glomeruli or both, together with some increase in cells. The chief increase is in cells resembling those of the normal splenic pulp, but multiplication of the living cells of the pulp spaces may be observed, as well as large multinucleated or ovoid and polyhedral cells whose origin is not clear. In some instances small areas of softening, looking like small abscesses, are met with. These are the so-called focal necroses seen also in the liver, kidneys, and lymph nodes in various infectious disorders.

Symptoms.—Apart from the change in size this affection is usually devoid of symptoms. In some instances, however, it is attended with a sense of weight, or distinct pain, in the left hypochondrium, and the organ itself may be tender to pressure. The enlargement of the spleen is detected by palpation, as a rule; but in some instances the spleen may be enlarged and yet not be palpable. In such cases the results of percussion must be relied upon, but they are always very uncertain and often deceptive.

Treatment.—From what has been already said it is apparent that acute hyperplasia of the spleen is in itself a symptom of many disorders, not a primary disease. The treatment of the primary affection is all that is required.

Chronic Hyperplasia of the Spleen.—*Etiology.*—Chronic hyperplasia of the spleen, like the acute affection, is not a primary disorder but a symptom seen in a variety of affections,—congenital or acquired syphilis, rickets, prolonged fevers especially typhoid,—and most of all, in chronic malaria and in leukæmia or pseudoleukæmia. The enlargement observed in the affection known as splenic anæmia will be considered elsewhere.

Pathology.—As a rule the enlargement of the spleen in this condition is marked, amounting in some instances to an increase of ten or fifteen times the weight of the normal organ. The spleen may, however, be but little larger than normal. The enlargement is usually symmetrical, so that the organ preserves in general the normal outline, and the notches and fissures can be seen or felt. The organ is usually harder than normal, and the change of consistence may be very marked. The capsule may show some patches of thickening, or in many instances it is generally thickened and a chronic perisplenitis with adhesions to the surrounding parts, the diaphragm, abdominal wall, intestines, stomach, etc., is a feature of the condition. The appearances upon section vary greatly. As in acute hyperplasia, the Malpighian bodies may be lost in the swelling of the pulp, but more often they are notably enlarged and prominent. The color may be uniformly dark, deep brown, or even black, but is more frequently mottled, red, and gray. The trabeculæ may be thickened to such an extent that they are readily visible as bands of fibrous tissue running in from the capsule of the organ and interlacing in a complicated network. Pigment may be collected in such masses as to be visible.

The microscopical picture varies even more than the gross. The enlargement may be due to uniform hypertrophy of both the pulp and the reticular tissue, but in most cases the increase in fibrous tissue is the more striking feature of these cases. The trabeculæ may show extreme hypertrophy, and even the meshwork of the pulp may be greatly thickened. The glomeruli may in some cases be enlarged, while in others they are almost obliterated by the hyperplasia of the pulp cells and the connective tissue. The endothelial cells of the pulp spaces may show increase both in size and in number. Pigment is often found in the cells, either of pulp or glomeruli, and even in the connective-tissue reticulum. This pigment regularly gives the reaction for hæmosiderin, and is, therefore, probably a derivative of the hæmoglobin of the blood.

Symptoms.—The symptoms of chronic hyperplasia of the spleen are those of enlargement of the organ, or are disturbances secondary thereto.

A sense of weight or oppression in the left hypochondrium is most common; this rarely amounts to positive pain. By pressure upon the stomach nausea or vomiting may be induced, and in some instances vomiting of blood in considerable quantities occurs. Any of the abdominal viscera may be disturbed in function by the pressure of an enlarged spleen, and at least one case is on record in which the pressure upon the uterus resulted in hemorrhages, which were attributed to fibroid tumor of that viscus. The enlargement of the spleen may cause it to fill the left hypochondrium, or the whole left half of the abdomen, or even to pass over into the right half and occupy the right iliac fossa as well. As has been already noted, the enlargement is regularly symmetrical, the spleen maintaining its accustomed shape, the anterior edge being sharp and notched and the lower end rounded, so that it is easy to recognize the tumor as the spleen.

Treatment.—As with the acute enlargement, treatment must usually be directed to the underlying complaint—syphilis, rickets, malaria, or the blood diseases. By such means the enlargement may be reduced to some extent; but if true fibrous hyperplasia or hypertrophy has taken place, the organ cannot return to a normal size. Usually the improvement produced by medicinal treatment is slight. An abdominal belt, properly fitted, will sometimes relieve distress of an enlarged spleen by supporting it.

In the more serious cases splenectomy may be required, but it is astonishing how little disturbance patients may have from a spleen large enough to fill the whole left half of the abdomen, without any treatment.

Rupture of the Spleen.—*Etiology.*—Rupture of the spleen is a rare occurrence. It may occur in a normal organ, but is relatively much more frequent in the enlarged spleen of malaria, typhoid, or the blood diseases. In the case of a normal spleen considerable violence to the abdomen is required to rupture the organ. It has occurred in cases of severe falls or blows upon the abdomen or of crushing of the body by great weight, such as the passage of a vehicle over it. In the case of an organ already enlarged by disease, rupture may occur spontaneously or as the result of slight violence. The explanation of this fact is not difficult in view of the pathological changes. Rupture seems to be especially common in malarial spleens, and for this reason is much more frequently observed in the tropics than in the temperate zones. Playfair is said to have seen twenty cases of rupture of the spleen during two and a half years in the East Indies. In one case within the writer's knowledge the enlarged spleen of a primary splenomegaly (splenic anæmia) was ruptured by a slight fall upon the abdomen.

Pathology.—The spleen may be torn in various directions. There seems to be no rule as to the location or extent of the tears which are often multiple. Usually the capsule as well as the substance of the organ itself is torn, and the escaping blood is poured into the abdomen. The tear may be in the pulp alone, the capsule remaining intact, and the hemorrhage being into the organ itself. In case of extensive adhesions of the spleen to the neighboring viscera and parietes, the hemorrhage may be encapsulated and so prevented from entering the peritoneal cavity. Litten says that when the spleen is adherent to the stomach or intestines, rupture may occur in such a way that the blood is poured into one or both of these parts. Rupture of the spleen is frequently associated with rupture of other viscera, most often the liver.

Symptoms.—These are essentially those of any abdominal injury associated with internal hemorrhage. There is usually severe pain referred to the splenic region, then the symptoms of profuse hemorrhage—pallor, rapid and feeble pulse, air-hunger, faintness or unconsciousness, possibly vomiting, and in some instances convulsions. The diagnosis is not likely to be made until the abdomen is opened, unless the presence of an enlarged spleen has been previously known and the location or nature of the operative violence be such as to suggest the result.

Treatment.—The only treatment must be laparotomy with suture or packing of the wound in the organ, or splenectomy. In a case recently reported by Eisendrath, attempts to suture a rupture of the spleen failed because the sutures would not hold in the softened substance of the organ and splenectomy had to be performed. The accident is generally fatal, but a few instances of successful operation are on record.

Infarcts of the Spleen.—Infarction of the spleen may arise either by the plugging of a splenic artery by a thrombus derived from some other part of the body, or by a local thrombosis. The thrombi which are carried to the spleen by the circulation have their origin in almost all cases in an endocarditis affecting the left side of the heart and resulting in the formation of thrombi upon the diseased valves. In some instances atheroma of the aorta may be the underlying process. Litten mentions the possibility of air or fat emboli, derived in one case from the opening of a vein and in the other from a broken bone, passing the capillaries of the lung and ultimately lodging in the spleen; but such occurrences, though possible, must be rare indeed.

As a result of an endarteritis of a branch of a splenic artery or vein, thrombi may form in the spleen itself, and either block the vessel at their point of formation or be carried farther to act as emboli in some of the smaller branches of the artery.

Pathology.—As the result of the occlusion of a branch of the splenic artery we have the circulation cut off from the area supplied by the artery in question. The resulting infarct usually appears as a wedge-shaped area in the periphery of the spleen, the base often being on the surface of the organ, paler in color than normal, and surrounded by a deeper zone of hemorrhage. The paler color is due to the death of the cells of the infarcted area, which undergoes the process of degeneration commonly termed coagulation necrosis, and becomes the so-called white infarct. Later, the degenerated cells are absorbed or replaced by connective tissue, and only a scar is left to mark the site of the infarct.

It was formerly supposed that the whole infarcted area immediately after the arrest of the circulation became charged with blood by an inflow from the veins, and that this blood was later absorbed to give rise to the appearances of the white infarct, but Litten has proved this not to be the case.

The deep red granular infarctions in which the tissue is found infiltrated with red cells as in an apoplexy Litten finds to be produced most often by a thrombosis in one of the branches of the splenic vein. They, therefore, do not represent a stage in the life of the ordinary infarct, but a condition due to a somewhat different process. In either case the terminal condition remains the same.

The most important question from the clinical standpoint with respect to these infarcts is whether they are septic or aseptic. If aseptic, the process follows the course indicated above. If septic, in which case they have developed usually in the course of a pyæmia or a malignant endocarditis, the infarct undergoes suppuration and an abscess of the spleen results.

With either of these two forms there is usually associated more or less perisplenitis, the greater development of this feature being, of course, seen in the suppurative cases.

Symptoms.—Localized pain, sometimes quite sharp at the time of the lodgment of the thrombus, swelling of the spleen, and in some instances a localized friction rub to be heard over the spleen are the only symptoms of the condition.

Treatment.—There is no direct treatment of the condition, and, as a rule, none is required. The cases of suppuration will be considered under abscess.

Abscess of the Spleen.—The chief cause of abscess of the spleen, as indicated in the last section, is the lodgment of an infected thrombus, derived most often from an ulcerative endocarditis or from some pyæmic focus. Abscess of the spleen may, however, arise from the extension of a suppurative inflammation from some neighboring organ or from the perforation of a gastric ulcer. It is also met with, probably from the formation of infected thrombi, in cases of typhoid, typhus, and, most especially, recurrent or relapsing fever. Abscess of the spleen is also said to have developed in malarial fever; but if so, it must have been due to a secondary infection. Some cases of abscess have been attributed to injury, and in other cases no definite cause of the abscess formation could be disclosed.

Pathology.—The majority of the abscesses of the spleen are small. If multiple, they are scattered through the organ and the intervening tissue is but little changed. Larger abscesses may, however, form, and in some instances the organ is reduced to a sac of pus. Such an abscess has been known to rupture into the stomach, the colon, the peritoneal cavity, or through the diaphragm into the pleura; or, if the lung is adherent, even into the lung itself.

Symptoms.—Many of the smaller abscesses of the spleen, especially if deeply placed, run their course without definite symptoms. With the larger abscesses, particularly those on the surface, there may be pain and tenderness in the region of the spleen, enlargement of the organ, and the irregular or intermittent fever of septic conditions. If the abscess be very large, it is possible that fluctuation may be obtained. In doubtful cases exploratory puncture may be required, but it should be resorted to only in extreme cases. If the abscess rupture, symptoms will depend upon the course which the pus takes, that is, whether it enters the peritoneum or discharges into the stomach, colon, pleura, or lung.

Treatment.—Naturally the treatment of this condition is purely surgical. In rare instances repeated aspiration has been successful. In the majority of cases incision and drainage are required. In some few cases splenectomy has been performed for this condition.

Splenic Anæmia.—Clinical interest in affections of the spleen at present centres in the question whether there is a definite symptom-group which can be denoted by the title splenic anæmia. After a thorough consideration of all the data obtainable Osler concludes that from among the conditions with which anæmia and enlarged spleen are associated a well-defined disease may be separated and may well be designated as chronic splenic anæmia. Various other names—splenic pseudoleukæmia, splenic lymphadenoma, splenic cachexia, primitive splenomegaly, and Banti's disease—have been proposed for the disease, but for many reasons the simplest designation seems the best. The description which follows is taken from Osler's recent review of the subject.

Incidence.—The affection is a relatively rare one. Rolleston records thirty-seven cases. Osler by inquiry among the members of the American Association of Physicians secured the details of twenty-six cases which could be grouped under this title, and has reported fifteen cases which he himself has observed. A few other cases which possibly belong in this category have been reported by Harris and Herzog, Brill, Field, and the writer.

Etiology.—In this relation the striking thing is that no adequate explanation of the affection can be had. There is no malaria, no syphilis, no tuberculosis, no leukæmia, in short, no apparent cause for the splenic enlargement. C. Wilson has reported a family in which in three generations six members had enlarged spleen. Collier and the writer have each reported two cases in sisters, and Brill three cases in one family. In none of the other reported cases is there any family history.

Symptomatology.—The symptoms of the affection may be briefly summarized as a remarkably chronic and often enormous enlargement of the spleen, associated with more or less marked anæmia, frequently accompanied by hæmatemesis and pigmentation of the skin, and in a few cases showing jaundice or ascites at a late stage. The splenic enlargement may exist for five, ten, even twenty-five years. The size of the spleen varies greatly, but in many instances the spleen is huge. In one of the writer's cases a girl, weighing seventy-two pounds, had a spleen weighing twelve and a half pounds. With this enormous enlargement the spleen retains its general shape, the edge remains distinct, and the notches in the anterior margin can be readily felt. Even with very large spleens the patients, as a rule, have no great pain, but complain only of a sense of weight and pressure or occasional dragging in the left side. As the organ enlarges, it emerges from beneath the left costal arch, gradually fills the left hypochondrium, then extends downward, filling the whole left half of the abdomen, and finally may pass the middle line and fill the right iliac fossa.

The anæmia which accompanies the condition is usually of a moderate grade. Of Osler's cases the average count of the red cells was 3,425,000 per cubic millimetre, the average hæmoglobin estimation forty-seven per cent. The hæmoglobin is relatively lower than the count of the red cells. The leucocytes occasionally show an increase, but are generally below normal. The differential count of the leucocytes shows nothing characteristic.

The pigmentation of the skin occurs in most of the cases, especially those of long standing. It is a general diffuse bronzing, especially upon the exposed parts of the body, very closely resembling that seen in Addison's disease.

In many of the cases the liver is notably enlarged, but without definite disturbance of its functions; in other cases the enlargement is associated with signs of obstruction and the cases suggest cirrhosis of the liver with secondary enlargement of the spleen. Ascites and jaundice, when they do occur, are terminal events in the development of the disease.

Pathology.—In this regard two quite distinct conditions have been observed. In one there is a chronic hyperplasia of the spleen with increase of connective tissue, atrophy of the pulp, and degeneration of the Malpighian bodies. In the other group, which has usually been described under the title of primary splenomegaly, the spleen is enormously enlarged, the fibrous hyperplasia is excessive, but in addition there are irregular spaces, apparently the enlarged and deformed spaces of the splenic pulp, filled more or less completely with very large endothelial cells, having clear protoplasm and two or more nuclei, with occasional giant cells. In the original description of Gaucher the condition was termed a primary epithelioma. The writer, after careful study of many sections from his case, concluded that the condition could not be regarded as a new growth, but was an unusual form of hyperplasia of the organ. In this view he has been supported by Harris and Herzog, although these observers do not agree in the view that the endothelial cells, which form so striking a feature of the picture, may later undergo transformation into fibrous tissue. A similar structure has been observed by Picou and Ramond, Collier, Harris and Herzog, and Banta. A remarkable feature of the writer's case was the marked pigmentation found in the spleen, retroperitoneal lymph nodes, and the liver. The lymph nodes also showed changes analogous to those in the spleen, and in the intralobular connective tissue of the liver there were groups of cells closely resembling the large endothelial cells of the spleen. As a rule the changes observed in the liver are those of a simple cirrhosis. The enlargement of this organ may be marked, but is not nearly so striking as that of the spleen.

Moderate enlargement of both external and internal lymph nodes is found in some of the cases, but this enlargement is not comparable to that of leukæmia or pseudoleukæmia.

Treatment.—The only treatment so far found effective in these cases is the removal of the spleen. Sippy tabulated seven splenectomies for this condition, to which Harris and Herzog have added twelve. Out of the total of nineteen, fourteen recovered and five died. In the majority, at least, of the recoveries the condition has been completely relieved by the splenectomy. Osler regards recurrent hæmatemesis as the most important indication for operation.

Tumors of the Spleen.—Although the spleen is frequently involved secondarily in cancer and sarcoma, primary tumors of the spleen of any form are exceedingly rare. Both solid and cystic tumors have, however, been met with. Among the cystic tumors Litten distinguishes three groups: (1) Uni- or multilocular cysts of non-parasitic origin, including serous, blood, and lymph cysts; (2) echinococcus cysts; (3) dermoid and atheromatous cysts. These are very rare. Among 235 cases of echinococcus of the abdominal organs Finsen found the spleen the seat of the parasite in only 2, and Neisser in 900 cases of echinococcus collected from literature found 28 cases of echinococcus of the spleen. The only peculiarity of these cystic tumors is the sense of fluctuation which may be obtained upon palpation. Naturally this can be had only when the cyst has reached a considerable size. In the case of echinococcus it is claimed by some that a peculiar hydatid crepitation may be obtained upon palpation, but so great differences of opinion as to its occurrence exist, even among those who have had opportunity to study these cases, that one must doubt the value of the phenomenon in diagnosis.

Fibroma, cavernous angioma, and lymphangioma of the spleen have all been observed, but are all exceedingly rare. Carcinoma, so frequent secondarily in the spleen, is almost unknown as a primary growth. Litten says that there are ten primary cases recorded in literature.

Primary sarcoma is also very rare, secondary sarcoma of the spleen not very uncommon. A number of cases of removal of sarcomata of the spleen are on record.

The symptoms and diagnosis of these various tumors present no unusual features by reason of their occurrence in the spleen.

The only treatment must be the removal of the organ.

With the recent advances of surgery removal of the spleen has become much more frequent, and has been attended with much greater success than was formerly had. For the details of the operation and its results one may refer to the elaborate articles of Jonnesco, Bessel Hagen, Warbasse, Bolton, and Warren. From the standpoint of medicine the interest of splenectomy lies in the effects produced upon the organism by the operation, and the light which is thereby thrown upon the function or lack of function of the spleen. (*Cf.* also the following article.)

Effects of the Splenectomy in Animals.—Ewing briefly summarizes the results of the work of several observers as follows: Splenectomy in animals is followed by moderate reduction in red cells lasting for from one to twelve months, by relatively greater loss of hæmoglobin more slowly restored, and in some cases by the appearance, during the first year, of megalocytes. Leucocytosis follows the operation, but its extent and duration are very variable. A polynuclear leucocytosis is observed during the first days or weeks, followed by relative or absolute lymphocytosis during the first year, while during the second year distinct eosinophilia may be observed.

With these changes in the blood are associated marked cellular hyperplasia of the marrow, approaching at times that of leukæmia, and often also affecting the lymph nodes. In the swollen nodes an excessive number of nucleated red cells have been found by Winogradoff, Tizzoni, Gibson, Komloff, and Grünberg.

Effects of Splenectomy in Man.—Ewing also gives a résumé of this subject. In comparatively healthy subjects splenectomy has often been performed without affecting the blood more than does any other laparotomy. In many graver cases the loss of blood and the shock of operation give rise to a considerable grade of secondary anæmia. The red cells in favorable cases are restored in from one to three months, but in less favorable cases there may be more persistent anæmia. The restoration of hæmoglobin seems to fall behind the improvement in cells rather more than in most secondary anæmias. The operation is usually followed by considerable polynuclear leucocytosis (15,000 to 50,000) which commonly lasts from two to six weeks, but may continue for months, in which case the polynuclear cells may be largely replaced by lymphocytes. Eosinophilia has been observed in a few cases in the second and third years.

In traumatic cases suffering from large hemorrhages splenectomy, especially when complicated by infection, may lead to very profound anæmia, marked by extreme loss of red cells, the presence of very many large, pale, sometimes polychromatic, and dissolving red cells, nucleated red cells, and to a high grade of leucocytosis. Among the leucocytes there may be a considerable proportion of large, pale mononuclear cells and myelocytes, so that the blood resembles that of acute leukæmia. This condition, however, is transitory and the blood may improve rapidly.

Leukæmia and amyloid degeneration of the spleen are contraindications to splenectomy. In other conditions the choice of operation may depend entirely upon the general condition of the patient. Beyond a moderate persistent leucocytosis or lymphocytosis, and possibly a slight delay in the restoration of hæmoglobin, there are no specific effects of splenectomy in man.

It therefore appears that whatever the function of the spleen, the organ is not indispensable, and its functions may, in case of need, be performed by other parts or organs. The changes found in the bone marrow and in the lymph nodes of animals after splenectomy suggest that it is these parts that are called upon for extra work, and indicate in this way that the functions of the spleen must be, in part at least, those of the marrow and lymph nodes.

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REFERENCES.

Prudden and Delafield: Pathological Anatomy.
Stengel: Diseases of the Spleen. Twentieth Century Practice of Medicine.
Rolleston: Allbutt's System of Medicine, vol. iv.
Litten: Die Krankheiten der Milz, 1898.
Osler: Splenic Anæmia. Am. Journ. Med. Sc., vol. cxxiv., 1902.
Jonnesco: Ueber Splenectomie. Arch. für klin. Chir., Bd. lv., 1897.
Bessel Hagen: Beitrag zur Milzchirurgie. *Ibid.*, Bd. lxii., 1900.
Warbassi: Annals of Surgery, vol. xx., 1894.
Bolton: *Ibid.*, vol. xxxi., 1900.
Warren: *Ibid.*, vol. xxxiii., 1901.
Ewing: Clinical Pathology of the Blood.
Jawein: Ueber die Ursache des acuten Milztumor. Arch. für path. Anat., 1900.
Harris and Herzog: Splenectomy in Splenic Anæmia, or Primary Splenomegaly. Annals of Surgery, July, 1901.
Field: A Case of Banti's Disease. Am. Jour. Med. Sc., March, 1903.
Bovaird: Primary Splenomegaly. Am. Jour. Med. Sc., October, 1900.

SPLEEN, SURGICAL AFFECTIONS OF THE.—Surgical interest in the spleen is increasing, for of late years quite a number of operations have been performed upon it on account of traumatism, abscess, inflammatory enlargement, tumor, or displacement.

ANATOMY.—The spleen is placed between the ninth, tenth, and eleventh ribs, being separated from them by the diaphragm, and in its upper portion also by the lung. In gunshot wounds of the spleen, therefore, the pleural cavity is frequently opened, and an abscess of the spleen may easily break into the pleural cavity. It is held in position by a suspensory ligament which attaches it to the diaphragm, and also by an extension of the greater omentum from the spleen to the stomach, which is called the gastro-splenic omentum. Behind this membrane is situated the splenic artery with its numerous branches and the splenic vein. Any incision which is made use of to expose the spleen sh uld give the surgeon easy access to these ligaments, in order that he may control hemorrhage when the ligaments are cut. Various incisions have been employed: for example, a vertical incision along the outer border of the rectus muscle, combined if necessary with a transverse incision parallel to the costal margin; or a lumbar incision similar to that employed for operations upon the kidney. In some cases it is necessary to resect portions of the ribs and reach the upper end of the spleen through tee pleural cavity.

Traumatism.—The spleen, especially if enlarged by disease, may be ruptured subcutaneously. It may also be injured by incised, gunshot, and stab wounds. If the capsule is not torn there may be hemorrhage into the substance of the spleen, producing a large hæmatoma with subsequent cyst formation. But usually the capsule is also ruptured and there is profuse bleeding into the peritoneal cavity. The chief symptoms are those of internal hemorrhage, the source of which is not likely to be suspected except in case of open wounds. A portion or the whole of the spleen may prolapse into an open wound.

The treatment is free exposure of the organ, repair of its injuries, if slight, and removal of the spleen if the injuries are extensive. Partial splenectomy has been performed, but in most cases it is more dangerous than total splenectomy; and, since the removal of the spleen has little or no permanent effect upon the health of the individual, partial resection of the organ should generally not be performed.

The mortality following removal of the spleen after traumatism is about forty per cent. for one hundred and thirty operations, two-thirds of which were performed previous to 1900. The mortality of forty-five cases treated in 1900–1901 was only twenty-eight per cent.

Abscess.—Abscess of the spleen is usually secondary, occurring in connection with endocarditis, pyæmia, typhoid fever, acute rheumatism, malaria, etc. Primary abscess may develop in a contusion of the spleen due to traumatism. Some splenic abscesses produce marked septic symptoms and terminate fatally in a short time. Others run a chronic course, the pus breaking through the capsule of the spleen and burrowing in various directions.

The proper treatment, if a diagnosis can be made, is to expose the spleen and open the abscess. If one has to pass through the peritoneal cavity to reach the spleen, it is better to fix the organ in the abdominal wound and to wait the formation of adhesions before opening the ab scess. The pleural cavity should be protected in a similar way if the incision is made high up. If the spleen is in large part destroyed it should be removed.

Cysts.—A blood clot in the spleen may become transformed into a serous cyst and the spleen may be the seat of an echinococcus cyst. Such cysts should be incised and drained, or, if the spleen is badly affected, it should be removed.

Solid Tumors.—Benign tumors of the spleen are extremely rare. The occurrence of primary carcinoma is doubtful. Metastatic carcinomatous nodules occur in the spleen, but are without surgical interest. Melano- and lympho-sarcoma are the two forms of solid tumor oftenest found. The chief symptoms are a rapid increase in the size of the spleen, with pain, in a person with no history of malaria and whose blood is unaltered. The treatment is splenectomy, which, in nine cases recently reported, had a mortality of thirty-three and one-third per cent.

Enlargements from Leukæmia, etc.—The spleen may become so hypertrophied in leukæmia, malaria, syphilis, tuberculosis, amyloid disease, interstitial hepatitis, etc., that by its very size it causes the patient great inconvenience. The removal of a leukæmic spleen is usually followed by death from hemorrhage, while the few patients who have survived the operation have not been benefited by it. In the other diseases mentioned the spleen has been successfully removed. But little benefit is to be expected from this operation if the patient is greatly weakened by a serious constitutional disorder.

Splenectomy performed upon malarial patients whose general condition is fairly good is an operation which, according to Bessel-Hagen, has a mortality of less than nine per cent., and by which many patients have been improved, although they are not protected from further malarial attacks.

Movable Spleen.—Like the other abdominal organs, the spleen may acquire an undue amount of mobility. Hypertrophy usually accompanies this condition. Like a movable kidney, it can usually be replaced, but it will not remain permanently in its proper position unless it is fixed there by adhesions. It may be found in the left iliac fossa, or even in the right iliac fossa or pelvis. It does not usually produce symptoms sufficient to render operation advisable.

A movable spleen may be sutured to the abdominal wall or it may be removed. Sutures do not hold well in its capsule, and for this reason Rydygier makes a pocket between the anterior parietal peritoneum and abdominal muscles into which he slips the movable spleen. If the movable spleen is diseased or its pedicle has become twisted it is better to remove it, since splenectomy under such circumstances has only a slight mortality and produces a radical cure.

Edward Milton Foote.

SPLINTS. See *Dressings, Surgical.*

SPONDYLOLISTHESIS. See *Spine, Diseases of.*

SPONGE.—(*Éponge fine*, Codex Med.) The household articles known by this name are the horny or silky skeletons of several species of invertebrate animals belonging to the order *Ceratosa*, in the great group *Parazoa* or *Spongiæ*. The commercial sponges are colonial in their composition, although the outlines of individuality are very obscure. They are soft, porous, gelatinous bodies, perforated by numerous openings communicating with irregular, ramifying cavities within them, as well as with digestive and respiratory chambers, and more or less regular tubes or canals. These minute chambers are lined with flagellated cells, which are probably the organs of nutrition as well as those by whose movements a constant stream of water is kept flowing into the sponge through the fine pores and out through the larger openings. Sponges are all aquatic, and those of commerce all of marine origin, growing upon rocks or other firm foundation, at a depth of from six to a hundred or more feet below the surface of the water. They are of slow growth, requiring from three to six years to attain a useful size. The mode of collection varies with the depth at which they are found, as well as with the habit and outfit of the collector; sometimes they are torn off the rocks by tongs or hooks, sometimes dredged for, but more generally they are gathered by divers from boats; these again may go down unprotected for three or four minutes at a time, or, equipped with modern diving-suits, make longer and deeper searches. Finally, the cultivation of sponges by fastening bits upon boards or sticks, and then sinking them to the bottom, has been proved practicable. When the sponges have been brought to land they are rubbed with sand or bruised to break up the soft parts, or exposed to the air until decomposition sets in, and then repeatedly washed and squeezed until they are clean and dried. Upon being marketed, they are carefully trimmed and assorted, according to kind, fineness, size, and shape, into numerous grades.

There are several distinct kinds, dependent upon the species producing them:

1. The *Levant* or *Turkey Sponge*, from *Euspongia* (*Spongia*) *officinalis* Linn., the finest and most expensive of all, from the waters surrounding the Grecian Islands, Asia Minor, Syria, etc. It has a soft, fine, very elastic texture, a light color, and great toughness of fibre. In shape it is rounded, tuberculated, lobed, hemispherical, cup-shaped, or irregular; it is very free from its gelatinous flesh when prepared for the market.

2. The *Zimocca Sponge*, from *Euspongia Zimocca* O. Schmidt; also a fine, strong, valuable sponge, but harsher to the feeling than the preceding, and not nearly so expensive.

3. The *Mediterranean Bath Sponge*, from *Hippospongia equina* O. Schmidt; in large, soft, rounded masses, with a loose texture and very large reticulating canals.

Besides these, this country is supplied in great abundance with cheap sponges from the West Indies; they are very inferior in texture and durability to the Mediterranean products: they are:

4. The *Reef Sponge*, *Euspongia officinalis tubulifera*, the common, cheap, fine "slate sponge." It is coarser, less elastic, and very much more tender than the Turkey sponge, and is of more or less conical shape, with a broad, cut base.

5. The *Sheepswool*, *Velvet*, and *Grass Sponges*, from various species of *Hippospongia*.

Composition.—Sponges contain a considerable quantity of fine sand, and sometimes pebbles, entangled in their meshes, which can generally be removed by mechanical means; there is also a varying amount of calcareous concretions or fragments, which stick more tenaciously and often have to be dissolved by dilute acid. These being removed, the remainder is nearly all a peculiar elastic, durable, nitrogenous substance called *spongin*, closely related in composition and texture to silk. Besides this, there are a little iodine, bromine, salt, etc.

Uses.—These are mostly mechanical, and familiar to every one. Carbonized sponge, *Spongia usta*, now obsolete, used to be given for the same conditions for which iodide of potassium is now used, and owed its value to the presence of that element.

In surgery, sponges were for a long time used for packing and dilating cavities, and as absorbers of blood in operations, but the general acceptance of aseptic methods in surgery has caused them to be looked upon less favorably than formerly. For surgical operations the fine, soft, Turkey sponges, though dear, are the best.

Sponge tents, now but little used, are made by soaking fine, tough sponge in melted cacao butter, or in mucilage or alcohol, and winding very hard to a cylindrical shape with strong twine; when dry or cold the cord is removed and the surface is filed or pared to shape.

Ether sponges are fine Turkey sponges of large size, requisite fineness, and of a regular cup-shape. No inhaler has yet been made so safe or comfortable to the patient as these, but they are wasteful of ether.

W. P. Bolles.

SPRAINS. See *Joints, Injuries to.*

SPRENGEL'S DISEASE. See *Chest, Deformities of.*

SPRING LAKE WELL.—Ottawa County, Michigan.

POST-OFFICE.—Spring Lake. Hotel.

Spring Lake is a station on the Detroit and Milwaukee Railroad, three miles east of Grand Haven. The town is located on a beautiful sheet of water of the same name, five miles long and one mile wide. The resort owes its rise to the citizens of Chicago, who frequent it in considerable numbers (Walton). The following analysis was made by Prof. C. G. Wheeler: One United States gallon contains (solids): Sodium bicarbonate, gr. 0.05; calcium bicarbonate, gr. 0.13; magnesium bicarbonate, gr. 0.01; iron bicarbonate, gr. 1.01; sodium sulphate, gr. 46.70; sodium chloride, gr. 405.53; potassium chloride, gr. 4.29; manganese bicarbonate, gr. 0.05; calcium chloride, gr. 113.42; magnesium chloride, gr. 36.20; bromides, gr. 2.17; organic matter, gr. 18.29; and small quantities of lithia, alumina, silica, and ammonia. Total, 628.37 grains. In chemical composition this water resembles that of the Elisenquelle, of Kreutznach.

James K. Crook.

SPUNK.—*Fungus Chirurgorum*, Ph. G.; *Agaric de Chêne*, Fr. Cod.; *Surgeons' Agaric, Touchwood*, E.; *Amadou*, Fr. The prepared tissue of *Polyporus fomentarius* or of *P. igniarius* Fries (fam. *Agaricineæ*). These are rather large species of fungi, parasitic upon the trunks of forest trees, especially of oaks and beeches. They are attached by broad bases and expand horizontally in large, roundish, hoof-shaped masses of corky texture and reddish or grayish-brown color. The upper surface is convex and marked by a series of distinct concentric rings, each indicating a year's growth. The under side is flat. The first-named species is said to yield the best product. The fungus has its upper and lower surfaces trimmed off, is softened in water, beaten with a wooden mallet into a tough, soft, and flexible buckskin-like sheet, and dried. In this condition it will absorb more than twice its weight of water. The uses of spunk are purely surgical. Before the days of modern styptic and absorbent appliances, it was largely depended upon for checking hemorrhage, through its mechanical properties, as lint and similar substances are now used. Its softness and flexibility also adapted it well to use for padding purposes. In this country its use has almost entirely ceased.

Soaked in a solution of nitre or chlorate of potassium, it becomes very inflammable, and such a preparation was enormously used as tinder before the days of matches.

W. P. Bolles.

SPUTUM is the term employed to designate the portion of the expectoration that is derived from the trachea, bronchi, and their ramifications. It is sometimes used to include the secretions from the upper air passages, and even to include the saliva and buccal secretions; it is better, however, to employ the term expectoration to designate the collective material discharged from the mouth and to use the term sputum in the restricted sense above indicated.

For its *collection*, special receptacles are provided. The simple paper spit-cups are inexpensive and convenient; there are also metal cups adapted for carrying in the pocket. For the hospital ward a simple porcelain cup is much used. The principle to be observed in disease is that all the expectorations shall be collected and disinfected or destroyed by burning. This is particularly important in the case of tuberculous sputa, the dried particles of which are so apt to become mingled with the dust in the air and infect those who inhale them.

The *amount* of the sputum in health is very small, scarcely more than a few cubic centimetres in twenty-four hours, while in disease it may increase up to 1,000 c.c. or more. The amount and character are dependent on the nature and extent of the disease process, a fact which renders observations of the sputum of value in clinical practice.

As regards *appearance*, sputa, if homogeneous, are recognized as mucoid, purulent, serous, or sanguineous, for reasons which these terms suggest. Most sputa, however, are admixtures of two or three of these types and are designated accordingly; *e.g.*, the muco-purulent sputum in many cases of bronchitis.

The consistence varies from liquid to extremely tenacious, according to the amount of mucus; serous and hemorrhagic sputa and purulent sputum, when composed of pure pus, are liquid, while a pure mucoid sputum exhibits a high degree of tenacity. I do not know that it has been determined whether the albuminoid basis is true mucin, as in saliva, or a nucleo-proteid.

The *color* of sputa is subject to great variation. If mucoid in character, they are transparent and nearly colorless; when the number of leucocytes is considerable they are opaque, yellowish, or, in case of nearly pure pus, greenish at times from the presence of the Bacillus pyocyaneus. This latter color may also be imparted by bile pigment in icterus and in perforation of a liver abscess into the lung; if the abscess is amœbic, the sputa have the color of anchovy sauce; unchanged blood imparts various degrees of reddish coloration, which may be characterized as rusty, prune-juice, bright or dark red, according to the condition; methæmoglobin, hæmatin, and hæmatoidin formed by decomposition of the hæmoglobin, impart colors varying from bread crust to chocolate or brownish-red. Sometimes decomposed blood gives a greenish or yellowish hue.

Pure mucoid, serous or sanguineous sputa are usually without *odor*, but where there is admixture of purulent products a slightly sweetish odor is observed; while in sputa containing pure pus and products of putrefactive decomposition a fetid odor is present, sometimes exceedingly offensive.

Macroscopic examination may be conducted by observing the material, spread in a thin layer, either between glass plates or in a petri dish, against a dark background.

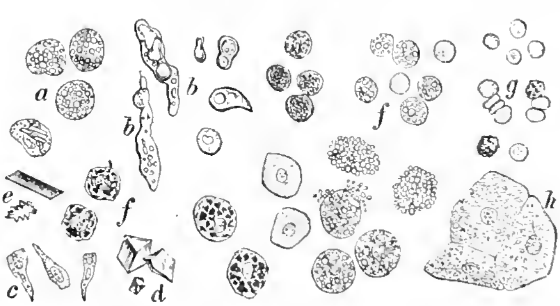


FIG. 4468.—Cells and Crystals of the Sputum. *a*, Alveolar epithelia; *b*, myeline drops; *c*, ciliated epithelia; *d*, calcium carbonate crystals; *e*, hæmatoidin; *f*, leucocytes; *g*, red blood corpuscles; *h*, squamous epithelia. (Magnified.)

In this way fragments of lung tissue, elastic fibres, fibrinous casts, spirals, and particularly the cheesy masses of tuberculosis and actinomycosis may be observed. For the recognition of spirals and casts of the bronchi it is also of service to observe the sputum when suspended in a considerable quantity of water.

Microscopic examinations are conducted: (*a*) By the direct examination of selected portions under the microscope, a procedure particularly valuable in examinations for crystals, the various epithelia, and for pus. (*b*) By the examination of the sediment obtained by centrifugalizing the sputum after it has been diluted with an aqueous solution of sodium hydroxide (about two- or three-per-cent. strength), and warmed. This sediment is especially adapted for the detection of elastic fibres. (*c*) By the examination of stained smears, which may be prepared as follows (W. H. Smith). Smear a selected portion thinly and uniformly on a cover-glass, fix by heat (passing through the flame three times without burning), cover with aniline-gentian violet, heat to steaming, wash off with Gram's iodine solution, cover with the solution and steam, decolorize as much as possible with ninety-

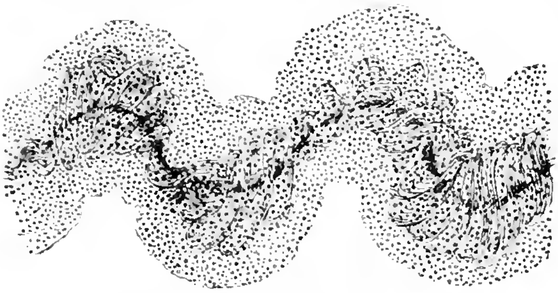


Fig. 4469.—Curschmann's Spirals. (Magnified.)

five-per-cent. alcohol, wash a few seconds in alcohol-ether, wash in water, stain for a few seconds in strong aqueous eosin, wash with Löffler's methylene-blue, cover with this, steam, decolorize slightly with ninety-five-per-cent. alcohol, wash in absolute alcohol, then in xylol, and mount in Canada balsam. In this preparation red blood corpuscles, cell protoplasm, eosin granules, cilia of epithelial cells and capsules of bacteria are stained red, nuclei blue, Gram-staining bacteria black or deep violet and Gram-decolorizing bacteria blue. Tubercle bacilli are not differentiated. (*d*) By the examination of smears stained for tubercle bacilli in the manner described in the article on *Bacteriological Technique* in the APPENDIX.

Abscess.—When the abscess empties itself through a bronchus there is likely to be a considerable quantity of liquid, purulent sputum with a more or less offensive odor. This same periodicity in the appearance of pus is observed in empyema and bronchiectasis, but elastic fibres, which are present in abscess, are usually absent in these conditions. Crystals of cholesterin, fatty acids, leucin, tyrosin, or hæmatoidin may accompany the large number of pus cells; the blood pigment, if intracellular, probably indicating some previous hemorrhage, if free a discharging abscess from a neighboring organ. In hepatic abscess, bile pigment or ameba coli may be present, and the sputum may be in part mucoid or watery. The presence of hooklets of Tænia echinococcus or ova of Distoma pulmonale or Distoma hæmatobium indicates infection with these parasites.

Actinomycosis.—The presence of the ray fungus in small (one-tenth to one-fortieth inch in diameter), round, yellowish masses, glistening and granular in appearance, is pathognomonic of the pulmonary seat of this disease. They are not always to be found. The general characters of the sputum are those of a chronic putrid bronchitis.

Asthma.—The amount of the sputum varies. It is apt to be more copious at the end of the attacks, and to be viscid, mucoid, and whitish, or pink from blood. Its occurrence in small pearl-like masses is quite characteristic. Unfolded, these masses are seen to be Curschmann's spirals, which are more common early in asthma than in any other disease, and aid in differentiating true asthma from the reflex type. Charcot-Leyden crystals are almost constantly present; eosinophiles are usually numerous, and free eosin granules may be present. Occasionally leucocytes and epithelial cells are found which contain yellow and brown masses of pigment, probably derived from the blood.

Bronchiectasis is accompanied by copious, intermittent expectoration which may be odorless, but ordinarily has a rancid fœtor, different from that of gangrene, is apt to be darker in color than in simple bronchitis, oily in consistence, has a tendency to form nummular masses appearing like coins (Dittrich's plugs), and casts of the minute bronchial tubes. Pus is usually present, and crystals of hæmatoidin, cholesterin and fatty acids, and Charcot-Leyden crystals may be found. Unless there is ulceration (abscess formation) elastic fibres are absent. Occasionally the sputa contain inspissated or even calcified portions.

Acute Catarrhal Bronchitis.—In the early stages the sputum is scanty and mucoid or sero-mucoid. Later, it becomes more abundant and muco-purulent, sometimes sanguineous, the change in character often being accompanied with a fall in temperature. After the lapse of two weeks the expectoration may take on the character seen in chronic bronchitis. When the bronchial capillaries are especially involved in the disease process, there is less admixture of air, and consequently a tendency for the sputa to sink in water; when the disease is limited to these smaller bronchial tubes the sputa may be scanty or absent. Microscopically, the muco-purulent sputum contains many pus cells, eosinophiles and ciliated, cuboidal, or alveolar epithelia, according to whether the larger or smaller bronchi or the alveoli are involved. The bacteria present usually include one or more of the pus organisms, and when the disease is secondary to some infective disease, *e.g.*, influenza or typhoid, they may include the specific agent of this infection as well. Diphtheria bacilli are usually not present in the bronchitis which sometimes accompanies this disease.

Chronic Catarrhal Bronchitis.—The sputum is extremely variable, that of the dry type of the disease being scanty and perhaps occurring as tough pellets of mucus, while the expectoration of the moist type is more abundant, sometimes copious, and either serous (thin) or purulent (thin or thick) in character. The purulent secretion is commonly yellowish-green in color. Microscopically there is commonly little of interest to be seen; numerous pus cells, a variable number of epithelia, usually cuboidal, bacteria, and ordinarily one or more of the various pus organisms, are present. In rare instances the fetid odor of the sputum justifies us in characterizing the disease as putrid bronchitis. The sputum is then usually thin, whitish, and may contain the yellow, dirty masses the size of peas which come from the smaller bronchi and are known as Dittrich's plugs. Microscopically these may contain fatty acid crystals, degenerated epithelia,

Fig. 4470.—Charcot-Leyden Crystals. (Magnified.)

spirals, and Charcot-Leyden crystals. Fetid sputum more frequently denotes bronchiectasis, gangrene, abscess, phthisical cavities, or empyema.

Plastic Bronchitis.—This is characterized by fibrinous masses, the recognition of which in the sputum forms the only means of diagnosis. If they come from the larger bronchi they do not necessarily present any recognizable form, but when they come from the smaller tubes they appear as casts, corresponding to the ramifications of the tube. In the sputum they may be mere spherical masses more or less obscured by the mucus and pus, but when floated in water their true character may be recognized. Their presence should be suspected whenever expectoration is accomplished by severe effort. In the acute process the sputum, aside from the presence of the casts, is much like that of acute catarrhal bronchitis. Curschmann's spirals and Charcot-Leyden crystals may be present. The chronic form of the disease is even more likely to be overlooked, as the fibrinous masses are more apt to be masked by the other constituents of the sputum, which presents the ordinary features of that which belongs to chronic catarrhal bronchitis.

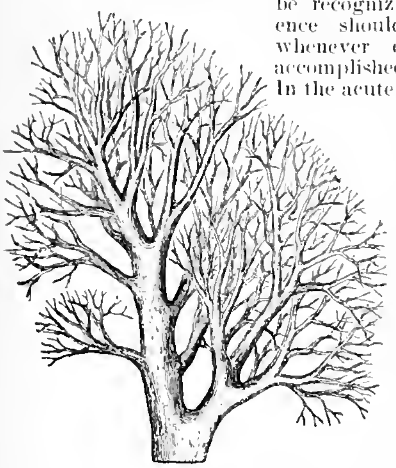


FIG. 4471.—Fibrinous Cast of Chronic Plastic Bronchitis. (Two-thirds actual size.)

An *empyema* that discharges into the bronchi gives rise to purulent sputa which may have an offensive odor. They differ from the sputa of bronchiectasis in the absence of oily appearance, mucous admixture, fatty acid crystals, and fibrinous casts of the minute tubes. The prevailing infecting agents are the Streptococcus pyogenes and the pneumococcus, the former being more frequent in children. The presence or absence of tuberculous infection is of importance.

Gangrene of the lung announces itself by a horribly fetid odor, less pungent than that observed in bronchiectasis. The sputum is apt to be tinged with blood, the color often suggesting prune juice, but being at times chocolate-colored from the development of hæmatoidin when the sputum is retained for some time before being discharged. It is frothy, in part liquid, in part mucopurulent, and may contain small portions of gangrenous lung, dark or greenish in appearance. The débris from the lung tissue does not always contain elastic fibres, as they apparently pass into solution under the strong solvent action of the ferments present. Putrefactive bacteria abound, and forms belonging to the other groups of fungi may be present. Even infusoria of the monad and cercomonad varieties are sometimes observed; they occur as minute, yellowish, slowly moving droplets. Robinowitsch in one case observed a bacillus not identical with, but morphologically resembling, the tubercle bacillus.

Active Hyperæmia of the Lungs.—The sputum is characteristic, being serous, not infrequently slightly sanguineo-serous, clear, containing the serum proteids in solution, and, in contrast to other sputa, having a high specific gravity (1.025-45).

Passive Hyperæmia of the Lungs.—As this is accompanied by a chronic catarrhal bronchitis, the sputum presents the characters of that disease plus two additional features induced by the chronic hyperæmia, namely, the presence of blood pigment, which may be in all stages of alteration, and many alveolar epithelia containing hæmatoidin crystals.

Influenza.—The pulmonary invasion is characterized by the presence of the specific bacillus in the sputum. Early in the acute stage it will be found free in the sputum, but later it is found only in the pus corpuscles. The clinical manifestations are those of bronchitis, either acute or chronic, or of bronchopneumonia. It may be a secondary invader in lobar pneumonia and even in phthisis. The general characters of the sputum, aside from the presence of the influenza bacillus, are in general those common to the particular clinical type of the disease, though in pneumonia it is bronchitic rather than pneumonic in character. When isolation of the bacillus is desired, the following method of W. H. Smith may be employed: A small portion of the fresh sputum is suspended in sterile bouillon, and one loopful of this bouillon is spread evenly over the surface of an agar slant; then a second drop is likewise spread on an agar slant, the surface of which has been smeared with human blood. The influenza bacillus does not grow on the first agar slant, but appears on that which is smeared with human blood—after remaining at 37° C. (98.6° F.) for forty eight hours or less—in the form of minute colonies, frequently unrecognizable without a lens, and showing in smear preparations the morphology of the influenza bacillus. Stain by floating for five to ten minutes in carbol-fuchsin, one part diluted with twenty of water.

Malignant Neoplasms.—The character of the sputa depends upon the condition which may be produced in the lung by the disease process—*i.e.*, upon the bronchitis, bronchiectasis, œdema, ulceration or gangrene, that may be present. It may contain lung débris, including pieces of the neoplasm, and may present peculiar appearances, sometimes resembling red currant jelly, while in some forms of sarcoma it appears bright green.

Catarrhal Pneumonia.—In this disease the sputum is less characteristic than in lobar pneumonia. It may present the character of the expectoration of an acute bronchitis, with which the disease is frequently associated, or it may be scanty and mucoid. It may be tinged with blood, generally an unfavorable sign, but it has not the characteristic sanguineous character seen in lobar pneumonia. Mixed infection being the rule, more than one organism is to be expected in the sputum, though early in the disease the primary agent, most commonly the pneumococcus, streptococcus, staphylococcus, or the pneumobacillus, in the order named, is the only or chief intruder. Broncho-pneumonias, which are pulmonary complications in specific diseases, are apt to have the organism causing the disease as the primary agent, and accordingly this organism appears in the sputum; but the specific organism may be a secondary invader.

Croupous Pneumonia.—During the first twenty-four hours the sputum may be wanting, or it may consist only of small mucoid masses. In the stage of red hepatization it presents pathognomonic characters, appearing "rusty" from blood and being exceedingly viscid and tenacious. As regards the quantity of the sputum, as much as from 100 to 300 c.c. is commonly raised in a day. Microscopically it shows red blood corpuscles in all stages of degeneration, alveolar epithelia, which are in large number in desquamative pneumonia, and sometimes small fibrinous casts. The stained smears show the infecting organisms if they are the exciting cause of the disease. The presence of the pneumococcus in abundance is presumptive evidence of the disease, and is an especially valuable indication in central pneumonia. The sputum is to be watched for complications. A sudden increase of serous fluid indicates œdema; a large quantity, dark brown in color, perhaps with elastic fibres, indicates necrosis; while a copious purulent discharge points to the existence of an abscess or a bronchiectasis and the fetid character to gangrene.

Pneumonokoniosis is usually recognized from the characteristic expectoration. The general nature of the sputum is that due to the associated condition, viz., chronic bronchitis, or chronic interstitial pneumonia with its usually copious, muco-purulent, or sero-purulent sputum, not infrequently hemorrhagic and sometimes fetid, or tuberculosis. The inhaled dust particles may be free or may be lodged within the leucocytes or mucous and epithelial cells. In anthracosis the color is so dark as to lead to the characterization "black spit"; in siderosis the oxide-of-iron color is seen; while in chalicosis the condition is recognized by the angular particles of silica seen under the microscope.

Pulmonary Tuberculosis.—In the acute miliary form, as in early acute bronchitis, the sputum is scanty and mucoid, tubercle bacilli usually not being found, certainly not till softening of the tubercles occurs. In acute pulmonary phthisis tubercle bacilli may be present in enormous numbers, the expectoration being rusty and then muco-purulent, and containing elastic fibres when a process of softening has set in; these features and the presence of the tubercle bacilli constituting the marks which distinguish the disease from ordinary pneumonia. In chronic phthisis the expectoration is variable, the variations in its amount and nature from time to time giving some indication of the activity of the disease. Its heterogeneity is characteristic, some portions being but slightly purulent, others yellowish, purulent, and forming nummular with here and there cheesy masses and possibly even calcareous particles. Microscopically, the important features are the tubercle bacilli and elastic fibres, together with the presence of the purulent organisms that are secondary invaders. Occasionally Curschmann's spirals are present. Nuttall estimates that four billion individual tubercle bacilli may be present in the expectoration in twenty-four hours. Lartigau states that only from ten to fifteen per cent. of those present are ordinarily alive, and that dead bacilli alone may be present and persist in the sputum for weeks. It is generally believed that the forms that take the stain irregularly, presenting a beaded appearance from the presence of unstained spaces, are attenuated in their virulence. *E. E. Smith.*

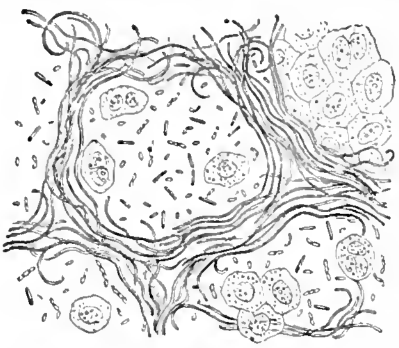


FIG. 4172.—Elastic Fibres Occurring in the Sputum. (Magnified.)

SQUILL.—(*Scilla*, U. S. P.; *Bulbus Scillæ*, P. G.; *Scilla*, Cod. Med.) The bulb of *Urginea maritima* (L.) Baker (fam. *Liliaceæ*), deprived of its dry, membranaceous outer scales, and cut into thin slices and dried, the central portions being rejected.

Squill is derived from a perennial herb of the Mediterranean coast region, especially in Spain. The bulb is large, four or five inches long, globular-ovoid, covered with two or three dry, reddish or gray, papery scales, and made up within of numerous thick fleshy ones. There are two varieties, the white and the red, distinguished by the color of the outer tunics of the bulbs. For medicinal use, the bulbs are collected in the latter part of summer, sliced transversely, dried in the sun, and the papery scales winnowed out. To produce the best article, only the outer scales should be preserved. The presence in the drug of the less valuable central portion is indicated by the relative shortness and thinness of the strips, and their higher degree of curvature. Squill occurs in irregular, more or less curved segments several centimetres (about one to two inches) long and 4–8 mm. ($\frac{1}{6}$–$\frac{1}{3}$ in.) broad, thinner in one direction, with two to four sharp edges; yellowish-white or somewhat reddish, slightly translucent, brittle, and pulverizable when dry, tough and flexible when damp; inodorous and of a mucilaginous, bitter, and acrid taste.

When consisting of very narrow, short, closely curved or coiled segments, from the inner portion of the bulbs, the product should be rejected.

Structurally, it consists of a simple parenchymatous tissue, loaded with mucilage and containing numerous oxalate-of-lime crystals, and traversed by occasional vascular bundles.

CONSTITUENTS.—Besides a large amount of gum, some sugar, the unimportant dextrin-like substance sinistrin, etc., squill contains as its active constituents several glucosides, the constitution and relations of which are not yet well known.

Scillitoxin is amorphous, light brown, soluble in alcohol, not in ether or water, a cardiac poison resembling digitalis; *scillipikrin*, a yellowish-white, amorphous, hygroscopic powder, similar to the above but less active; and finally *scillin*, of no medicinal qualities.

ACTION AND USE.—Few medicines outrank squill in antiquity, it being mentioned by nearly all medical writers from the earliest down. It possesses in a measure the heart-slowing and diuretic action of digitalis, for which it is occasionally substituted and with which it is more frequently given as an adjuvant. As a slightly depressing expectorant it is a common ingredient of cough preparations. Large doses (from six to twelve grains) occasion vomiting and purging.

It is stimulant, or in overdoses irritant, to mucous membranes; hence it acts as a direct diuretic in its passage through the kidney, in addition to its indirect diuretic effect through increased blood pressure. Hence, also, the frequent production of bloody or suppressed urine, and bloody stools and other indications of intestinal inflammation, in cases of poisoning.

ADMINISTRATION.—Squill is difficult to powder, apt to cake up when powdered, and seldom given in substance.

The following preparations are official: Fluid Extract (*Extractum Scillæ Fluidum*, strength, $\frac{1}{1}$), dose, ♏ i.–ij.; Tincture (*Tinctura Scillæ*, strength, $\frac{15}{100}$), dose, ♏ viij.–xxiv.; Vinegar (*Acetum Scillæ*, strength, $\frac{1}{10}$), dose, ♏ xv.–lx.; Syrup of Squills (*Syrupus Scillæ*), dose, 4–8 c.c. (ʒ i.–ʒ ij.). The Compound Syrup (*Syrupus Scillæ Compositus*) is rather a preparation of antimony than of squill. *Henry H. Rusby.*

STAFFORD MINERAL SPRING.—Jasper County, Mississippi.

POST-OFFICE.—Vosburg. Small hotel.

ACCESS.—Viâ the "Queen and Crescent" route to Vosburg, thence one mile and a half southeast to spring.

The location is a romantic one, surrounded as it is by Indian mounds and relics, and shaded by graceful and towering gums, sycamores, poplars, and pines. The Choctaws gave the name of Bogohama ("Water of Life") to the spring; hence it is inferred that they used it for medicinal purposes. Its properties have been known to the whites, however, only during the last five or six years. At present there is, within one hundred yards of the spring, a large, well-kept boarding-house, where guests will find all arrangements for their comfort. It is the intention of the company controlling the spring to build a large and commodious hotel, with all modern conveniences, to accommodate the rapidly increasing number of guests. The many natural advantages of the spot in the way of charming scenery, salubrious climate, and mineral waters will no doubt serve to make it one of the popular spring resorts of the country in the near future. The following analysis of the water was made by Prof. A. L. Metz, of the Tulane University, New Orleans, in 1892: One United States gallon contains (solids): Sodium chloride, gr. 0.96; sodium carbonate, gr. 0.41; potassium sulphate, gr. 0.98; magnesium bicarbonate, gr. 0.97; calcium bicarbonate, gr. 13.69; calcium sulphate, gr. 0.56; ferrous (iron) bicarbonate, gr. 0.24; alumina, a trace; silica, gr. 1.99; no organic matter. Total, 19.80 grains.

The analysis shows a very good calcic water, with ferruginous properties. The entire absence of organic matter adapts it for table and domestic use. The water has tonic and diuretic properties, and ought to be useful in the diseased or disordered conditions to which this class of waters is applicable. It has been found to render excellent service in Bright's disease of the kidneys and in diabetes, bladder disorders, and other conditions. The water is bottled and sold throughout the United States.

James K. Crook.

STAFFORD SPRINGS.—Tolland County, Connecticut.

Post-Office.—Stafford Springs. Accommodation in private families.

Access.—Viâ New London and Northern Railroad from junctions at Willimantic, Conn., and Palmer, Mass.

This historical old spring has been known as a resort since the year 1750, and its waters were celebrated among the aborigines for many years prior to that date. During the latter part of the eighteenth and for many years of the nineteenth century the place was held in high favor throughout New England and the neighboring States. The records of the guests of former days are filled with the names of people distinguished in all the walks of life. Among these names we find those of Dr., afterward General, Joseph Warren, and President John Adams. The development of other springs has detracted from the prestige of Stafford, but under an enterprising management the resort will no doubt again acquire a prominent place in public favor. Heretofore the water could be obtained only at the spring, but it is now bottled and shipped to any desired point. The country about Stafford Springs is diversified by hills and valleys, and the landscapes are very pleasing during the summer months. The flow of water from the spring amounts to about fifty-five gallons per hour. We are indebted to Dr. J. M. Sheehan for the following analysis by Lewis Norton, Ph.D., of the Massachusetts Institute of Technology. One United States gallon contains (solids): Sodium chloride, gr. 0.31; potassium sulphate, gr. 0.21; sodium sulphate, gr. 0.96; sodium bicarbonate, gr. 0.46; sodium phosphate, gr. 0.22; iron peroxide, gr. 0.67; iron protoxide, a trace; alumina, gr. 0.11; lime, gr. 0.41; silicic acid, gr. 2; magnesia, volatile matter, etc., gr. 1.75. Total, 7.10 grains. Carbonic-acid gas, 25 cubic inches.

The water is clear and sparkling and excellent for table purposes. It has attained its greatest reputation in the treatment of blood and skin affections. It is said to be actively diuretic.

James K. Crook.

STAMMERING AND STUTTERING are terms often used to denote speech defects in general, without reference to their origin. Technically the word stuttering should be limited to tonic or clonic spasms of the muscles concerned in phonation and articulation. Stammering is imperfect articulation, not spastic, but due to malformation of the organs of speech, or to imperfect innervation of the muscles used in articulation.

Stammering has nothing to do with the joining together of sounds, but is the inability to render them properly, even when given alone. The terms stammering and stuttering are confused, always in the older writings, often in more recent ones.

Stammering must be distinguished from aphasia. That has to do with neither the production nor the joining together of sounds, but with the construction of syllables and words as a whole. It is caused by the disabling of those parts of the cerebral cortex which contain the sensory or motor speech memories, or of the fibres connecting these with other parts of the nervous system.

Aside from occasional faulty pronunciation, to which every one is more or less liable, there are many cases of stammering in which the trouble is due to carelessness and inattention, fixed by habit. These cases are important as well from a diagnostic as from an educational standpoint, as they may be mistaken for cases of acquired speech defect, especially when organic brain disease co-exists with them.

The capability of pronouncing different sounds is largely a matter of race and training. Every one stammers in a foreign language, if he undertakes to learn its new sounds after his habits of speech are formed. Thus the German *ch*, French nasals, and Italian *r* are seldom perfectly acquired by an adult. But, according to Kussmaul, "the most choking guttural of a Swiss throat modestly retires before the vomiting throat sounds of an Arabian."

We may divide our subject into stammering from habit or carelessness, organic defect of the organs of speech, and disease of the nerve centres. The speech defects in all these cases may be identical, and in order to distinguish one from the other a careful examination and attention to the history are often necessary. A complete list of sounds which may be mispronounced is not possible. It will be sufficient to indicate a few of the more common ones.

The mispronunciation of the letter *r* is called rhotacism or burring. This letter has the same general sound, but is produced in various ways by different nations. In English-speaking countries it is formed by approximating the sides of the tongue to the roof of the mouth, but in certain localities it is often slurred. Its place is then taken by a *ŭ* or *ä* sound. In Southern England it is produced by the tip of the reverted tongue. In Italy it is made by a rather prolonged and rapid vibration of the tip of the direct tongue against the palate. The Italian nobility profess to be unable to produce this sound, and use the English *r*. In Northern Germany it is made by the uvula, in Sweden by the glottis. It is evident that correct speech in one country is stammering in another; *e.g.*, the use of the uvula in pronouncing the English or Italian *r*. Again, the ordinary sound may be replaced by an entirely different one. In this case *l* or *w* is usually employed. This is commonly done by children, who acquire the *r* sound among the last.

L is often mispronounced, *r*, *d*, *t*, *y*, etc., being used instead. This is called lambdacism. *L* should be made by placing the tip of the tongue against the hard palate, and then phonating so as to make a continuous sound, the air escaping at the sides of the tongue. If the air does not escape, the explosive *d* is produced instead; if the tongue does not touch the palate, the half vowel *y* is made, and so on.

Lisping, or sigmatism, is the most common form of stammering. It consists in giving *s* a wrong sound, usually that of *th*, by carrying the tip of the tongue too far forward, so as to touch the upper teeth. In this way both the hard and soft sounds of *s* are replaced. This occurs even among the Germans, who have no *th* sound in their language.

Gammacism is the mispronunciation of the letter *g*. It is sometimes hardened into *k*, sometimes changed to *d*, especially by children.

Stammering of vowel sounds consists in slurring them so that they lose more or less of their individual character. A certain degree of this is in conformity with the spirit of the English language; in fact, many of our different vowels are, under certain circumstances, rendered in exactly the same way, *e.g.*, in bird, burn, and father, and in bun and monkey. When carried beyond the degree sanctioned by general usage, this is stammering.

Hesitating speech with interpolation of a *ŭ* sound is popularly called stammering, but usually is simply a device for gaining time.

All the above varieties are often simply the result of habit. Examination shows that the patient has always spoken in the same way, and reveals absence of other symptoms of disease.

Treatment is simply education. The patient should be carefully shown how to place his articulating apparatus so as to produce the required sound. Sometimes it will be found that he can readily do this when shown how. It is then only necessary to insist that he take the requisite amount of trouble every time he speaks. Other patients, especially adults, have the greatest difficulty in accustoming themselves to the change. The great point is to begin early. The acquiring of a new sound in his own or a foreign language is to an adult often an impossibility.

Organic defects of the organs of speech may be congenital or acquired, and lead to the same vices of articulation mentioned above, but often in a much higher degree; at the same time the voice may be changed in quality, acquire a nasal twang, etc. The production of the normal sounds is then an impossibility, even if the patient is instructed how to do it.

Harelip interferes especially with the pronunciation of the labials, cleft palate and uvula with the gutturals, besides giving a nasal twang to all sounds.

The tongue may be bound to the floor of the mouth by a short frænum, causing thickness of speech and imperfect utterance of the linguals

All these conditions must be ascertained by inspection. The treatment is surgical, followed at an appropriate interval by instruction in speaking.

Excision of the tongue for cancer interferes less with articulation than might be expected; *d, t,* and *l* are the only sounds which are lost, and the patient is able in a little while after the operation to make himself understood.

The larynx has little to do with articulation. Disease there causes aphonia. Even after its total extirpation patients have acquired the power to speak, setting in vibration the column of air contained in the pharynx.

Nervous diseases may cause literal as well as other defects of speech. The diagnosis must be based on a careful review of all the symptoms. The mode of development of the stammer is of the greatest importance.

Most characteristic in this respect is the defect in bulbar paralysis. In this disease the ganglion cells in the medulla oblongata are destroyed one after the other. The process usually begins in the nucleus of the hypoglossal nerve, and extends to the facial, spinal accessory, and glosso-pharyngeal. Wherever it extends it is accompanied by a paralysis of the muscles supplied by the affected ganglion cells; and as the tongue, lips, and palate are successively involved, the sounds formed by these parts become indistinct and finally disappear. In this way the patient loses the power to form the linguals; paresis of the lips causes at first disappearance of *o* and *u*, later of the explosives *b, p,* and *m*; when the disease extends to the uvula the nasal cavity is not properly shut off, and, besides the nasal quality which is given to it, the voice becomes much weaker from the large quantity of air which escapes through the nose. At the same time the lips, tongue, and palate are paralyzed for ordinary movements to a corresponding degree; whistling is impossible, swallowing difficult, and there is marked atrophy of the muscles with reaction of degeneration. There is no true aphasia nor amnesia, but speech may finally be entirely lost by the successive elimination of its component sounds. These changes are eminently progressive in character and usually slow; the symptoms may appear rapidly, from hemorrhage or embolism. During the prodromal stage, with heaviness of speech and occasional difficulty of articulation, diagnosis is not easy.

In paretic dementia the symptoms are more complicated. The disease process is scattered through the greater part of the nervous system. If the medulla is involved there may be much the same defects of articulation as in bulbar palsy, but they never reach so high a degree. At the same time there is apt to be marked tremor of the face and tongue, elision of syllables, loss and misapplication of words, and weakening of the logical powers. In typical cases it may be possible to make the diagnosis from the speech alone. It should be remembered, however, that stammering and stuttering may coexist with congenital mental defect and simulate this condition closely. The occurrence of delusions of grandeur and the somatic symptoms will then decide.

Multiple sclerosis may or may not cause disturbances of speech, according to the location of the areas of induration. When the cerebrum is affected it is apt to be so in the subcortical portion, and the fibres coming from the left third frontal convolution may be involved. If they are involved, they may be cut across, and aphasia will then result. Usually they persist, altered more or less by the sclerosed tissue around them, motor impulses are transmitted through them with difficulty, and speech becomes measured and slow. This is called scanning. At the same time there is irregularity in the force with which syllables are brought out. The voice is monotonous and on a high key. But areas of sclerosis may occur below the basal ganglia and cause true stammering.

In ordinary right-sided hemiplegia speech may suffer from implication of the fibres of the knee of the internal capsule, and possibly from affection of the basal ganglia. Clinically, when aphasia of this origin passes off there is generally left an indistinctness of articulation which coexists with partial paralysis of the tongue and lips. This is not observed with aphasia of purely cortical origin.

The treatment of these forms of stammering is simply the treatment of the diseases which cause them.

Functional diseases are not often the cause of a literal dysarthria. In chorea, if the lips and tongue are affected, speech is irregular or absent during the spasm. This, however, is not the result of any disorder of the central speech mechanism.

Stuttering is a functional speech defect, consisting of clonic or tonic spasm of the muscles of respiration, phonation, and articulation, induced by the attempt to utter articulate sounds.

The intensity of the spasm varies greatly in different cases, from a scarcely noticeable impediment in speaking to an attack which renders speech for the moment impossible. The disturbance results in closure of the air passages, which is with difficulty overcome by the patient, and usually occurs in connection with the explosive consonants, in producing which there is normally a closure either by the lips, by the tongue, or by the soft palate. It may, however, occur with the pure open sounds, or before a sound has been uttered, in which case the spasm originates at the glottis. There may or may not be repetition of the offending sound, but there is likely to be when it is one of the explosives.

The attacks occur irregularly, and are much influenced by circumstances. Thus a stutterer may be able to converse easily with his friends, may be able to carry on an ordinary conversation, but have trouble in telling a story or in making any prolonged effort at speech. One may stutter only when tired or slightly out of health. Stutterers are usually exempt when whispering or singing, but this rule has frequent exceptions.

Stuttering has been known from the earliest times, but has been generally confused with other speech defects, so that it is often impossible to tell whether an account relates to this or to aphasia, or to stammering. It differs from the latter in origin, is never due to organic defect, nor entirely to carelessness, is intensified when the patient's attention is directed to his speech, or when he is embarrassed, and it is only occasional, while stammering is regular. Under favorable circumstances the stutterer's enunciation is perfect. It is evident, then, that it is no mere defect of articulation nor of co-ordination, for the muscles at times harmonize perfectly in their action.

Stuttering is mentioned by Hippocrates, Aristotle, and Galen, but in a somewhat indefinite way. We are told by Plutarch that Demosthenes had a difficulty of enunciation, which he overcame by declaiming as he walked uphill, and by holding pebbles in his mouth as he rehearsed his speeches. The latter plan has points of resemblance with modern devices, as we shall see; but it is not at all certain, from the account, whether the defect which it removed was really a stutter, or some form of stammer. At any rate, he adopted an excellent form of respiratory gymnastics, which are the foundation of most of the modern systems of treatment. During the Middle Ages writings on the subject appeared occasionally, imputing the trouble to malformation of the tongue, cerebral disease, etc., but no work of importance was done until the beginning of the present century.

Itard (1817) divided stuttering into two classes, congenital and accidental. Under the latter head he included speech defects due to cerebral lesion or organic disease of the tongue. He recommends beginning treatment early, and teaching the child slowly and carefully the pronunciation of a foreign language, dropping for a time his own. In this way he is taught, from the very first, to combine sounds properly, and to give prominence to the vowel sounds rather than to the consonants.

In 1825 Mrs. Leigh, of New York, discovered a method of treatment which was kept for a long time secret. She thought the trouble due to a faulty position of the tongue, which is spasmodically depressed during the attack. To overcome this, she taught her patients to voluntarily raise the tip of the tongue, and keep it in this position while speaking. Her results were at first surprisingly good and attracted much attention, as well throughout Europe as in this country.

M. Serres d'Alais (1829) published a more scientific résumé of the subject, in which he divided the cases into two classes:

1. Those due to a stiffness, as if tetanic in character, of the muscles of the voice and respiration.

2. Those due to a chorea of the muscles of articulation. He recommended in severe cases gymnastic movements of the arms while speaking; in light cases he considered it sufficient to pronounce the syllables in a short and brusque way, at the same time making the movements of articulation as extended as possible. He admitted that recovery is never quite complete, differing in this respect from most writers of the time, who, sceptical as to the statistics of others, claimed infallible results from their own particular method of treatment.

Arnolt (1830) ascribed the difficulty to spasmodic closure of the glottis. To overcome this he caused his patients to make a *u* sound between the words, so as to bind the consonant rather with the preceding than with the following vowel sound. In this way he threw the consonant into the background, as one does in singing.

At about this time Colombat, in France, attracted a good deal of attention by his brilliant success in treatment. He claimed to have cured one case in a single sitting of three hours, but, in a later edition of his work, he considerably modified this statement, and other authorities say the case relapsed several times In fact, so many tables of statistics have been compiled from the immediate results of treatment, without waiting to see whether relapse occurred, that they are almost entirely worthless. Colombat gives a classification of cases much like that of Serres d'Alais into:

1. Repetition of syllables due to convulsive movements of the tongue and lips, or labio-choreic form.

2. Tetanic stiffness of the muscles of respiration, or gutturo-tetanic form.

For the first form he recommends the use of a rhythmical movement of the thumb and index finger during speech, and an instrument for beating time, of his own invention, called the muthonome. If the case is complicated by gutturo-tetanic spasm, he adds "lingual and guttural gymnastics, which consist in taking a deep breath before difficult words and phrases, and bringing the tongue into the pharynx, at the same time raising the point well toward the velum palati." His method is, after all, only a combination of preceding ones, but seems to have been effectual in producing, for a time at least, very good results.

The year 1841 is unique in the annals of this affection. In that year operation was proposed, and hundreds of stutterers were operated on, but before the end of the year the surgeons themselves were convinced of the uselessness of operation. The idea was suggested to the mind of Dieffenbach, of Berlin, by the frequency with which stuttering and strabismus exist in the same patient, and occurred to him, he says, when a man asked, with a marked stutter, to be operated on for strabismus. The operation which he usually performed was section of the root of the tongue, sometimes with excision of a triangular piece throughout its entire length and breadth. This proceeding was based on the theory that stuttering is purely a local affection. At about the same time several other operations were invented, *e.g.*, cutting the hyoglossi, genioglossi, etc., varying with the different theories of the surgeons as to the cause of the trouble. At first, cases were reported as cured by each of these methods. Later, relapses were said to have occurred. Then several deaths were reported, and operation was soon, by common consent, abandoned as useless. Dieffenbach himself admitted the extreme danger of the proceeding. The deaths were the result of secondary hemorrhage and gangrene. The results attained immediately after operation seem to have been due to the impression on the nervous system of the patient, which wore off as soon as the effects of the operation subsided.

Since that time a good deal has been written on the subject of stuttering, largely by stutterers themselves, both in and out of the profession: by Guillaume in France, Merkel, Klencke, and Kussmaul in Germany, and Potter in America, and many others.

Guillaume lays especial stress on the disturbances of respiration.

Merkel thinks that the difficulty lies in combining a consonant with the following vowel sound. He locates the trouble, not in the articulation, but in the vocalizing apparatus, or, farther back still, in the nerve centres which govern that apparatus.

Bristowe likens stuttering to chorea.

Causation.—Among the many theories which have been propounded to account for the symptom under discussion, that which ascribes it to malformation or disease of the organs of articulation is one of the oldest, and one which held its ground longest. It is the foundation of all operative interference, and is readily disposed of. In many pronounced cases of stuttering the tongue and lips execute ordinary movements perfectly. No abnormality is noticed except during speech; and when organic trouble coexists, its removal does not entirely cure the affection. Any conceivable degree of deformity may exist and cause nothing but stammering, which is then proportional to the amount of the lesion.

Stuttering is not due to a faulty position of the tongue, as is shown by the constant relapses which occurred after treatment by Mrs. Leigh's method. It is true that in many cases the tongue is pressed against the floor of the mouth, and is affected with clonic spasm in this position. This is, however, not always the case, and when it exists it is a result, not the cause, of the malady.

The trouble is not a chorea of the muscles of articulation. The characteristic of choreic spasm is that it is irregular and jerky and occurs during rest. The spasm of stuttering occurs only during voluntary excitation of the speech mechanism. Again, chorea, when it affects the lips and tongue, causes marked stammering, never stuttering. Chorea of the speech centre, or coprolalia, causes a spasmodic ejaculation of words or phrases independently of volition, and the words are perfectly articulated.

That the trouble is due to confusion of ideas, or disproportion of words and ideas, is obviously false. Stuttering occurs in persons of every grade of mental power. The greatest disproportion between words and ideas occurs in acute mania, and leads, not to stuttering, but to a chaotic mixture of words and syllables. In most persons failure of ideas is marked by a drawl, not a stutter.

It is not due to a simple ataxia of the muscles used in speech. If it were, the patient could at once control the irregular movements by ceasing to speak. But when he does this, the spasm invariably persists for a short time. Again, stuttering is only occasional, and made worse when the patient's attention is directed to his speech; ataxia is constant, and is diminished by attention.

The theory that it is an inability to combine the consonant and vowel sounds is inadequate to explain the symptoms. The occasion of so combining them is often the proximate cause of an attack, somewhat as general convulsions are caused by teething or other peripheral irritation; but stuttering may occur on an attempt to utter a pure vowel sound entirely apart from a consonant.

In order to understand the phenomena presented, it will be necessary to review briefly the structure and physiology of that part of the motor speech centres which serves for the production of articulate sounds. The motor impulse travels from the motor speech centre in the left third frontal convolution, downward through the knee of the internal capsule, and reaches the medulla. The nerves carrying it here communicate with the articulo-respiratory centre. These nuclei lie close together, and constitute practically one collection of cells bound together by fibres running in every direction. Here, and possibly also in the cerebellum, is effected the exact degree of innervation of all the muscles of articulation, so as together to produce the vowel and consonant sounds and at the same time to approximate the vocal cords, and so regulate the respiration as to cause exactly the necessary amount of air to pass through the glottis. This exceedingly complex action is entirely apart from the conscious act of speech, and is only known to the sensorium through the intervention of the sensory nerves supplying the mucous membranes and deeper parts of the lips, tongue, and palate. The amount of innervation of each muscle is determined by lines of least resistance in the connecting fibres, which are formed as a result of repeated transmission of motor impulses. This whole system is probably under the influence of one or more controlling centres, which serve to check over-action, or the undue diffusion of nerve force.

Stuttering is a disturbance of this co-ordinating mechanism. It may be due to abnormal excitability of the primary system, or to weakness of the inhibiting centre. The result is an overaction of the muscles innervated, and transmission of the impulse to other muscles more or less distant, sometimes even to those of the arms and trunk; the attempts of the patient to overcome the spasm only serve to intensify it, until the controlling centre resumes its function or the patient ceases the effort to speak.

Several facts tend to show that the trouble is adynamic in origin—*e.g.*, the fact that patients usually stutter worst when tired; that persons sometimes stutter when exhausted, or during sickness, who do not otherwise; that stutterers are often, though not always, of weak or scrofulous constitution.

This disturbance of equilibrium between the centres is often the result of an inherited tendency. It may follow severe illness, fright, or any shock to the nervous system. In such cases the trouble may pass off when the depressing influence ceases, or may persist for a long time, or through life. In any case the intensity of the disturbance depends much on the treatment and surroundings of the patient, anything like ridicule or punishment aggravating it tenfold.

Occurrence.—Stuttering occurs in all ranks of society and in most nations. The Chinese are said to be exempt, on account of the peculiar intonation of their language. It affects men much oftener than women, although trustworthy statistics on this point are lacking. Some authorities have thought that women do not stutter; others place the proportion of women affected as high as thirty-five per cent. Kussmaul believes the fact to be due to the greater tact and delicacy of women.

Symptoms.—These vary much in point of severity and mode of sequence of the spasm. In lighter cases, which are fairly under control, when one of the explosive consonants is met with, the organs of articulation remain fixed in their closed position for a moment, there is slight choking and tremor of the facial muscles, an effort of the will is made, and the parts resume their functions.

In rather more severe cases there may be added a good deal of thickening and tremulous movement of the tongue and tonic spasm of the glottis. The breathing is then apt to be irregular, and the approximation of the vocal cords causes a crowing sound on inspiration, which is sometimes utilized for speech.

When the spasm occurs before speech has actually commenced, the trouble begins with tonic spasm of the glottis, there is tonic and clonic spasm of the tongue, lips, and face, and the diaphragm acts irregularly in its efforts to overcome the resistance at the rima glottidis.

In severe cases the attack may be brought on by any sounds, less frequently the open vowel sounds; the closure may be effected by the lips, tongue, or palate; the under jaw is set; there is marked tremor of the facial muscles, and sometimes even of the arms; the glottis may be closed so as almost or entirely to prevent respiration, or it may be opened at the same time that there is spasm of the respiratory muscles. In the latter case the lungs are emptied of air, and the patient must pause for a deep breath before he can proceed with his sentence. At the same time the face becomes flushed, the flow of saliva is increased, and the mental torture of the patient tends to prolong rather than cut short the attack.

Diagnosis.—The diagnosis is usually easy. In addition to the clinical features given above, the duration of the malady should be carefully ascertained. Its diagnostic features have already been considered.

The speech defect which occurs in paretic dementia may simulate stuttering quite closely.

In clergymen and other public speakers there sometimes occurs a difficulty in speaking, which may be mistaken for stuttering. It is one of the occupation neuroses, of which the type is writer's cramp, and is due to exhaustion of the co-ordinating mechanism of respiration. Some speakers entirely empty their lungs before taking breath; the action of the reflex mechanism is then kept too long in abeyance. When this is habitual, the centres become exhausted and fail to respond to the reflex stimulus. The trouble usually begins in the glottis, which fails to open on inspiration; a crowing sound is produced when the speaker takes breath; the diaphragm cannot be promptly filled for the next sentence. This may happen only toward the end of the discourse, when the speaker is tired, but may become so marked that any attempt to speak causes great distress, and rest is then an imperative necessity. This affection differs from stuttering by occurring comparatively late in life, not involving the muscles of articulation, and being rather of a paralytic than of a spastic nature. It ordinarily yields to rest and respiratory gymnastics.

Another rare affection, aphthongia, is probably allied to the preceding. Here the spasm occurs in the muscles supplied by the hypoglossal nerve, and is brought on by any attempt to speak, so that articulation is rendered impossible. In the few cases recorded the disease has been caused by emotion or fright. During the attack the jaws and tongue are fixed; the sterno-thyroid, sterno-hyoid, and thyro-hyoid muscles may be in a state of clonic spasm, which begins and ceases with the attempt to speak. The prognosis seems to be good. Too little is known of the disease to speak of its probable relation to stuttering. It may be distinguished by the character and history of the attacks.

Prognosis.—There is no doubt that sufferers from this affection may be aided by treatment, especially if the latter is vigorous and instituted early. The prognosis is better in non-hereditary cases, and in patients of strong will power. Almost all writers on the subject have a favorite method of treatment, especially those who are connected with an institute for voice-training, and claim a large percentage of cures. Investigation shows that in most cases relapse takes place after an even brilliant result. This should not discourage patients from effort, but it is necessary to bear in mind that only constant and long-continued exertion will overcome a vicious tendency fixed by habit. The difficulty tends to decrease with time, and many stutterers are able to master their defect at forty or fifty years of age. They are apt to ascribe this to some particular form of treatment, which they then ardently recommend

Treatment.—Too much stress cannot be laid on beginning treatment early. The child should be kept as much as possible from association with stutterers. It should be remembered that he is sensitive as well to sympathy as to blame for his malady, and as little notice should be taken of it as possible, except in connection with stated lessons. He should be taught, when he has an attack, to stop speaking at once until he has mastered it.

Breathing exercises are very important. They may be given, following Guillaume, by causing the patient to take a long breath, hold it for a moment, and then let it out slowly, with occasional stops, but without sound. He should especially be made to take a deep breath at frequent intervals, and never to speak with nearly empty lungs.

After breathing exercises have been continued for some time, the patient may proceed to the vowel sounds, first the most open one, *ä*, then *ā*, *ă*, *ē*, *ĕ*, *ō*, *ŏ*, and so on; then the aspirates, *hä*, *hā*, etc.; next the easier consonants in combination, *lä*, *lā*, *lē*, *lō*, *lū*, *mä*, *mā*, etc. Sentences may then be used in which the difficult sounds do not occur. Lastly, the explosives *dä*, *dā*, *bä*, *bā*, etc., may be tried. With all of these the patient should be taught to lay the stress on the vowel sounds, so as to avoid the slight over-action with the consonants, which is usually the beginning of the spasm. One must be sure that the pupil has mastered each of the above classes before he is permitted to go on to the next.

We have a mass of evidence from stutterers, in the profession and out of it, testifying to the efficacy of rhythmical movements accompanying speech. They serve a twofold purpose—they divert the patient's attention, and give his sentences something of a sing-song character. They are aids, but are in no sense curative. The thumb and fingers may be opened and closed, or any other movement made which is convenient to the patient. Somewhat the same effect is produced by elevating the tip of the tongue, as recommended by Mrs. Leigh, but it will be better, in most cases, to draw the patient's attention to a more distant part of his body.

Hypnotism has been tried of late as an aid in treatment. If it is ever of use as an educational measure it should be so here. Good results are claimed for it. Whether they will prove to be permanent, and without accompanying injury to the patient, it is possibly too early to judge.

Drugs are of little value. Stimulants should be used moderately, if at all. Scrofulous and anæmic tendencies should be corrected, and the patients should be kept in good general health by exercise, cold sponging, and like measures.

The question is often asked, whether it is possible for an adult to master his defect without assistance from a teacher. That is entirely an individual matter. Some men have perseverance enough to educate themselves in this as in other respects. Proper teaching, however, saves much time and disappointment.

Henry S. Upson.

STAPHYLORRHAPHY. See *Cleft Palate*.

STARCH.—(*Amylum*, U. S. P.) ($C_6H_{10}O_5$, or multiple). "The fecula of the seed of *Zea Mays* L. (fam. *Gramineæ*)." U. S. P. There appears to be no special reason why the Pharmacopœia should thus restrict its requirements to corn-starch, except that this variety is cheap and abundant

Fig. 4473.—Section of Seed of Vetch, *Vicia sativa* Linn., showing rounded granules of starch in cells otherwise filled with granular nitrogenous substance. × 170.

and readily defined and described. Our account of starch, therefore, will apply to the entire class, and will be followed by the differential characters of the more important varieties.

Starch is the ordinary form of reserve carbohydrate nutriment in plants, at least in most of those of the higher classes, and in many of those of the lower classes. It may be reserved for but a brief period, at the point where it is produced, or it may, after production, be changed into diffusible forms and transported to special storage reservoirs, where it is again transformed into starch, and may remain for months or even for years. For example, being produced only under the influence of light, it may be consumed during the succeeding hours of darkness, or, upon the other hand, it may be transported to the bulb or tuber of a desert plant, which may exist dormant in the sand for several years, consuming this starch supply upon the recurrence of a period of activity. In the most highly developed and largest family of plants, the *Compositæ*, and in some others, inulin, a related compound, altogether replaces starch as a reserve food. The amount of starch present in vegetable tissues is often very great, being about seventy per cent. in dried potato, and about the same in corn meal and wheat flour. With the exception of some rare cases in which special forms are found, starch occurs in peculiar grains, which are free in the cell cavity. It originates in a small colorless body known as the amylogenic body, upon which the starch gathers in layers, the central body becoming the *nucleus*, and being located in the grain at the *hilum*. The numerous layers of the grain are discernible under the microscope by their different degrees of refraction, due apparently to different amounts of water, as they disappear under the effect of drying heat. The grains may exist singly, or coherent in masses containing a variable number. The limits of this numerical variation are often fairly constant in a given plant, and may thus be utilized as a characteristic. This cohesion often produces peculiar forms of the grains, which forms also become characteristic. Even if this is not the case, the form of the grains in a given plant is usually characteristic, as is the position of the hilum. The larger grains usually become ruptured or fissured at the hilum. This fissure may be simple or in various ways compound, and the forms so resulting are also characteristic. In all starches in the living plant there must be small grains of various sizes in process of formation, but the largest of them usually fall fairly well within certain limits, so that

Fig. 4474.

Fig. 4475.

Figs. 4474 and 4475.—Granules of Potato Starch Swollen by Boiling; those shown in Fig. 4475 afterward shrivelled as they cooled, or they may have lost some of their contents.

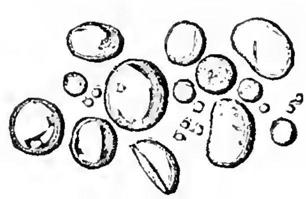


Fig. 4476.—Wheat Starch.

Fig. 4477.—Maize Starch.

the extreme limits of a given variety are of diagnostic value. Although single starch grains are colorless and semitransparent, masses of them are pure white.

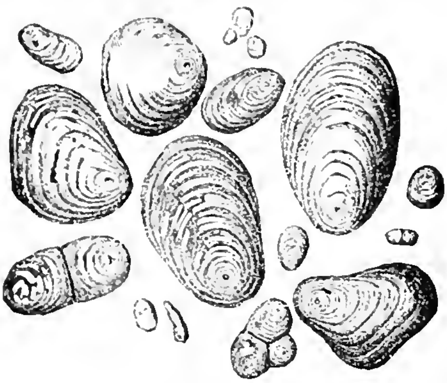


FIG. 4478. Potato Starch.

Starch powder is very fine and smooth, but the ultimate grains are hard and gritty. They are very hygroscopic.

Starch has no odor, but a peculiar, though slight, farinaceous taste. The grain consists of two substances, *granulose*, which is colored blue by iodine, and another substance very similar to cellulose, colored pale yellow by iodine. Starch is insoluble in water and alcohol. Several substances are often spoken of as solvents of starch, but they all apparently change it into some other compound before the solution takes place. Water, under the influence of heat, converts it into hydrated starch, a transparent, jelly-like mass, which is then soluble in water. Alkali hydrates of a strength of more than five per cent. similarly dissolve it. Both these solutions are then precipitated by lime water, lead acetate, tannin, and some other reagents. Diastase, the principal enzyme which naturally exists with starch, is the agent which in the plant converts it into sugar, suitable for immediate use as food. The same agent can be made to perform this office artificially, as can dilute acids under the influence of heat, and as is done by the natural processes of digestion within the animal body. From the above-mentioned characters of starch, it is seen that it can readily be obtained by grinding finely any cellular structure which contains it, washing out with cold water and filtering or allowing to settle. It is also seen that, besides the interest which centres in starch for its own value, the characteristics of the starches contained in different plants, and more especially in drugs, may be utilized in the identification of the latter, in powdered form, as well as in the detection of adulterations.

FIG. 4479. Arrow-root Starch.

FIG. 4480. Sago.

VARIETIES.—The only certain means of determining from what source a given specimen of starch has been derived is to examine it microscopically, when the size, shape, markings, and other visible peculiarities of the granules will generally suffice to make it certain. The accompanying illustrations of the commoner kinds are magnified uniformly three hundred and fifty diameters.

1. *Wheat Starch* (from various species and varieties of *Triticum* L. [fam. *Gramineæ*]) (Fig. 4476). In irregular, angular masses, which are easily reduced to powder; under the microscope appearing as granules, mostly very minute, *more or less lenticular in form, and indistinctly concentrically striated.* The granules average about 0.050 mm. in diameter.

FIG. 4481.—Tapioca.

2. *Maize*, or *Corn Starch* (defined above, Fig. 4477), is smaller than the preceding, about 0.030 mm. in diameter, of polyhedral form, with central hilum.

3. *Rice Starch* (from *Oryza sativa* L. [fam. *Gramineæ*]) resembles maize starch, but is very much smaller.

4. *Potato Starch* (from *Solanum tuberosum* L. [Fam. *Solanaceæ*], Fig. 4478) consists of two classes of granules mingled together—fine spherical ones, from 0.01 to 0.03 mm. in diameter, and large ovoid ones with very eccentric hilums and very distinct *rugæ*, recalling oyster or clam shells, from 0.14 to 0.18 mm. long.

5. *Arrow-root* (from *Maranta arundinacea* L. [fam. *Marantaceæ*] Fig. 4479) is finer than potato starch, which it somewhat resembles; the granules are more spherical, with blunter, thicker ends, very distinct eccentric fissures, and less distinct *rugæ*. Canna starch, a variety of arrow-root, has enormous granules, nearly twice as large as those of potato. Neither of these varieties has the small forms of that from potato.

FIG. 4482.—Oat Starch.

6. *Sago* (chiefly from several species of *Metroxylon* Rottb. [fam. *Sabalaceæ*] Fig. 4480) has medium-sized (0.04–0.07 mm.), oblong, rather irregular, often faceted, sometimes shoe-shaped granules, with eccentric hilum and fairly distinct *rugæ*. The sago of commerce is often half-cooked, with many of the granules destroyed.

7. *Tapioca* (Fig. 4481) has spherical, medium-sized granules, with large facets; commercial tapioca is also partly cooked. (See also separate article on *Tapioca*).

Besides the above are the starches of numerous familiar grains and roots, which are not separated for sale or use, but which are of interest in detecting adulterations, mixtures, etc., or in identifying the powders of drugs. The accompanying cuts of oat and turmeric starches will serve as illustrations of this large class.

FIG. 4483.—Turmeric Starch.

Medical and Surgical Uses of Starch.—This substance can in no sense be called a medicine, as it is absolutely without physiological action. It is the type of crude carbonaceous or non-nitrogenous food, and its conversion into sugar in the mouth and intestine is one of the elementary facts of digestive physiology. As a toilet powder the finer varieties—rice and corn starches—are in universal use, and one or other of these is the foundation of most of the proprietary powders.

Boiled starch, and especially the flours of starchy substances, are frequently used as poultices, but they are not so convenient and suitable as the mucilaginous flours of linseed and slippery elm.

Starch mucilage is occasionally used for immovable bandages, but it is less adhesive and less suitable for this purpose than flour paste, glue, dextrin, silicate of potash, or plaster of Paris. One part dissolved glue, as prepared for cabinet-makers' use, and two or three of starch mucilage, a little thinner than the laundress uses it, mixed and applied hot, make a most excellent combination for such bandages—light, very stiff, and agreeable in color.

The only official preparation of starch is the Glycerite (*Glyceritum Amyli*, ten parts of starch dissolved in ninety of hot glycerin). This is a permanent translucent jelly, useful in moistening pill masses, for emulsions and similar purposes. Iodized Starch (*Amylum Iodatum*, formerly official) is rather a preparation of iodine. It is made by triturating five parts of iodine with ninety-five of starch, with the aid of a little water. It is a blue-black powder, and a suitable preparation to administer for free iodine if it is desired to give that drug internally.

W. P. Bolles.
Revised by *Henry H. Rusby.*

STARK MINERAL SPRING.—New London County, Connecticut.

Post-Office.—Bozrah. Visitors accommodated in private families.

Location.—Three miles from Yantic, on the Central Vermont Railroad.

The waters of this spring issue from a rocky hillside on the farm of Mr. Everett W. Stark, at an altitude of about 1,000 feet above the sea-level. Its history has been known to a few old families in the neighborhood since the first settlement of the country, and dates back to a time when all accurate record is lost in the obscurity of tradition. There seems to be no doubt, however, that its waters were used for medicinal purposes by the Indians long before the region was known to the European settlers. The surroundings of the spring are very charming during the summer months, and an increasing number of visitors are attracted to the spot every year. The flow of water is about three gallons per minute, and its temperature about 40° F. The following analysis was made by Prof. S. W. Johnson, of Yale University, in 1880:

One United States gallon contains (solids): Sodium chloride, gr. 0.33; sodium sulphate, gr. 0.18; sodium bicarbonate, gr. 0.30; potassium bicarbonate, gr. 0.10; calcium bicarbonate, gr. 1.23; magnesium bicarbonate, gr. 0.33; iron bicarbonate, gr. 0.06; silicic acid, gr. 0.85. Total, 3.38 grains.

The analysis shows the spring to be but feebly mineralized. The waters, however, have been considered useful in some of the functional disorders of the liver, kidneys, and bladder. It is a good table water.

James K. Crook.

STARVATION; FASTING.—The latter term signifies the partial or complete abstinence from the normal quantity of food. It may include the absence of both liquid and solid food, or of the latter while water only is ingested. This process, when carried out to a fatal result, constitutes starvation. The somewhat cumbersome word inanitiation has been used to refer to the condition of the animal which is progressing toward inanition.

The fasting animal carries on its vital functions, and whatever muscular action it may perform, not, as normally, by the conversion of food supplied by its ingesta, but at the expense of its own tissues. The physiology of fasting, which has not as yet been thoroughly elucidated, may be studied to best advantage by experiments upon the lower animals, for, in addition to the ability to control conditions, we thus eliminate psychical influences, and those other disorders which complicate the problem in those instances in which human beings undergo starvation while under the possibility of medical observation.

Loss of Weight.—This is the earliest and most obvious symptom of the fasting animal. The daily loss is not, however, constant. It is greatest during the first day of the fast. Then it diminishes, and after a few days becomes a nearly constant quantity until the last days of life, when it again increases, but not usually to the amount of the first day. The proportional daily loss—that is, the loss in grams per kilogram of the animal's weight—is readily obtained from the absolute daily loss, the weight of the animal being known. But it must be remembered that the latter factor must be ascertained for each day in question, and must not be taken to be the original weight of the animal. Thus, for instance, a constant total daily loss of 200 gm. in an animal originally weighing 4 kgm. would at first mean a proportional daily loss of 50 gm. per kilogram, but would, with every successive day, represent a larger proportional loss. The mean daily loss may be obtained by dividing the total loss in a given number of days by that number; but of course it must be remembered, as said above, that the actual daily loss is not so constant. A mean daily proportional loss can, in the same way, be computed.

This figure varies with the different species of the animal kingdom. It is, as a rule, higher for the smaller animals. The horse loses less daily per kilogram than the dog, and the dog less than the cat. This fact is in accord with the greater nutritive activity of the small animals. That this greater activity is not due to increased heat production is shown by the fact that these small animals consume more oxygen per unit of time and weight, even when placed in a medium of the temperature of their bodies. An adult animal loses less daily per kilogram than a young animal of the same species. The daily mean proportional loss varies widely, being ten per cent. of the weight in the young turtle, and only 0.7 per cent. in the horse and dog.

What proportion of the body weight can an animal lose before succumbing to inanition? If we know this, and if the total weight loss during a period of starvation bore a constant ratio to the original body weight, we could easily compute, knowing the daily proportional loss, the length of time that life could last. It is, however, only true that the amount of the daily proportional loss, and the number of days that life can endure, are inversely proportional. Chossat stated that the total proportional weight-loss of an animal dying of inanition was forty per cent. of the initial weight. But further experiments have shown that a fat animal may lose fifty per cent. of its weight, while a lean one can lose only thirty-five per cent. Young animals in a growing stage have been observed to lose only thirty per cent. before they succumbed. Thus we have two reasons why young animals can endure fasting but a short time, namely, that their daily proportional loss is a maximum, and the total proportional loss of which they are capable a minimum. The reason of this last-mentioned fact seems to be that the demands of the growing organism have used up force which might otherwise be applied to the nutritive reserve of the body.

Organs and tissues.	Loss in grams per 100 gm. of organ.		Loss in grams of each organ per 100 gm. of loss of whole animal.
	Fresh.	Dry.	
Osseous system	13.9	13.9	5.4
Muscular tissue	30.5	30.2	42.2
Liver	53.7	56.6	4.8
Kidneys	25.9	21.3	.6
Spleen	16.7	63.1	.6
Pancreas	17.0	17.0	.1
Lungs	17.7	18.0	.3
Heart	2.6	2.6	.02
Brain and cord	3.2	.0	.1
Fat	97.0	97.0	26.2
Blood	27.0	17.6	3.7

The proportion of the entire weight-loss which falls upon the different structures of the body varies somewhat with different experimenters. Voit found that a rather lean cat, which died on the thirteenth day of its fast, lost 734 gm. of solid material, of which 248.8 were fat and 118.2 muscle. The table on page 441 shows the most important facts of the loss of several of the organs in proportion to their original weight, and in proportion to the entire weight-loss of the animal.

It should be said that Bidder and Schmidt, whose experiments were made upon a very fat cat, found that the muscular system lost sixty-seven per cent. of its original weight, the brain and cord 37.6 per cent., the blood ninety-four per cent., and the fat eighty per cent. Some of these discrepancies seem irreconcilable. Others, like the fat-loss, depend on different conditions in the respective animals. That of the latter observers had so much adipose tissue that, though he lived seventeen days, he had consumed only eighty per cent. of his fat, while the cat experimented on by Voit had used up ninety-seven per cent. of his in thirteen days.

What is substantially agreed is that the fatty tissue is the heaviest sufferer in the fasting animal; that certain glandular organs, principally those whose metabolic activity is greatest, come next, the average for all these being greater than for the body at large. The loss of the voluntary muscular system is about in the same proportion as that of the whole body, as is also that of the digestive tube (thirty per cent.—Voit). Those structures which are most essential to the life of the organism are spared longest. The heart muscle and the central nervous system lose practically nothing, and though their metabolic activity is high, they are sustained at the expense of less important tissues.

Temperature.—The experiments of Chossat, upon pigeons, show a remarkable and continuous effect upon temperature from the beginning to the end of a period of starvation. This shows itself at first in an increase of the diurnal range, owing to a lowering of the midnight temperature. Whereas, in the healthy pigeon, the daily oscillation is only 0.76° C. (from 42.22° at noon to 41.48° at midnight), in the fasting animal the mean noon temperature (prior to the last day) was 41.70°, and the mean midnight temperature 38.42°, giving an average diurnal range of 3.28° (four times as great as normal). The average loss of temperature at noon was only 0.52°, while that at midnight was 3.06°. That is to say, the loss of temperature at midnight was six times as great as at noon. Moreover, the diminution of temperature was progressive from the beginning to the end, as was also the amount of the daily oscillation. This latter was 1.9° the first day, and 4.3° the last day but one. The mean daily refrigeration during this period was 0.3°. As the animal grows weaker, the period of minimum (midnight) temperature begins earlier and lasts longer.

On the final day of starvation there is a great exaggeration in degree and in duration of this midnight refrigeration. Chossat gives it as a mean, in a number of pigeons, as 14°. In other words, the reduction of the animal heat is forty-seven times as great on the last day of life as on the average of the previous days.

This final plunge of the temperature is observed in all cases of starvation, and there seems little reason to doubt that it is the immediate cause of the fatal result. In the mammalia there was not that regular daily loss of heat that was observed in the pigeons. The temperature fell for the first day or two, but then nearly regained the normal, and so remained until the last day, when it rapidly sank. Chossat found that when this fall occurred, the resulting torpor, the precursor of death, could be dispelled by raising the temperature of the surrounding medium, and that sufficient vitality was thus imparted to allow of the taking of food and consequent perfect restoration of the animals. The nearly complete maintenance of temperature of warm-blooded animals for several successive days does not prove that the heat production was equal to the normal, for there is probably a lessening of the heat expenditure. Senator found that with dogs, on the second day of the fast, when the rectal temperature was not sensibly lowered, the heat production was nevertheless diminished about ten per cent.

Temperature studies in fasting men, of course, have been rare. Jürgensen found that in a healthy man, fasting for sixty-two hours, the rectal temperature, taken every ten minutes during the first thirty-eight hours, showed a slight prolongation of the period of diurnal minimum, with but very slight reduction (0.1°–0.2°) in the reading of the minimal temperature. But after that time there was a prolongation of the period of the maximal temperature, which Jürgensen accounted for by supposing that the substance of the consumed body set free more heat than the materials metabolized under ordinary circumstances.

Respiration.—The frequency of the respirations diminishes during fasting to four-fifths, or during the last day even to three-fifths, of the normal rate. Sometimes, however, just before death the breathing becomes hurried, shallow, and panting. The quantity of carbonic acid exhaled, which normally exceeds that of the oxygen taken in the proportion of about five pounds of carbonic oxide to four pounds of oxygen, becomes relatively smaller during fasting, and may even be absolutely less than the oxygen absorbed.

Circulation.—No very constant effects have been noted in this connection further than a general tendency to increase in the rate of the pulse accompanying exhaustion. One observer (Strelzoff) noted an increase in the blood pressure, which he ascribes to an atrophy and obliteration of a large number of the capillaries. Though this latter event occurs in the stomach and small intestine, and perhaps in other parts of the body, it probably is not sufficient to cause any general rise of blood pressure. The mass of the blood proportionally to the total weight, as above indicated, seems not to suffer very great reduction. Panum found no diminution in the number of blood corpuscles when the animal (a dog) was allowed all the water desired. On the other hand, Malassez found that in the guinea-pig the corpuscles were reduced on the fifth day from 4,156,000 per cubic millimetre to 3,444,000. In a chicken he observed a reduction, in an equal time, from 3,380,000 to 2,912,000. The diminution in both the last cases fell chiefly upon the latter days of the fast.

The density of the blood was found by Frerichs and others to diminish during a fast. In a dog, in which before the fast it was 1058.09, on the fourth day of the fast it was 1051.11, and on the twelfth 1037.69. On the other hand, in Voit's cat the density of the blood increased.

Urinary Secretion.—The amount of the urine during the first day of the fast is not usually affected. After that time, however, it gradually grows less and less. The specific gravity has been found during this period to range between 1.025 and 1.034.

The urea diminishes in the carnivora with every successive day of fasting, but never entirely ceases. The extent of the diminution depends upon the richness of the food in nitrogenous elements prior to the fast. The herbivora, on the other hand, which during a fast become carnivora, experience at that time a change in the character of the urine, which becomes denser, higher-colored, acid, and richer in urea. At the end of life the urea diminishes rapidly. In guinea-pigs it has been found that the urine taken from the bladder after death had only one-eighth as much urea as that passed on the preceding day.

The urea forming a measure of the decomposition of nitrogenous materials in the body, and nitrogenous ingesta (with all other) having been stopped in the fasting animal, the daily secretion of urea affords a means of estimating the amount of nitrogenous matter consumed each day of the fast. Physiologists have been divided over the question of a *luxus consumption*, a term applied by Bidder and Schmidt to the metabolism of certain surplus proteid material which, though inside the body, did not form a component part of any of its tissues, but constituted a kind of reservoir of force upon which the organism could draw. Not to enter upon this question, however, we will simply say that it is found that the excretion of urea bears no fixed proportion, at any period of the fast, to the total weight of the animal, although after the first three or four days it tends to a uniformity for several days. If the animal possesses an abundance of fat there is a smaller consumption of proteids during fasting. This diminution of the urea is very noticeable in animals that have been freely fed, previously to beginning the fast, on fatty food. In the lean cat of Voit, already referred to, the urea was less for several days than in the animal of Bidder and Schmidt; but at the end of life (twelfth and thirteenth days) there was a rise of fifty per cent. in the urea excreted over that of the previous day, while the other animal showed no such increase even up to its death, on the seventeenth day. The former animal was found at the autopsy to have used up all his fat tissues, and the final rise in the urea was due to the metabolism falling entirely upon albuminoid material.

Of the other constituents of the urine the phosphates and sulphates undergo a diminution parallel to that of the urea. The chlorides also diminish, but more rapidly from the first. Albumin has been noted in some cases, but is not constant.

FÆCES.—On the first day of the fasting there is usually an evacuation from the bowels, the fæcal matter containing the residue from the preceding alimentation. After this the fæces are scanty, often none being passed for many days. They consist, after the second day, almost entirely of bile. Scarcely any gastric or pancreatic juice is formed. Sometimes a colliquative diarrhœa sets in on the last day of life.

In the foregoing remarks we have had reference to a total deprivation, for a longer or shorter period of time, of food. It is now necessary to examine briefly the effects when, although a completely nutritious diet is wanting, certain partial nutriments are allowed. As is well known, the proteid foods, though uneconomical in the quantity required, and in the tax imposed on the digestive organs, are of themselves competent to support life. Not so, however, with the non-proteid albuminoids, gelatin and chondrin, or the non-nitrogenous fats and sugars. Yet all these classes of food will spare the destruction of a certain amount of the albuminoid matters of the body and thereby prolong life. Gelatin is the most effective of these palliatives of starvation. Voit estimates that 100 gm. of dry gelatin economize 50 gm. of dry albumin. If fat be given with plenty of water, not only some of the fat tissue of the animal is spared, but also some of the albuminoid, and there is a slight increase in the carbonic-acid elimination over that observed in an absolute fast. Sugar also (if water be allowed) prolongs life, and under its administration the carbonic-acid elimination is greater than when fat is allowed.

We come now to the influence exerted by the allowance or withholding of water upon starving animals.

WATER ALLOWED AND SOLIDS WITHHELD.—The most important fact in this connection is that the administration of a moderate amount of water materially diminishes the loss of body weight and prolongs life to a corresponding degree. The elimination by the kidneys, and especially that by the lungs and skin, is increased by the drinking of water, but not to an extent equal to the water consumed. There is also less urea excreted when water is drunk.

Contrary, however, to what might perhaps be expected from what has just been said, the fasting animal requires a less quantity of water than the one which has plenty of food. The reason of this is that a considerable quantity of water is set free and put at the disposal of the organism by the destruction of tissue. Muscular substance contains 3.15 parts of water for each part of dry substance. In a dog experimented upon by Pettenkofer and Voit there was a loss of 175 gm. of albuminoid matter. This would set free 551.25 gm. of water. The water eliminated was found to be, as a matter of fact, less than this amount, being only about 506.1 gm., and in this case the animal, which was allowed to drink freely, took only 33 gm. The ingestion of water, then, while postponing the fatal result of a fast, produces no important change in the mode of death from that which occurs in simple inanition.

SOLIDS ALLOWED AND WATER WITHHELD.—When an animal is deprived entirely of water and of foods containing any considerable amount of moisture, starvation takes place almost as it does when solids also are withheld, for the animal soon ceases to eat. Two pigeons on which this experiment was tried by C. Falck and Scheffer gave as a mean the following figures: At first, being given enough water and wheat to maintain a uniform weight, they took per 1,000 gm of body weight, 103 gm. of water, and 85.5 gm. of wheat, a total of 188.5 gm., against which their total excreta were 187 gm. For the next four days water was withheld and wheat allowed *ad libitum*. Of the latter they took only 25.5 gm. per day, and their total daily excreta weighed 79.5 gm. Again, for eight days they received all the water and wheat they wished. This amounted in the first day to 442 gm. (342 of water and 80 of wheat). The excreta on this day were 180.5 gm. The average total ingestion for the first four days was 248.5 gm. (water 148.5 gm., wheat 100 gm.), the excreta 201 gm. On the next four days the ingesta were 176 gm. (water 91 gm., wheat 85 gm.); the excreta 176 gm. They had thus regained their former nutritional equilibrium. They were then again deprived of water until their death, which happened on the thirteenth day. The ingestion of wheat fell to 19 gm., and the excreta were 56 gm.

The mean daily loss of weight in pigeons so treated is from three and a half to five per cent. of their original weight, and the duration of life from nine to thirteen days. The total loss is from thirty-five to forty-nine per cent.—not materially different from what occurs where solids are withheld

DURATION OF LIFE DURING FAST.—As has been seen above, this has wide variations, depending as it does upon many factors, as the temperature of the surrounding medium, the quantity of fat possessed by the animal, etc. Perhaps an average would be from eight to ten days, during which the animal loses say forty per cent. of his weight. But, as we shall see in speaking of fasting in the human subject, this length of time may be enormously exceeded, as indeed it frequently is, in animals. In the classical case of the fasting pig, the imprisoned animal, which was enormously fat, was released alive at the end of one hundred and sixty days, having fallen away in weight from one hundred and sixty pounds to forty pounds.

In Man.—Inanition in man is usually more or less incomplete, but in a partial form it is not very uncommon. The insane frequently refuse food, and inanition may become quite advanced before the patients are put into an asylum, where, of course, they are fed, if necessary, forcibly. One such case is reported where a young man took nothing but water flavored with orange juice for sixty-one days. At that time he was seen by a physician and induced to eat, but, perhaps through injudicious treatment, he died on the eleventh day afterward.

Hysterical patients are particularly given to fasting, and reports of such cases often get into the daily press. Critical investigation usually develops the fact that there has been a good deal of deception of the attendants; but it is undeniable that such patients do subsist for long periods on an incredibly small amount of nutriment. In one notable case investigated by Charcot, the urine and the vomitus showed, on a most careful analysis, that the daily excretion of urea was only 5 gm. In a man, during complete abstinence, it was found to be not less than 10 or 12 gm. Many instances are on record in which hysterical women have dropped off one article of food after another, and have finally reached a point when, under perhaps one-tenth the normal amount of food, they pass a merely vegetative existence, lying on the back, obstinately constipated, with dry, rough skin, saying nothing, and, perhaps, only by a turn of the eye after a moving attendant, showing any appreciation of their surroundings. If they have practised deception they will sometimes, when put under strict surveillance, die of inanition without taking food. In the case of the so-called "Welsh fasting girl," who was reported to have lived without food of any kind for weeks, death occurred in eight days after she was placed under strict watch.

Inanition sometimes declares itself during the period of convalescence from acute fevers. There has been a large amount of tissue waste, with perhaps a small amount of nutriment taken. The importance of maintaining the nutrition in fevers is better recognized now than formerly, and probably extreme inanition is correspondingly rarer. But when the amount of food supplied has for some time been inadequate to the combustion maintained, we may expect to find the convalescence impaired by some of the symptoms of inanition.

The effect of starvation on the blood is temporarily to increase the number of red cells. This is apparent rather than real, and is due to a concentration of the blood. It is most marked in proportion as the *fluid* ingesta are withdrawn. In more advanced stages of starvation some deformity of the corpuscles may be expected, and a true anæmia.

Patients suffering from stricture of the œsophagus and from cancerous affections causing obstruction of the upper alimentary tract, sometimes die of inanition, though the recent development of the surgery of the stomach has much diminished the frequency of that event. Still, inanition plays a part in the symptomatology of many cases of cancerous disease, its effects being usually associated more or less indistinguishably with those of cachexia. In a case reported a few years since in *The Lancet* (November 27th, 1880), a patient having an œsophageal stricture was for ten months able to take nothing but milk. During this time he fell away in weight from one hundred and twenty to sixty pounds. For the next seven months he could swallow neither fluids nor solids, and was kept alive by rectal alimentation. He was able to walk about and his intellect remained unimpaired till three days before his death. At death his weight was forty pounds.

The new born are subject to a form of inanition due to incapacity to digest and assimilate the food ingested. Here a diarrhœa frequently replaces the constipation which, as we have seen, is a usual attendant of starvation. There is progressive emaciation, which may increase to the extent of thirty or even forty per cent. of the original weight. The skin wrinkles and the features take on an old look. The skin becomes inflamed from the contact of irritating discharges or from pressure. Often pustules of ecthyma appear. The chest is deformed; there is a sinking just above the epigastrium, while the xiphoid cartilage is pressed forward by the liver. The bones of the cranium overlap at the sutures and the fontanel is depressed. The belly is flattened; the stools are fetid. A peculiar odor, almost pathognomonic of starvation, exhales from the mouth and from the skin. The appetite at first is ravenous and the child calls for the breast constantly; later the appetite fails. The pulse and temperature lower progressively as the inanition increases; occasional transient elevations of temperature may, however, occur. The weight loss averages, in a child of 3 kgm., perhaps 100 gm. daily, and the duration of life may be eight or nine days. There is some reason to believe that robust infants succumb to inanition more quickly than weaker ones, perhaps because the latter require a less amount of force-production for their daily needs.

Clinical Observations of Simple Fasting in the Human Subject.—Few experiments, naturally, have been made upon human beings, and such as have been possible from the willingness of individuals to subject themselves to deprivation of food, have, unfortunately, been almost entirely devoid of scientific value. One is alluded to above under the subject of temperature. In the summer of 1880, a man named Tanner accomplished, as was claimed, a fast of forty days in New York. For the first two weeks he was not watched by any regular physician, but after that time one or more physicians remained with him constantly, and there seems little reason to doubt that he did actually keep the fast as represented, though there was an unfortunate lack of scientific observation of the phenomena presented. It being warm weather, there was comparatively little demand for heat-production. At the sixteenth day the man began to drink water, which was attended with marked improvement in his condition. The total loss of weight was thirty-two pounds. Toward the latter part of the time there was considerable nausea, ending in vomiting of biliary matter, mucus, epithelium, and a few blood corpuscles. There were very troublesome tympanites and obstipation after the first day. There was mental irritability, but no delirium. During the first part of the time he walked about and rode out daily, but later spent much of his time lying on a cot covered with blankets. One estimate of the urea gave on the first day 29 gm., on the fifth day 18 gm., on the eighteenth day 14 gm.

Famine and siege, which in years past have carried off multitudes of human beings by starvation, are no longer, it is to be hoped, capable of causing such destruction, at least in civilized countries. Shipwreck, however, remains as a not infrequent cause of starvation, under varying conditions as to heat, moisture, etc. Medical observations are not wanting upon the condition of men reclaimed at various degrees of inanition. The members of the Lady Franklin Bay expedition, under command of Lieutenant Greely, passed the winter of 1883–84 at latitude 78° 45′ N., longitude 74° 15′ W. From November 1st to March 1st, their daily ration was 14.88 ounces of solid food, the regular army ration being forty-six ounces. From March 1st to May 12th, the daily ration was ten ounces of bread and meat, with one to three ounces of shrimps. From May 12th to June 22d, there was no food but a few shrimps, reindeer moss, and black lichen scraped from the rocks. There was water, brackish in quality. The temperature of the surrounding medium was 5° to 10° F. There was no artificial warmth. The men, in general, slept much of the time (sixteen to eighteen hours daily), approximating a condition of hibernation. There was not much pain, even after going several days without food. It was only after the ingestion of food that the craving became great. Constipation was excessive; the intervals between the stools were eight to ten and even sixteen days. The men were obliged to dig out the hardened fæces with their fingers—the abdominal muscles being too weak to extrude them—and often fainted after evacuating the bowels. The deaths occurred seemingly from pericardial dropsy. There was œdema of the feet and face, then a short spasm of præcordial pain, and a slight general convulsion followed by death. The party consisted of twenty-five men; one died in January, of scurvy; sixteen died between March 1st and June 22d, when the survivors were rescued. The medical report showed the condition at that time to be as follows. (The report of one is given which is closely representative of all.) The patient fainted and vomited on first being removed. A sickly, offensive odor, as of stale urine, was emitted from the body, which was greatly emaciated, with skin hanging from the limbs in flaps. Weight one hundred and twenty pounds, the normal weight being one hundred and sixty-eight. Mind excitable and irritable, at times almost irrational. Loss of memory, attended later by amnesic aphasia. At first very talkative. No pain. Tongue dry and cracked, abdomen empty, and lying almost in contact with vertebral column; had had no stool for six days; ravenously hungry. Pulse 52, soft, compressible. Blowing murmur over base of heart in systole. Respirations twelve per minute. Temperature (under tongue) 97.2° F. No specimen of urine obtainable. Inability to move or stand without support. No sleep. Soreness and pain were felt in the muscles.

In the next few days there were alvine dejections, small, dark, and highly offensive, and showing diminution of bile. The skin became jaundiced for several days. The urine, normal in amount, was highly albuminous, and so continued for several days. No casts. Examination of the blood showed marked increase of white corpuscles (one to twenty red). The red corpuscles showed little tendency to cohere or to run into rouleaux. They lacked their distinctive biconcave disc shape. On the third day there were three or four hours of natural sleep. The pulse and temperature gradually rose. The anæmic murmurs continued for some time, as did the albuminuria. After a week the patient had gained nine and a half pounds, and was able to sit up. The appetite was still voracious. The mental condition was tranquil, and the amnesic aphasia disappearing. In six weeks the normal weight had been regained.

The *diagnosis* of inanition admits of no doubt except in cases in which it is complicated with other conditions. Yet it is just here that the diagnosis is sometimes of most importance, as, for instance, in the convalescence from acute fevers, where the success of the treatment depends on recognition of this element. It is first important to bear in mind that inanition is liable to occur whenever the supply of nutrient matter to the body has been interrupted.

In infants, as has often been remarked, most of the symptoms of inflammatory disease of the meninges may show themselves as the result of simple starvation. In fever convalescents there is sometimes delirium with headache, dimness of sight, and hallucinations. This condition has been mistaken for meningitis. But the headache in inanition is usually less severe, and the delirium, which probably corresponds to a condition of cerebral anæmia, is generally, though not always, of a calmer type. Still the hallucinations which result from it may lead to suicidal or homicidal attempts. One important point is, that the temperature is usually normal or subnormal, while in most other forms of delirium, save in light cases due to alcohol, it is elevated. The diagnosis of delirium due to inanition depends not so much on any peculiarity in the character of the delirium as upon the complexus of symptoms, the opportunity for starvation to have occurred, and the low temperature.

Sometimes vomiting sets in during inanition, a fact which should be borne in mind, in order that there may be no cessation of the nourishment on account of a misapprehension as to the nature of the vomiting. The food must be made as easy of digestion as possible, and, if it is rejected, rectal alimentation must be used as a temporary expedient. There is nothing in the character of the vomiting which is distinctive evidence of its source being in starvation. But, as with the more common symptoms just referred to, its nature must be diagnosticated from the other circumstances. Of course, vomiting may itself be the cause of inanition in cases of structural or functional disease of the stomach, but here we shall have a history of vomiting having preceded the excessive emaciation, instead of having followed it.

TREATMENT.—Much care is required, in the dietetic treatment of persons who have been subjected to starvation, that the nourishment be given in small quantities, and that the ravenous appetite of the patient be not followed as an indication of the amount of food required. In extreme cases some stimulant is often required at first on account of the great reduction of temperature; external heat should be freely applied. Meat seems to be the article best adapted to the resumption of long suspended nutrition. Scraped raw beef is one of the most valuable foods, and should be given in teaspoonful doses, flavored, every hour or half-hour. The fluid preparations of beef are also very useful. Milk may be given in alternation with these. From these beginnings the diet may be built up in the usual way. When inanition has been due to some disease not necessarily fatal, the same method of feeding may be relied upon to restore to health; but, of course, in cancerous and other destructive cases the treatment of the element of inanition is greatly circumscribed. Rectal alimentation should, however, always be maintained as long as possible.

A word should be added as to the use of fasting as a therapeutic measure, which formerly had more adherents than now, and was dignified with the name *cura famis*. With the increasing belief in the importance of maintaining nutrition for the sake of all vital processes, its application has become more and more limited. Its chief value is in the treatment of acute disorders of digestion, where the temporary withdrawal of food gives the organs a chance to obtain physiological rest.

Starvation, in whole or in part as to some articles of diet, has been made use of, from a therapeutic point of view, in the treatment of certain diseased conditions, notably obesity and diabetes.

Many years ago, one Banting, who was successfully treated by Harvey for obesity, wrote an account of the treatment pursued, from which the noun Bantingism and the grotesque verb "to bant" acquired a place in our language. The rules of Chambers, Banting, Cantani, and others amounted practically to a starvation cure, almost nothing but proteid food being allowed. They are open to the following objections: (1) They are usually tolerated for only a brief period, during which the patient is undergoing the "cure," and are not capable of being followed as a permanent rule and habit of life. Hence, after losing a few pounds of weight under their application, the patient returns with increased avidity to his original diet and at once regains what he has lost. (2) When persisted in, the starvation process is likely to aggravate an anæmia to which many obese persons are already liable, and hence to start a new chain of morbid processes. (3) An excessive albuminoid diet often leads to a loathing of all food, to indigestion, and chronic diarrhœa. (4) An exclusive albuminoid diet will, in supplying the necessary amount of carbon, cause the ingestion of something like four times as much nitrogen as the body requires, which overtaxes the eliminative system. (5) In reducing the fatty tissues of the body any starvation cure also reduces the albuminous elements, and so produces a failure in the nitrogenous equilibrium of the body.

The various mineral springs which have been recommended for the treatment of obesity, like Marienbad, Carlsbad, Kissingen, Soden, and Homburg, are effective only when conjoined with a dietetic regimen, and those waters which are strongly purgative are dangerous to many plethoric people.

The most satisfactory regimen for obesity is probably that of Ebstein, which is capable of maintenance permanently and does not incapacitate the patient for work. It contains, however, a qualitative and a quantitative diminution of food. The former, like that of Bantingism and the other starvation methods already noted, excludes carbohydrates. Sugar and sweets of all kinds are forbidden, as are also potatoes. Bread is allowed sparingly. The essential peculiarity of the method, however, consists in the addition of fats to the diet.

As the introduction of fat into the economy checks the decomposition of albuminoids, its effect as a constituent of the diet is to diminish the craving to make good that waste, or, in other words, to diminish hunger. Then the patient will require less meat in his diet. But whereas the amount of fat required by an average laborer is seven or eight ounces a day, Ebstein allows only about three ounces to his obese patient. He further limits the diet quantitatively, giving only three meals a day with three to three and one-half ounces of bread. The green and leguminous vegetables are allowed in small quantity. The proteid food, it is found, when accompanied by fat, can in itself be reduced from the thirteen to sixteen ounces allowed by Banting to two-thirds that amount.

An important addition to the dietetic treatment of obesity is the restriction of water and other fluids ingested. Although this point was made by some of the earlier writers, Oertel was the first to put it forward as a suggestion founded on scientific facts. The only alcoholic drinks allowed are a small quantity of a light red or white wine.

The dietetic treatment of diabetes is discussed elsewhere. But attention may here be called to the similarity in the restrictions called for in this disease and those called for in obesity. Also it will be noted that in both conditions the inclusion of fats in the diet facilitates the diminution in the harmful carbohydrate group. In applying even partial starvation methods for obesity, then, while we must limit the number of aliments allowed in order that the quantitative restriction may be more readily applied, we must beware of a too rapid and radical diminution in weight, and must make our regimen so tolerable that it can be continued as a permanency.

Charles F. Withington.

STASIS. See *Circulation, Pathology of.*

STATUS LYMPHATICUS.—(Synonyms: Constitutio lymphatica; Lymphatic constitution; Lymphatic habitus; Lymphatic dyscrasia; Lymphatic diathesis; Lymphatic chlorotic constitution; Lymphatism.)

Definition.—A so-called constitutional disorder characterized by a persistence or hyperplasia of the thymus and by general lymphadenoid hyperplasia, frequently associated with cardiac and arterial hypoplasia and the osseous evidences of rachitis.

History.—The term lymphatic diathesis is an old one in medical literature, and was no doubt applied to certain cases of status lymphaticus as above defined. Inasmuch, however, as scrofulous (see *Scrofula*) or tuberculous adenitis was particularly indicated by this ancient term, and that it was also applied to cases of pseudoleukæmia, chlorosis, and leukæmia, it is impossible to determine in how far it was definitely employed.

The most prominent anomaly of status lymphaticus, the persistent or enlarged thymus, was recognized by early pathological anatomists like Félix Plater (1614), Ch. Richa (1723), Bichat and Verdries (1726), and by Allan Burns, Franck, Kopp, Friedleben, and a number of others in the first half of the nineteenth century. (See also *Thymus, Diseases of.*) These pioneer students in their close attention to the thymus overlooked the accessory anatomical features of status lymphaticus; an error that has persisted to the present time and which has been productive of considerable confusion, since much of the literature bearing upon such clinical manifestations of status lymphaticus as laryngismus stridulus and sudden death is to be found by reference to the thymus alone. A clear conception of the lymphatic state was possessed by that pathological anatomist of wide and fruitful experience, Carl Rokitansky, who, in his text-book (1842–46), under the head of "Diseases of the Lymphatic Glands," mentions "lymphatic diathesis" or "lymphatic habitus." He observes that hypertrophy of the lymph glands occurs in childhood to puberty, or even beyond to mature life. The nodes of the abdomen (mesenteric and lumbar plexus) are most frequently involved, and this condition is commonly associated with hypertrophic development of other blood-forming organs, as, for instance, the thyroid gland, and more especially a highly developed spleen, "obstructed involution of the thymus," a hypertrophic state of the follicular apparatus of the intestines, and hypertrophy of the nervous centres. Such hypertrophies affect either the whole system or one portion, as, for instance, the glands of the abdomen. Under "Diseases of the Thymus Gland," Rokitansky says: "Its abnormal enlargement is almost entirely restricted to children, in whom we simultaneously observe a great predominance of the whole lymphatic system, rachitis, and hypertrophy of the brain." The hypoplasia of the heart and arteries, now acknowledged to be one of the frequently concomitant anomalies, commanded the attention of Wunderlich, Virchow, Rokitansky, Riegel, Kulenkampff, Bruberger, and Küssner between 1840 and 1880. On the assumption that vascular hypoplasia was fundamentally related to chlorosis, the condition was described by Virchow as the "lymphatic-chlorotic constitution."

Interest in the lymphatic state, both from the clinical and from the pathological standpoint, has recently been awakened, principally through the labors of the Vienna school, of which A. Paltauf, whose contribution in 1889 marked the new era, is a representative. The various morbid anatomical features of status lymphaticus were emphasized by Paltauf and illustrated by a series of careful autopsic studies. He revived the name "constitutio lymphatica," which is widely prevalent in recent German contributions; although, notwithstanding the care with which Paltauf endeavored to demonstrate the accessorial relationship of the enlarged thymus, one finds it still occupying the most prominent and often quite exclusive position in the reports of many recent writers.

Morbid Anatomy.—*Thymus.*—The predominant anatomical feature of status lymphaticus and the one that attracts attention most readily is the enlarged or persistent thymus gland. In children below the period of puberty the thymus of the lymphatic state is usually larger than in normal individuals. The enlargement of this organ has been repeatedly noted in infants dying by one of the several usually abrupt modes characteristic of lymphatism, and, as has already been said, this striking anomaly has often been noted to the exclusion of other accessory features. Such expressions as "thymus swollen," "thymus much enlarged," "thymus hypertrophic," appear in the autopsy protocols, together with data referring to the size and weight of the organ. The enlarged organ, which usually retains its bilobed shape, extends from the isthmus of the thyroid well down upon the pericardium, sometimes even to its diaphragmatic junction. Laterally, the thymus spreads after passing beneath the sternoclavicular union, generally expanding into two leaf-like lobes which reach a combined width of 5 to 6 cm. The thickness varies from 0.5 to 3 cm. The length of the enlarged thymus in children varies from 6 to 8 cm.; and its weight has been recorded as from 20 to 53 gm. Recklinghausen reports a thymus "as large as the liver of a new born infant" in a boy dying suddenly. A vigorous controversy has been waged as to the possibility of asphyxia from compression exerted by the swollen thymus upon the trachea at the point where the organ passes through the thoracic dome, the "critical space" of Grawitz, and some evidence seems to sustain the pressure theory as applicable to a few recorded cases.

It is generally conceded that the thymus in normal individuals undergoes an involution after the second or third year, and that this involution is usually complete at or soon after puberty (see *Thymus*). But in victims of status lymphaticus the involution of the thymus is retarded, in consequence of which a persistent and sometimes hypertrophic organ is encountered in adults, particularly those less than forty years of age. The location of this persistent thymus corresponds to that in children, and the state of enlargement varies in individuals as shown by the recorded weights of 20–135 gm.

Both in children and in adults the thymus of status lymphaticus resembles in appearance the normal organ of infancy. It is pinkish or flesh-like in color; and a distinct lobulation like that of the sweetbread of the calf, often with clearly outlined follicles, is seen. Its consistence is soft. Hemorrhages and consequent ecchymoses are present in certain cases, particularly those in which asphyxia has accompanied the sudden death. At times the thymus is the seat of an active hyperæmia, and a few instances are recorded in which a milky juice exuded from the cut organ.

The pathological histology of the thymus of status lymphaticus is not yet thoroughly elucidated, and more careful studies of a large material by the use of recent methods is highly desirable. In a general way it appears that the enlarged organ reproduces the microscopic structure of the normal thymus of infancy, differing only in the multiplication of the lymphoid cells which serve to increase the size of the follicles, and to produce new ones both in the normal sites and in the adipose tissue surrounding the gland proper. The normal division of the thymic follicle into cortex and medulla is usually retained, though the hyperplasia of lymphoid cells tends to invade the medulla and to infiltrate the trabecula of the follicles. Some authors have described an increase of eosinophilic leucocytes in the enlarged thymus, but we have evidence that this is not a constant feature. Endothelioid cell proliferation has also been described.

But while persistence and hypertrophy of the thymus is a prominent characteristic of status lymphaticus, it is not an invariable one, for we may have a non-thymic lymphatism in which general lymphadenoid hyperplasia and arterial hypoplasia exist with a thymus of normal size or one that has undergone perfect involution.

Further, it is well to recall that the anatomical evidences of the lymphatic state may be erased by a number of different causes, and that the thymus is one of the earliest structures so affected. Advanced years, particularly after the fortieth, usually induce rapid subsidence of the enlarged lymphatic structure. Various chronic diseases, and particularly those associated with debility, marasmus, and wasting, act similarly. Some acute diseases may produce the same effect.

Lymphadenoid Hyperplasia.—A generally hypertrophic state of the lymphadenoid tissue is, next after the anomaly of the thymus, the most noticeable evidence of status lymphaticus. This is shown by an increase in the size and number of the lymph follicles in various portions of the body. In the lymph glands, both superficial and deep, it is made apparent by their increased size and also, at times, by enlargement of the individual follicles. Sometimes the superficial lymph glands are not particularly augmented, while those of the abdomen, especially of the mesentery, are affected. Usually the enlarged lymph nodes remain discrete, but there may be a diffuse increase of lymphatic tissue, particularly in the mesentery.

In the respiratory and gastro-intestinal tracts the lymph follicles are generally very prominent. The faucial, lingual, and pharyngeal tonsils, with the intervening solitary follicles, and those at the base of the tongue, in the larynx, œsophagus, and stomach, participate in the process. In the intestines both the solitary follicles and those aggregated in Peyer's patches are unduly prominent. A distinct adenoid ring may appear occasionally in the duodenum, and more frequently at the ileo-cæcal junction. In the small intestine, and particularly in the lowermost portion of the ileum, the follicles of Peyer's patches may protrude above the surface of the mucosa, sometimes appearing as subspherical projections half a centimetre in height; and such augmented patches may reach a length of 9–11 cm. Here the solitary follicles also project prominently, at times even taking the appearance of polypoid outgrowths. In the colon an increased prominence of the solitary follicles, with their pit-like central areas still remaining, is observed. Taken as a whole, the hyperplasia of the lymphatic structures of the intestines in status lymphaticus closely simulates that seen in the stage of swelling of typhoid fever, and might readily be so mistaken.

The retroperitoneal lymph glands usually participate in the hypertrophy, to the same degree as that observed in the mesenteric nodes; and the bronchial glands are also involved, although not invariably. Of the superficial nodes, those of the inguinal, popliteal, axillary, cervical, supra- and infraclavicular regions may be affected to a varying degree, but usually not extensively. Collections of lymphoid cells have been described in the liver, thyroid, and bone marrow, and Kundrat cites a case in which red marrow was present in the shaft of the femur.

Spleen.—A moderate enlargement of the spleen is the rule in status lymphaticus, while the prominence of its Malpighian bodies is more striking. Generally, the splenic pulp is firm, the organ filling its capsule well. In cases of sudden death in individuals of robust condition the splenic pulp is hyperæmic. In the midst of the more or less deeply colored pulp the follicles composing the Malpighian bodies stand out with startling distinctness as pale round areas, often measuring 2–3 mm. across, and resembling large miliary tubercles.

Histologically one finds the enlarged Malpighian bodies to consist of closely packed small lymphoid cells, generally surrounding the arterioles and supplied with few blood-vessels, thus contrasting sharply with the adjacent pulp tissue with its dilated and engorged blood sinuses. Not infrequently the hyperplastic lymphoid cells of a follicle will infiltrate diffusely into the adjoining pulp tissue, and at times small foci of lymphoid elements, without direct connection with a well-formed follicle, will be found scattered throughout the splenic substance.

The dilated sinuses of the splenic pulp are filled with blood, and in some cases evidence of extensive hæmolysis and the deposit of blood pigment appear in the pulp cells.

Cardiac and Arterial Hypoplasia.—In certain cases of status lymphaticus, particularly those coming under Virchow's class of "lymphatic-chlorotic constitution," a pronounced hypoplasia of the arteries, and sometimes of the heart as well, has been noted. Some authors have described a general arterial narrowing, others a narrowing of the aorta; in fact, so far as the aorta is concerned, a diminution in calibre has been pretty uniformly discovered. In view of our ignorance as to the causation of aortic narrowing, whether real or only apparent and due to varying degrees of elasticity, we are not prepared to assert just what is the nature of the change found in victims of status lymphaticus; but that the aorta, at times the general system of arteries, and rarely the heart, are smaller than the same structures in average normal individuals is unquestionable. Even in adult lymphatic males of full stature and well developed otherwise, an aorta measuring but 4 cm. in circumference at its cardiac end has been found, and a circumference of 5 cm. at the aortic ring is the rule. These narrow aortas are usually thin-walled and quite elastic. Rupture of such thin-walled arteries has been reported; and in certain cases in which the heart also was hypoplastic, a patent foramen ovale has been found.

Rachitic Bone Changes.—That there is a close morbid anatomic association of status lymphaticus and rickets is abundantly proven, particularly in the case of lymphatic infants. Still we are not at present in a position to say that all cases of status lymphaticus are associated anatomically with the rachitic dyscrasia, nor do all cases of rickets exhibit the evidences of lymphatism, though its coincidence with enlarged spleen and hyperplasia of the mesenteric nodes is well known. In infants dying in the lymphatic state a mild grade of craniotabes, the rosary, curvature of the long bones or spine, and enlarged epiphyses, have been manifested as rachitic osseous changes; and in older children or adults several instances of rachitic spinal curvature, pigeon breast, narrow pelvis, and curvature of long bones have been found. Microscopically the affected bones present the lesions characteristic of rickets.

Skin.—A thick skin and an increased fat layer have frequently been noted among the anatomical findings. In the skin an increase of the elastic elements has been described as a factor in augmenting its thickness. Pallor of the skin of the peculiar kind known as pasty ("pasteos") is looked upon as an evidence of lymphatism.

Blood.—Observations upon the blood in status lymphaticus are still meagre, and a unanimous opinion as to the characteristic alterations has not been reached. One would expect a lymphocytosis in these cases, and this has been reported in several cases. Thus Ewing found a pronounced increase in the number of mononuclear large and small lymphoid cells in the blood of one of his cases, and he suggests that further systematic search may reveal this as a constant condition. In the red cells no abnormality in number or structure has been detected.

Occasional Features.—In many of the cases of sudden death among the victims of the lymphatic state a pronounced active hyperæmia of the thoracic and abdominal viscera, and occasionally of the brain, has been described. Further, particularly in those sudden deaths in which asphyxia figured, hemorrhagic ecchymoses of the pericardium, thymus, pleura, and endocardium were present in the order of frequency of the structures mentioned.

Hypertrophy of the thyroid is a quite common accompanying anomaly. There may be a simple hypertrophy, a parenchymatous goitre, or a cystic goitre. In about one-half of the reported cases the thyroid has been found enlarged.

Œdema of the skin, or more commonly eczema, is occasionally found. Œdema of the lungs has been discovered in some cases of sudden death in lymphatic individuals; and in lymphatic epileptics dying after one or several attacks, or from rapid status epilepticus, this condition is encountered as the general rule.

Hypertrophy of the brain is mentioned by Rokitansky as one of the features of status lymphaticus, at times combined with cerebral œdema or with widening of the ventricles and increase of intracerebral fluid. In some of the recently studied cases one or more of these conditions are mentioned, and, in certain epileptics in the lymphatic state, general cerebral hypertrophy, localized hypertrophy, œdema, or hydrocephalus may appear.

On the side of the sexual organs peculiarities are occasionally encountered. A retarded development of the external genitals and the delayed appearance of the beard, the pubic and axillary hair in the male, are examples of these. In the female an infantile (and sometimes double-horned) uterus with undeveloped tubes, ovaries, and mammæ, together with a masculine aspect of the whole body, are likewise occasionally found.

Before dismissing the subject of the morbid anatomy of status lymphaticus we should emphasize the fact that a number of the characteristic features are profoundly modified by the individual's state of nutrition. In those victims of status lymphaticus who die suddenly in a good state of nutrition such anomalies as the large thymus, lymphadenoid hyperplasias, and thick fat layer appear prominently; but when nutrition has suffered through the exhausting influence of chronic diseases or the rapid wasting of certain acute affections, these structures atrophy along with the rest of the body. On the other hand, the aortic or arterial hypoplasia, and the osseous changes of ancient rickets are ineradicable, though these, it must be remembered, are not invariably present.

Again, one may find status lymphaticus associated with certain other diseases and their anatomic changes, as, for example, Basedow's disease, struma, scrofula, and pseudoleukæmia.

Clinical Manifestations.—Status lymphaticus has been found in a number of diseases in which the association seems to have been more than a mere coincidence.

Thymic Asthma.—Up to very recent times that peculiar spasmodic neurosis known as spasm of the glottis, laryngismus stridulus, child-crowing, or by the term "asthma thymicum" given by Kopp in 1824, has been looked upon as having its morbid anatomical basis in an hypertrophy of the thymus. But in the last decade more exhaustive studies have disclosed one or several of the other features of the lymphatic state in these cases, and there need now be little hesitancy in considering this affection as one of the clinical evidences of the latter condition and in describing it in this connection.

Thymic asthma, a disease of infancy, may be defined as a paroxysmal suffocation, and is a not uncommon cause of sudden death, especially between the fourth and tenth months. Its symptomatology has been well described by Kopp, and more recently by Pott. In a typical fatal attack the child suddenly jerks its head backward with a sharp noisy inspiration like that of whooping cough, but sharper and shallower; the eyes are upturned, fixed, and pupils dilated; the face has a painful, anxious expression, is blue at first and then pallid; the nostrils are dilated. The tongue swells and arches so as to press against the hard palate, while the veins of the neck become engorged and stand out prominently. The arms assume a condition of tonic extension with fists clinched and thumbs turned into the palms. The legs become extended, great toes abducted and dorsally flexed. An attitude of opisthotonos is assumed by the spine. A convulsive tremor of the facial muscles and an ineffectual gasping inspiratory attempt follow. Suddenly the spasm ceases, the face becomes ashy, then cyanotic; the tongue and lips are livid; and after one or two minutes the child is a corpse. Urine and fæces are involuntarily passed if artificial respiration is attempted. The heart ceases its activity at the onset of the paroxysm; its sounds are inaudible and the pulse is absent. Reflex irritability is lost. In attacks not fatal the clinical phenomena resemble those just described; there is the abrupt onset, the paroxysm of suffocation and convulsive movements of various groups of muscles, often with involuntary evacuations, and occasionally with complete loss of consciousness. Friedleben, one of the older observers, states that these attacks occur most frequently in well-nourished infants, though they may appear in the debilitated. The interval between the spasms may be hours, days, or weeks, though they tend to increase in frequency and severity. Twenty to forty attacks have been noted in twenty-four hours. The period of the first dentition is the one particularly prone to this affection, though it has been recorded in the new-born infant. The so-called idiopathic spasm of the glottis of adults is probably dissimilar at least in so far as its relations to status lymphaticus are concerned, though this point has not been definitely settled.

Thymic asthma and thymic sudden death in infants stand so closely allied as to make a separate consideration unnecessary, for while many infants have succumbed suddenly, in which, for want of actual observation or for lack of trained observation, none of the symptoms of thymic asthma has been described, it is highly probable that one or more of the convulsive phenomena just mentioned actually preceded death. Many of these sudden deaths in infants are tragic occurrences, and not infrequently they have called for medico-legal investigation. Some of the children in seeming good health have expired abruptly in the presence of spectators or even in their parents' arms (Grawitz and others); they have been found dead in bed, and suspicions of foul play have been entertained against a mother or nurse under these circumstances; or death has been ascribed to suffocation in the bedclothes. Some, at least, of the deaths from fright recorded among children doubtless belong to this same category, and here also probably belong those occasional instances in which animals like cats or dogs have been suspected of causing the death of infants, as in those popularly described as "cats sucking the breath."

As to the etiology of thymic asthma and thymic sudden death the controversy aroused by Kopp's theory is still waging. Kopp maintained that the weight of the enlarged thymus on the heart, lungs, and great vessels induced the spasm of the glottis either by direct pressure or by irritation of the recurrent laryngeal nerve. Even to the present time the mechanical theory advanced by Kopp is accepted by some authors, or the modification of it proposed by Grawitz, who held that direct compression of the trachea is produced by the swollen thymus at the point where it emerges from the dome of the thorax ("critical space"), particularly when the head is suddenly drawn backward. Ever since the time of Friedleben's masterly studies upon the diseases of the thymus (1858) the pressure theory has been combated, and a large controversial literature has appeared. That the mechanical factors are concerned in some of these cases seems undeniable, but even in those in which the marks of tracheal compression are indubitable, it is still impossible to say that compression alone was the active agency in exciting the spasm or the sudden death. Because of the inadequacy of the mechanical theory to explain the majority of the cases, the tendency in the last few years has been more and more toward the view advanced by Pott, and extended by Paltauf. Pott believed the fatal issue to be ascribable to sudden arrest of the heart, though he charged the cardiac affection to the results of pressure of the suddenly congested and already hypertrophied thymus upon the trachea, pulmonary artery, and right auricle. Paltauf also ascribes thymic sudden death to a spasmodic arrest of the heart, but he goes beyond the thymus and looks to status lymphaticus as the responsible condition. He points out that the enlarged thymus coexists with general lymphadenoid hyperplasia, and arterial hypoplasia—that is, with the lymphatic state—and that the victims of this dyscrasia possess a lowered vital resistance and a particular proneness to convulsive disorders, among which cardiac or respiratory spasm or paralysis are the most dangerous. In this light, spasm of the glottis or thymic asthma becomes a reflex respiratory spasm, and thymic sudden death a reflex cardiac paralysis, both in some way dependent upon the exaggerated irritability incidental to status lymphaticus.

Infantile Eclampsia.—That teething fits are often associated with rickets has been pointed out by a number of authorities. The relationship of infantile eclampsia and status lymphaticus has not been emphasized, but there is reason for believing that this convulsive neurosis, like glottic spasm, occurs in lymphatic children. In a few cases eclampsia and spasm of the glottis have been noted in the same infant in which status lymphaticus was disclosed at autopsy. As we shall see in the section following, tetany is one of the neuroses frequently combined with eclampsia and one in which status lymphaticus has been found to exist. It therefore appears quite proper, even in the absence of an abundance of direct evidence, to discuss the general convulsions of infancy in their present connection; and the writer is of the belief that more careful study from the point of view just indicated will show the correctness of this position. I have, during the last year, had the opportunity of performing an autopsy on a six months' infant dying of general convulsions, and found a large thymus with pronounced hyperplasia of the intestinal and splenic follicles, and hypertrophy of the mesenteric glands.

Idiopathic Tetany of Infancy.—Closely allied to spasm of the glottis and eclampsia is the carpopedal spasm of infancy which is, by most recent authors, classed as infantile idiopathic tetany. Tetany in infancy may manifest itself by carpopedal contractures alone, which occur in intermittent attacks or very rarely as a persistent spasm; it may exist as a latent affection, only showing under certain conditions of irritation; it occurs in combination with laryngeal spasm, or with laryngeal spasm and eclampsia. Its relations to rachitis have been repeatedly pointed out, and discussions as to the invariable association of craniotabes and tetany and the causative influence of the former have frequently arisen. The association of tetany and status lymphaticus has been emphasized particularly by Eschereich, whose opportunities for the study of this and its allied neuroses have been especially good. He affirms that the lymphatic state may exist as a complication of tetany, and that it is of especially grave import. The various anomalies of status lymphaticus have been disclosed in autopsies on victims of tetany, although not always recognized in their proper connection.

Epilepsy.—A mention of persistent thymus in epilepsy was made in 1890 by Kruse and Cahen, based on their finding this anomaly in autopsies on two epileptics. The association of epilepsy with status lymphaticus has been particularly emphasized by the writer as the result of his studies in the Pathological Laboratory of the Ohio Hospital for Epileptics. In autopsies upon the victims of idiopathic grand mal, particularly in young and robust individuals, evidence of the lymphatic state occurs with a regularity that suggests more than an accidental relationship, though the tracing of a possible causal connection between epilepsy and status lymphaticus is at the present time largely a matter of speculation. I have already noted that a clinical kinship has been traced between epilepsy and the neuroses above mentioned, particularly infantile eclampsia and spasm of the glottis, and, as already suggested, these neuroses have been associated both with rickets and with the lymphatic state. As for epilepsy, no less an authority than Gowers has concluded from purely clinical and statistical observation that rachitis must be looked to as a fundamental factor in the occurrence of teething fits and more remotely of the epilepsy which so frequently follows in a victim of infantile eclampsia. My studies in the morbid anatomy of epilepsy have revealed the evidence of an ancient rickets in a proportion of cases, and the anomalies of status lymphaticus as a relatively constant occurrence in the subjects of idiopathic grand mal dying under circumstances favorable to the retention of the anomalies of the lymphatic state.

Epileptics are very prone to sudden and often tragic deaths, as by asphyxia (sometimes mechanical, sometimes not), "syncope," "heart failure" without anatomical cardiac lesions, rapid status epilepticus, œdema of the lungs, "cramps," and drowning, and I have endeavored to define an affinity between the sudden death in epilepsy and that seen in such neuroses as thymic asthma, the various forms of thymic sudden death of infancy, and those in adults presently to be described.

Death in Surgical Narcosis.—Gradually, but more particularly since the report upon Kundrat's observations, we are coming to learn that status lymphaticus is to be held responsible for most of the deaths in chloroform anæsthesia, and probably for many of those occurring in surgical narcosis by the use of other agents like ether, nitrous oxide, etc. Our information concerning chloroform sudden death is particularly definite because of the almost exclusive use of this drug in Austria and Germany, where, to the present time, thorough autopsies with the possibility of discovering the existence of status lymphaticus have alone been practised. Unquestionably when we come to make a careful anatomical analysis from the standpoint just indicated we shall find the conditions attending anæsthetic accidents in America identical with those recorded in Europe; though the impression now seems to prevail that chloroform *per se* is the especially dangerous anæsthetic in victims of the lymphatic state.

As to the time and mode of death no regularity has been determined. Any stage of anæsthesia from the first few whiffs to the completion, or during the period of recovery, or even several hours after the narcosis and operation have been ended, may be selected as the fatal moment. Death may be very abrupt with evidence of cardiac and respiratory failure, or the patient sinks more gradually with enfeebled pulse and shallow respiration. Methods of resuscitation, such as avail in the ordinary accidents of anæsthesia, are here fruitless.

For their protection in cases of the often distressing accidents of surgical narcosis it is important that the surgeon and anæsthetizer keep clearly in mind this now well-established association of status lymphaticus. Unfortunately, our means of ante-mortem diagnosis in status lymphaticus are at present quite unsatisfactory, particularly in the case of adults. In children the existence of adenoids, enlarged tonsils, enlarged superficial lymph nodes, and osseous rickety changes, together with a history showing eclampsia, laryngismus stridulus, or idiopathic tetany, should be seriously considered as having grave prognostic importance.

Death from Trivial Surgical and Medical Procedures.—Closely allied with the sudden death in surgical narcosis are those which occasionally follow minor operations. In some of these, especially those in which incomplete anæsthesia has been employed, it is questionable in how far the anæsthetic or the shock of the operation is to be held accountable for the fatal termination. Illustrations of this point are the deaths which have followed operations for the removal of nasopharyngeal adenoids. Here a partial anæsthesia is commonly employed, and most of the sudden deaths have been found under these conditions.

Although the point has not yet been prominently emphasized, I am personally inclined to the belief that careful study will reveal all the unexpected deaths following adenoid operations (including those on hypertrophied tonsils), either with or without anæsthesia, to be associated with status lymphaticus. It is at least pertinent to recall that the lymphatic overgrowth making the basis of nasopharyngeal adenoids and enlarged tonsils is one of the manifestations of status lymphaticus.

Allied to the accidents just alluded to are the deaths occurring in other minor operations done in incomplete anæsthesia, and heretofore ascribed either to the anæsthetic alone or to the shock and drug effect combined. A well-known illustration is the occasional fatal accident during or after the extraction of a tooth. The occasional deaths after minor accidents, and following various trivial operations in which no anæsthetic is used, will doubtless gradually find their way into the group of neuroses associated with the lymphatic state.

A particularly appropriate illustration concerns the sudden deaths following the injection of curative sera, of which the first pronounced example was in the case of the young son of Professor Langerhans, of Berlin, who died suddenly a short time after the injection of a small dose of diphtheria antitoxin, used by his father for preventive purposes. At the time of the occurrence this case excited much discussion, and various theories were put forward to explain the accident, especial stress being laid upon the possible toxic effect of the antitoxin. However, the autopsy revealed certain evidences of status lymphaticus like swollen spleen with prominent follicles, enlarged tonsils and pharyngeal follicles, hyperplastic intestinal follicles, and slight rickety thickening of the costosternal margin; and while these were not taken into serious consideration during the immediate examination, they were dwelt upon later, and by such experienced students as Paltauf, Escherich, and others, it was concluded that this unfortunate accident was one of the fatalities of the lymphatic state.

Escherich reports the case of a lymphatic child who died in a salicylic-acid pack. Galatti records a similar fatality after an external application for eczema; the child developed tonic and clonic convulsions, and died in twenty-four hours, and here Kolisko found, along with the eczema, œdema of the brain, rachitis, and anæmia with evidence of lymphatism. In connection with his case Escherich points out the danger of narcosis, prolonged hydrotherapeutic treatment, or weakening therapeutic measures in children with status lymphaticus.

Sudden Death in Adults, and Death in the Water.—Abundant evidence has accumulated to show that adults, especially young, apparently strong individuals, are, like infants and children, the subjects of status lymphaticus and therefore exposed to such accidents as sudden death under the various circumstances just related, as that in surgical narcosis and after trivial operations. Death in the water by so-called "drowning" is one of the modes noted more particularly in adults, though mentioned in the case of some infants. In some of these fatal accidents the victims have been found dead with no external evidence to indicate the mode of termination. Others have died before spectators by a variety of tragic methods. A number have expired in the water with so-called "cramps" or by "drowning," in which the usual post-mortem findings of fatal immersion were absent. Most of these occurrences have demanded medico-legal investigations, and their importance from this standpoint is so great that it seems desirable to illustrate the subject by citing some typical cases.

Nordmann describes the case of a twenty-six-year-old scavenger, in apparent good health, who was found dead in the situation of his work. Autopsy showed the body of a medium sized, strongly developed man, with diffusely ecchymotic skin; tonsils and papillæ of the tongue prominent; lungs congested and moist; heart ecchymotic; flesh somewhat thickened, tough, and pale; liver and kidneys dark and hard; thymus persistent and enlarged, measuring 7 × 5 × 1.5 cm.; lymph glands in neck, axilla, and mesentery much enlarged and pale; aorta narrow (5.5 cm. above valve), wall thin and smooth.

Another case, noted by Nordmann, is that of a twenty-five year old man who died suddenly without assignable cause while playing cards with several companions. Section (by Kaufmann) revealed a thymus gland, thin, but as large as the palm of the hand, general hyperæmia; flaccid, slightly dilated heart, and slight enlargement of lymphatic glands and follicles.

Still another case recorded by Nordmann illustrates a form of sudden death after bathing. A soldier in good physical condition, twenty-six years old, went bathing on a warm August afternoon with a number of comrades. All precautions were taken as to the proper temperature of the water. He entered the water slowly, swam about for two or three minutes, and returned to the shore. After emerging from the water he complained of chilliness, suddenly stiffened his extremities, became pale, turned his eyes upward, and with a long-drawn inspiration fell to the ground. He was assisted to a sitting posture, where Nordmann found him pulseless, with a deeply cyanosed face, and after two or three spontaneous attempts at breathing respiration ceased. Artificial respiration and stimulation were of no avail. On autopsy the body was found to be well formed, in good nutrition, with pronounced rigor, and cyanosis of the face. The brain was merely congested. The thoracic organs were entirely normal. Bronchial glands were somewhat enlarged, gray-black, and a little firmer than usual. A thymus gland, larger than a fist, lay in the anterior mediastinum, dark red in color, with follicles plainly visible. The tonsils were enlarged, as were also the lymph glands, and the follicles of the tongue and spleen. The thyroid was symmetrically enlarged.

Several instances have been reported in which people in apparently good health suddenly fell into the water, and, although at once removed, before death by asphyxia could possibly have occurred, could not be resuscitated. A thirteen-year-old boy fell unexpectedly from on board a ship in the docks, and although immediately removed from the water, could not be revived. The autopsy was conducted by von Recklinghausen, who reports, aside from an enlarged thymus, enlarged tonsils and lymph glands, nothing abnormal. Another case noted by von Recklinghausen is that of a man, twenty-seven years old, who, while bathing in a forbidden spot, was suddenly accosted. He arose from the water frightened, and at once fell, to sink below the surface. He was promptly dragged from the water, but did not revive. Section of the body of this large, lean, well-formed man showed a general hyperæmia; flaccid, dilated heart, with a tough myocardium and normal valves; and slight narrowing of the ascending aorta. The lymph glands in the neck, axilla, mesentery, and the tonsils were enlarged and pale; the follicles of the spleen, tongue, and epiglottis were swollen (intestinal follicles not mentioned). In the anterior mediastinum a persistent thymus measuring 9 × 6 × 1.5 cm. was discovered.

At least two well-authenticated examples of thymic and lymphatic hyperplasia in individuals sinking suddenly while swimming are described by Nordmann in his excellent paper upon the relation of the thymus gland to sudden death in the water. These two cases Nordmann credits to von Recklinghausen. A twenty-year-old mechanic, while swimming, uttered a sharp cry and sank beneath the surface, and, though promptly removed from the water, was dead. On post-mortem examination his body was found to be lean; the organs were generally congested; the lymphatic glands in the neck, axilla, and groin were enlarged, along with the spleen. The follicles in the nose, glottis, and tongue were very prominent. The thymus was persistent and measured 10 × 6 × 1 cm. In the other case a man twenty eight years of age suddenly sank while swimming beside some companions. He was at once removed from the water, but death had already taken place. The body was well nourished. The noticeable features of the section were the enlarged tonsils, lymph glands, and spleen; and the hyperplastic follicles of the tongue, spleen, and intestines (Peyer's patches). The heart was flaccid, and the aorta measured but 4 cm. at its origin. The thyroid was enlarged. The persistent thymus was 10 × 8 × 1 cm. in size.

Lower Resistance to Infection.—A predominant peculiarity of the constitutional condition which we are considering is, as Paltauf and others have shown, a lowered vital resistance, and this is apparent in the event of certain acute infections. Diphtheria, as demonstrated in Escherich's clinic by Moriz Daut, tends to assume a particularly severe type and to prove frequently fatal in lymphatic infants and children. Between the years 1890 and 1897 there were seventy-nine deaths from diphtheria in the clinic at Graz, and twenty-three of these showed status lymphaticus. Susceptibility to diphtheria in lymphatic children shows itself in several ways. Thus in the midst of an otherwise mild epidemic the lymphatic victims may die early in the attack with no diphtheritic anatomical lesions to explain the unexpected ending. There are hoarseness of the voice, hoarse cough, and a tendency to suffocation. Only a thin false membrane is present in the throat and larynx, and nowhere is there a mechanical obstacle to explain the hoarseness and dyspnœic symptoms. One or two days after entering the hospital the children become much worse; after coughing, severe dyspnœa and cyanosis appear with a small, weak, irregular pulse; consciousness is lost, and death supervenes in spite of various heroic efforts at resuscitation, including intubation or tracheotomy. In another class of cases there is a pronounced tendency to rapid extension of the diphtheritic exudate into the bronchi and bronchioles with bronchopneumonia following. Here, of course, the anatomical findings fully explain the fatal termination. This also holds true for the septic type of cases with early death; but the point is made that subjects of status lymphaticus are, from their constitutional weakness, especially prone to suffer severely from this infection. All the ordinary therapeutic efforts for diphtheria fail in these cases, and such is likewise the case with the extraordinary measures like tracheotomy and intubation. It is here also that the specific serum, the antitoxin of diphtheria, fails to exert its usually prompt and beneficial results. Even in early cases in which antitoxin usually produces a marvellous effect, none follows, and this seems to be independent of the dosage, for Daut, in his cases, used the antitoxin promptly and freely. It is very desirable for physicians generally to be clearly informed as to the unfavorable prognosis of diphtheria in status lymphaticus, and especially as to the possibility of failure with that sovereign remedy—antitoxin—in this class of individuals. Alike is the danger of accidents following the use of a prophylactic antitoxin injection, and, in the absence of the specific therapeutic response to the remedy, it behooves the practitioner to be on his guard both for his own protection and to spare ill repute to so valuable a therapeutic agent as the antitoxin of diphtheria. We have had, at the Ohio Hospital for Epileptics, three cases of fatal diphtheria in adult epileptics in which we ascribed the unexpected termination to the existence of a status lymphaticus as demonstrated at autopsy. In each of these cases antitoxin treatment was unavailing.

Among other infectious diseases toward which the resistance of lymphatic subjects is lowered may be mentioned cholera as shown by Virchow, pneumonia by Ortner, typhoid fever by Fraentzel, Virchow, and Hiller. Ortner found pronounced evidence of status lymphaticus in some fatal cases of anæmia after removal of the exciting cause, Bothriocephalus latus, and he holds the connection to be more than a coincidence. In most of the cases just mentioned the especially prominent anomaly was the hypoplasia of the heart and arteries, the cases being, in fact, examples of Virchow's "lymphatic chlorotic constitution."

Bronchial Cough.—West has reported several cases in which a harsh, spasmodic, croupy cough was assigned to the irritation of enlarged bronchial lymph nodes and which improved under the administration of creosote. The enlarged and offending glands were looked upon as manifestations of lymphatism, of which the patients exhibited certain other clinical manifestations like enlarged superficial lymph glands, hypertrophied tonsils, palpable spleen, dulness over the upper sternum, and, in half of the cases, evidences of a previous rachitis.

Association with Other Diseases.—As has already been stated, hypertrophy of the thyroid, *i.e.*, goitre, has been found in about one-half of the cases of status lymphaticus in adults. This may be simple goitre or it may take the form of exophthalmic goitre. Möbius, in 1891, emphasized the concurrence of persistent thymus and Basedow's disease, and this has been verified by Mosler, Spencer, Johnston, White, Ross, Bradford, Hektoen, and a number of others. Several of these cases died abruptly under circumstances strongly suggestive of thymic sudden death as now recognized, and in the several thorough autopsies, besides the persistent and hyperplastic thymus, such lymphatic alterations as prominent intestinal and splenic follicles, etc., have been described. In explanation of this syndrome it is urged that experimental evidence points to some sympathetic relation between the thyroid and thymus as shown by the enlargement of one following the extirpation of the other. It is also suggested that the tachycardia of exophthalmic goitre is analogous with the tendency to cardial paralysis in status lymphaticus.

As long since shown by Virchow, hypoplasia of the heart and arteries is frequently associated with chlorosis, and Copeland and Bamberger noted the coincidence of hæmophilia with aortic narrowing. It has also been found that other features of the lymphatic state are associated with the hypoplasia of the heart and arteries, and this, recognized by Virchow, led him to define the condition as the "lymphatic-chlorotic" constitution.

The extensive hyperplasia of lymphadenoid tissue in status lymphaticus brings it anatomically to resemble some cases of leukæmia and pseudoleukæmia. In the latter conditions we not only encounter enlargement of the lymph glands and lymph follicles, but hypertrophy or lymphoid overgrowth of the thymus as well. There seems, however, to be little or no clinical analogy between these affections. The blood changes, like the anæmia, and the disturbance of balance in the various kinds of leucocytes are either entirely absent in status lymphaticus or but imperfectly exhibited by occasional lymphocytosis. Ewing has shown that while the enlargement of the intestinal follicles may reach the extent observed in less pronounced pseudoleukæmia, in the latter disease the small nodules of lymphoid tissue grow laterally for some distance before producing much elevation of the mucosa, contrasting with the sharply circumscribed, abruptly projecting follicles of status lymphaticus. The nodules of pseudoleukæmia frequently ulcerate at their central points owing to improper blood supply, here again differing from the well-vascularized follicles of lymphatism. Ewing remarks: "In the majority of the cases of lymphatic constitution the enlargement of the lymph nodes does not pass beyond the limits of what may be called a physiological hypertrophy, and bears little resemblance to a tumor formation. The spleen is rarely much enlarged. The presence of considerable pigment in the spleen pulp is too ordinarily seen to be interpreted positively as the result of an excessive blood destruction, such as characterizes the severe anæmias. Yet it must be admitted that the very considerable degree of pigment deposit reached by the two cases referred to above* indicates that in some instances the blood has suffered severely. These children are, however, not usually anæmic, but in excellent health, and even the sickliest of them do not resemble cases of infantile leukæmia, pseudoleukæmia (von Jaksch), or chlorosis. As for the hyperplasia of the lymphoid marrow, it may be said that the normal limits of lymphoid marrow are as yet by no means definitely settled. Such hyperplasia may be seen also in the secondary anæmias, and in any case the hyperplasia of the lymphoid marrow may be regarded as merely a part of the general and more or less physiological hypertrophy of the lymphoid structures of the body."

Diagnosis.—Paltauf distinguishes two varieties of status lymphaticus, one rachitic, the other non-rachitic. In the first group a pale skin, well-developed fat layer, enlarged spleen and thymus, with lymph glands and follicles in varying grades of enlargement, and the epiphyseal changes of rickets are prominent; while in the second the pale skin, rich fat layer, and pronounced hyperplasia

* Cases reported by Ewing.

of the lymph glands and follicles, with a thymus above the average, are encountered

As a rule, the subjects of status lymphaticus appear in what we are pleased to call a well nourished condition, though its anomalies are sometimes found in debilitated subjects, particularly in infants advanced in rickets. The lymphatic infants usually appear plump and well-fed; the adults are robust, even inclining to moderate corpulence, and the young adult males are generally well-built, well nourished, and even decidedly athletic in appearance. In infants, however, notwithstanding the appearance of good nutrition, a condition of perfect health is contradicted by the peculiar pallor of the skin and the flabby state of body. The skin is both pale and of the condition called pasty, giving, as the Germans describe it, the "pasty habitus." A tendency to eczema, either of the head or universal, is quite common in lymphatic infants. In adults the thick, coarse skin, and muddy complexion are found

For purposes of diagnosis, aside from the general features just noted, it becomes important to discover, if possible, the evidences of a general or local hyperplasia of lymphatic structures and of narrowing of the arteries where this is associated. The hypertrophy of the faucial, lingual, or pharyngeal tonsils, of the "pharyngeal ring," with augmented prominence of the follicles at the base of the tongue, should, if accompanied by enlargement of the cervical, axillary, or inguinal glands, suffice to arouse suspicion, as Ewing says. The mesenteric glands may occasionally increase until they become distinctly palpable tumor-like masses. Generally the spleen is enlarged to a point which can be determined by careful exploration. Hypertrophy of the thymus manifests itself by increased substernal dulness, and has, especially in infants, been detected during life and confirmed at autopsy. In adults, and especially in the well-nourished, enlargement of the thymus of the relatively moderate grade incidental to status lymphaticus is not easily demonstrable by physical examination. It may be possible under exceptionally favorable conditions to detect hypoplasia of the peripheral arteries both by their reduced size and by their increased tension, and Ortner noted an absence of aortic pulsation in the neck in his cases which he regards as pathognomonic if found in a muscular subject. Hypertrophy of the left ventricle, and dilatation of this chamber have been mentioned as accompanying aortic hypoplasia.

The frequent association of rachitis with status lymphaticus should always be in mind, and when one or more of the osseous manifestations of rickets appear, along with lymphatic enlargement, increased thymic dulness, etc., a diagnosis of the lymphatic state may safely be hazarded. In infants a mild grade of craniotabes, retarded closure of the fontanels, retarded dentition, the rosary, enlarged epiphyses of the long bones, and curvature of the legs and spine are found in varying degrees in those cases of status lymphaticus which are associated with the rachitic dyscrasia In adults, marks of one time rickets may still be demonstrable, especially such as pigeon-breast, spinal curvature, narrow pelvis, bow-legs, etc.

The blood changes of status lymphaticus are, as has already been said, too indefinite to permit of diagnostic discrimination

Etiology and Relationship to Associated Clinical Manifestations.—We are still in the dark as concerns the etiology of the strange constitutional condition whose morphological characteristics have been portrayed. It is well established that some relationship exists between rachitis and status lymphaticus, and one would be inclined to call the latter the lymphatic form of rachitis were it not that cases are encountered without manifest evidences of rickets, that is to say, we have a non rachitic status lymphaticus. The frequency with which the conditions coexist, especially in infants where changes of rickets retain their prominence, argues for the direct relationship of the two affections, and I am inclined to believe that more exhaustive search, especially such as is comprehended by histological studies of the epiphyseal bone changes, would demonstrate the presence of rachitic lesions in cases of the lymphatic state where none of the coarser anatomical manifestations are to be found. It is, in fact, quite probable that status lymphaticus and rickets of a gross or a microscopically demonstrable grade will be found to be invariably associated. Were this the case we would still be a-field in the question of etiology, since the direct exciting element in the causation of rickets is as yet unknown. Of all the theories, however, the one attributing rickets to an infectious agency seems most plausible, and adherents to this view are rapidly increasing. According to this theory, rachitis is the result of a microbic infection, not necessarily due to a single bacterial species, but to one of several of the pyogenic organisms which act slowly, and which elaborate poisonous products capable of producing the osseous or other alterations found in the disease. The view that rachitis is caused by a slumbering or latent pyogenic infection, like a focus of middle-ear or mastoid disease, and that the gradual or periodic discharge of toxins from this focus induces the rickets, is particularly inviting, and even at the present moment claims some experimental data in its support. If we accept the infectious theory of rickets it becomes easier to reconcile its association with status lymphaticus, for the latter then becomes its lymphadenoid form, in which the various lymphatic structures give a hyperplastic reaction in response to the chronic intoxication. That various forms of lymphatic overgrowth result from infections has long been definitely determined, and at the present moment we witness the tendency to include such pronounced diseases of the lymphatic system as pseudoleukæmia and even leukæmia in the category of infectious diseases. In the face of this tendency it seems entirely reasonable to look to the enlarged lymph nodes, lymph follicles, and swollen spleen of status lymphaticus as the products of a slowly acting latent infection, or to the gradual or periodical discharge of attenuated pyogenic products from a hidden focus of infection.

As to the relations which exist between status lymphaticus and the clinical phenomena associated with it we possess but little information. We have already found that the theory of reflex cardiac paralysis has been admitted to explain the sudden deaths of status lymphaticus, the increased susceptibility of the heart to various forms of irritation being a part of the lowered vital resistance incidental to this constitutional disorder. This hypothesis has been generally accepted, but it still leaves something to be desired in the way of more fully explaining the exact mechanism by which the cardiac paralysis is induced.

The causal relationship between status lymphaticus and such convulsive disorders as spasm of the glottis, eclampsia, idiopathic tetany of infants, and epilepsy is largely conjectural. Escherich, who regards spasm of the glottis (thymic asthma) as one of the syndromes of tetany, attempts to account for these neuroses by an hypothesis somewhat like the following:

If, from analogy with the thyroid, we assume that the hyperplasia of the thymus and its coördinated organs (characteristic of status lymphaticus) is, or may be, the expression of an incomplete or perverted metabolism, the condition (status lymphaticus) might be regarded as a dyscrasia or chronic intoxication, comparable to Basedow's disease or the myxœdema of cachexia strumipriva. The changes in the skin and in blood formation, and especially the phenomena referable to the central nervous system, show a decided similarity, but differences are present quite sufficient to distinguish the two dyscrasias. While the strumous diathesis tends to impair the intellect to the point of imbecility or idiocy, we find, in the case of the hypothetical lymphatic-chlorotic constitution, that a latent irritability of the nervous system exists, which reacts to trifling stimuli, ineffective in the case of ordinary individuals, with spasmodic conditions in various portions of the body. To this is added, especially in severe cases, the fatal tendency to syncope, mostly in consequence of some opportune case further acting harmfully upon the heart.

Galatti directs attention to a peculiarity of status lymphaticus which, in my opinion, is a factor of importance in explaining some of the clinical phenomena, viz., the peculiar predisposition to œdema. This, as Galatti asserts, is shown by the pasty condition of the skin, by the tendency to eczema, and by the occurrence of œdema of the brain. I would add, from my observation upon lymphatic epileptics dying abruptly in a single seizure or from rapid status epilepticus, œdema of the lungs as another of the manifestations; an observation already made by Kundrat in a case of sudden death during chloroform anæsthesia, by Langerhans in the case of his son's sudden death after a prophylactic antitoxin injection, and by Paltauf in at least one of his cases of sudden death. Galatti holds that slight factors like auto-intoxications of various kinds may incite this tendency to œdema into activity. Piedecocq, in his belief that sudden death in infants with hyperplastic thymus is due to increased intracranial pressure resulting in compression of the medulla, is evidently upon the tack taken by Galatti, though he wishes to ascribe the increased cerebral pressure to compression of the great vessels in the neck caused by a backward flexion of the head, aggravating the pressure already exerted by an enlarged thymus.

Whatever its mechanism, I am, from my observation upon lymphatic epileptics and my reflection upon these studies, strongly disposed to the belief that a periodic increase of intracranial pressure, acting either on the exterior or interior of the brain, or on both portions simultaneously, and manifesting itself as a result of the tendency to œdema characteristic of status lymphaticus, is a directly provocative factor of such neuroses as spasm of the glottis, tetany, infantile eclampsia, epilepsy, and the various forms of sudden death incidental to the lymphatic state. According to this view, the clinical phenomena would depend upon the extent and location of the intracranial œdema, or, in other words, upon the portion of the encephalon particularly subjected to pressure. In the event of compression of the external portion of the cerebrum, various convulsive disorders of the motor apparatus are provoked; when the balance of pressure becomes so distributed as to raise the intracerebral tension, other more severe symptoms supervene, ending, in case of pressure upon the floor of the fourth ventricle, in sudden respiratory or cardiac failure. Granting the hypothesis just advanced, we are brought one step nearer the explanation of the *modus operandi* of several obscure neuroses whose kinship has repeatedly been recognized on purely clinical grounds, and whose morbid anatomical association is proven by the establishment of the lymphatic state as a common basis for all. Cheadle's dictum that "laryngismus, tetany, and general convulsions are the positive, comparative, and superlative of the convulsive state of childhood," finds support and elaboration.

Treatment.—Recalling the intimate association of status lymphaticus and rickets, treatment, particularly in its prophylactic phase, is clearly indicated. Measures which are efficient in the prevention or treatment of rachitis are, on *a priori* grounds, destined favorably to influence the lymphatic state, and incidentally to control those disorders which result from these constitutional dyscrasias. While not recognizing the kinship of rickets and status lymphaticus, Gowers, for instance, reached the conclusion that a certain proportion of cases of epilepsy were ascribable to rickets, and he urged the prophylaxis of rickets as a means destined to prevent epilepsy. My studies on epilepsy and its relations to the lymphatic state have brought me to this same conclusion, and I agree with Gowers that the prevention of rickets is a matter of great moment in suppressing epilepsy, as well as in favorably influencing such other neuroses as spasm of the glottis, tetany, and infantile eclampsia. It is out of the province of this article to discuss the means, especially those of a dietary and hygienic nature, advised for the prevention of rickets, or for combating it when once established. These agents, with the medicinal aid ordinarily employed, are rationally indicated in the prevention or treatment of status lymphaticus.

On the supposition that the thymus is the chief anomaly of status lymphaticus and the agent in producing an auto-intoxication, numerous suggestions for the employment of extracts of the gland have been made. Permanently beneficial results have not been recorded in cases in which thymus extract has been administered, and this is likewise true for the thyroid and adrenal extracts. Very recently Mendel, who attributes rickets to disturbance of the internal secretion of the thymus, has reported good results following the exhibition of fresh calves' thymus in doses of one gram for each month of the child's age.

Partial removal of the thymus has engaged the attention of those who adhere to the pressure theory of thymic asthma, and in at least two cases this heroic procedure has been practised. One case reported by König, and quoted by Blake, was a child nine weeks old, which since it was eight days old had suffered from severe attacks of dyspnœa. The thymus was made out to be enlarged, extending to the cricoid in the neck. By means of a transverse incision it was exposed, the cervical portion excised, and the thoracic portion drawn up and anchored by sutures to the fascia over the manubrium. The operation was completely successful in relieving the dyspnœa, and healing was uneventful.

The second case, also reviewed by Blake and reported by Siegel, was a boy of two and a half years, who had been tracheotomized for a sudden attack of dyspnœa. The insertion of an ordinary cannula did not afford relief, and it was not until a tube had been inserted nearly to the tracheal bifurcation that the dyspnœa ceased. A diagnosis of enlarged thymus was made, and the thymus was drawn up and sutured to the fascia over the sternum. Recovery was uneventful, with no recurrence of the dyspnœa. What interpretation to place upon these two cases is uncertain. Whether, for instance, the apparent good results were due to relief of pressure, as König and Siegel believe, or whether due to the extirpation of a portion of the thymus *per se*, or to a changed anatomical relationship of the gland, by which some autotoxic effect was annulled, cannot be decided from two isolated cases. However, these cases are at least suggestive from the standpoint of the surgical therapeutics of status lymphaticus, though it is not probable that such a severe measure as partial extirpation of the thymus will be recommended as a legitimate procedure in any except the class of cases indicated by König and Siegel. In this connection, however, it is well to recall the remarkable results which usually follow the removal of nasopharyngeal adenoids and of hypertrophied faucial tonsils, which, as we have learned, are manifestations of the lymphatic state. After making due allowance for the good effects resulting from the relief of the mechanical obstacles imposed by these enlarged structures, the remarkable change in bodily and facial configuration, and the brightening of the intellect not uncommonly observed in these cases, has suggested to more than one observer the possibility of other far-reaching influences besides those of a mechanical nature. It seems highly probable, indeed, that the removal of the offending lymphatic structures carries with it some deep-seated beneficial effect such as one might imagine to result from the removal of an auto-intoxication. There is certainly abundant evidence to show that the surgical treatment of the enlarged lymphatic structures of the nose and throat is a rationally indicated procedure in the therapeutics of status lymphaticus.

Albert P. Ohlmacher.

Bibliography.

Owing to the confusion concerning the relations of the enlarged thymus to the constitutional disorder, most of the literature bearing upon status lymphaticus will be found under the diseases of the thymus as indicated by such titles as "Hypertrophy of the Thymus," "Sudden Death and Hypertrophy of the Thymus," "Thymic Asthma and Sudden Death," etc.

Therefore, instead of attempting to enumerate the papers in which the anatomical and clinical features of status lymphaticus are more

or less explicitly discussed, the student's attention will be invited merely to the leading articles dealing specifically with status lymphaticus in its different aspects. Even in some of these articles the title refers directly to the thymus:

Rokitansky: Path. Anatomie, Wien, 1842–46. Definitely mentions the lymphatic dyscrasia and plainly points out the coördinate relations of the enlarged thymus to the lymphadenoid hyperplasias.

Virchow: Beiträge z. Geburtsh. u. Gyn., 1872. Discusses the relation of arterial hypoplasia and chlorosis and defines the "lymphatic-chlorotic constitution."

Grawitz: Ueber plötzliche Todesfalle im Säuglingsalter. Deut. med. Wochenschr., No. 22, 1888. Reopens the discussion upon thymic, or, more properly, lymphatic sudden death, and marks what may be called the recent era in the study of status lymphaticus.

Paltauf, A.: Ueber die Beziehung der Thymus zum plötzlichen Tod. Wiener klin. Wochenschr., No. 46, 1889, and No. 9, 1890. Clearly defines status lymphaticus by its morbid anatomical basis, and deals with various forms of lymphatic sudden death.

Pott: Ueber Thymusdrusenhyperplasia und die dadurch bedingte Lebensgefahr. Jahrb. f. Kinderheilkunde, No. 34, 1892. Deals especially with spasm of the glottis and resulting sudden death. The relation of status lymphaticus as the anatomical basis is kept in view.

Nordmann: Ueber die Beziehungen der Thymusdrüse zu plötzlichen Todesfällen im Wasser. Correspdbl. f. schweizer Aertze, No. 7, 1894. As its title indicates, this paper deals especially with lymphatic sudden death in the water. Status lymphaticus in its anatomical and etiological relations is discussed, though the thymus claims most attention.

Kundrat, v.: Zur Kenntniss des Chloroformtodes. Wiener klin. Wochenschr., Nos. 1–4, 1895. The relations of status lymphaticus to fatal surgical narcosis are there elucidated together with a number of original cases.

Escherech: Bemerkungen über den sog. Status lymphaticus des Kindes. Berl. klin. Wochenschr., No. 29, 1896.—*Ibid.*: Tetanie. Traité des maladies de l'enfance, tome iv. Considers the various neuroses of status lymphaticus like tetany, spasm of the glottis, eclampsia, and lymphatic sudden death, and elaborates a theory to explain the association.

Galatti: Zur prognostischen Bedeutung des Status lymphaticus der Kinder. Wiener med. Blätter, No. 50, 1896. Lymphatic sudden death is considered, including a discussion of fatal accidents after antitoxin injections as illustrated by the Langerhans case. Mentions the predisposition to œdema.

Ewing: The Lymphatic Constitution and Its Relations to Some Forms of Sudden Death. New York Medical Journal, July 10th, 1897. An excellent review of status lymphaticus in its different aspects, with a presentation of most of the literature. Especially valuable as being readily accessible to the American student. Apparently the first article in English dealing with status lymphaticus *per se*.

Ohlmacher: Bulletin of the Ohio Hospital for Epileptics, Nos. 1, 2, and 3, 1898–99. Several papers discussing especially the question of status lymphaticus and epilepsy.

Daut: Ueber die Beziehungen des Status lymphaticus zur Diphtherie. Jahr. f. Kinderheilkunde, Heft 2 and 3, 1898. As shown by its title, this paper concerns the relations of status lymphaticus to diphtheria and contains the most exhaustive study of this phase of the subject thus far published.

Klein: Neuere Arbeiten über die "Glandula thymus." Zusammenfassendes Referat. Cent. f. allgem. Path. u. path. Anat., Nos. 16–17, 1898. Though primarily considering the diseases of the thymus, this review cites all of the important papers bearing on status lymphaticus, and reviews them briefly.

Blake: The Surgical Aspects of the Status Lymphaticus. Annals of Surgery, June, 1902. The most recent American paper, the purpose of which is indicated by the title.

STAVESACRE.—(*Staphisagria*, U. S. P.; *Staphisagriæ Semina*, Br.; *Staphisagria*, Codex Med.) The dried ripe seed of *Delphinium Staphisagria* L. (fam. *Ranunculaceæ*).

This seed is derived from a handsome annual or biennial species of larkspur, native of the South European countries, Asia Minor, etc., and also cultivated. The seeds are imported from the south of France and Italy. They were known to the ancients, and for twenty centuries have been used for about the same purpose as at present—killing pediculi and similar vermin.

Description.—About 5–7 mm. ($\frac{1}{5}$–$\frac{1}{4}$ in.) long and nearly as broad, flattish-tetrahedral, one side convex, another small and opposite to a pointed extremity, the edges rather acute; brown, gray-brown, or sometimes blackish, strongly and coarsely reticulate-wrinkled, containing a whitish, or becoming gray-brown, oily perisperm and a small, straight embryo; nearly inodorous; taste very bitter, acrid, and somewhat biting.

Composition.—The seeds contain about twenty-five per cent. of a non-drying fixed oil, and about one per cent. of alkaloids, occurring mostly in the shell, of which the following have been isolated and named: *delphinine*, in fine, large crystals, *staphisagrine*, amorphous; *delphinoidine*, also amorphous, and *delphisine*, in crystalline tufts. Of these, the first is the most important and active, the second least so, while the third and fourth resemble the first, but are weaker.

Action and Use.—Stavesacre is an active and poisonous drug, irritant to the skin and mucous membranes, causing itching, stinging, burning, sneezing, etc., as well as diarrhœa and vomiting. Of the alkaloids, delphinine best represents the drug; rubbed into the skin, this causes local inflammation, on the tongue burning and numbness, in the stomach nausea and distress, and, when absorbed, cardiac and respiratory slowing, diminished spinal irritability, and sometimes mental disturbance. The others resemble delphinine, but are less intense. Delphinine reminds one of both aconitine (to which it is botanically related) and veratrine. Staphisagrine is somewhat peculiar; it is not very active, but appears to resemble curare in its action upon striped muscle.

Neither the crude drug nor its alkaloids are given internally; so its exact action has but little practical bearing. It has from a remote time been employed, either by itself or in ointments or other vehicles, solely for the purpose of killing pediculi and related animal parasites, on man and animals. At the present time it is mostly consumed in veterinary practice, kerosene or petroleum, petrolatum, sulphur, and *Unguentum hydrargyri* taking its place in human medicine. An ointment can be made with twenty per cent. or so of the powdered seeds, or with from one-half to one per cent. of the alkaloid.

Larkspur seeds, the product chiefly of *Delphinium Consolida* L., and produced in Europe, are almost identical in constituents and properties with stavesacre. They were formerly official in the United States Pharmacopœia, and tincture of larkspur is a very popular application for head lice. They are several times smaller than stavesacre seeds, of about the same form, but with sharper angles and markings, and usually of a jet black color. *Henry H. Rusby.*

STEAMBOAT SPRINGS.—Routt County, Colorado.

Post-Office.—Steamboat Springs. Hotels.

Access.—Viâ Denver and Rio Grande Railroad to Walcott, thence by stage, a twelve hours' ride to springs. Also connected by good mountain roads with Laramie City, Wyo., and with Georgetown, Dillon, Glenwood Springs, Hayden, and other points.

The town of Steamboat Springs is located in a charming valley in northwest Colorado, just over the main range of the Rocky Mountains and near the headwaters of the Yampa River. The site is upon a bend of the Yampa, where, from its northerly flow, it turns sharply to the west. The mountain range here follows the contour of the river, lifting its lofty summits, covered all summer with their ever-melting but never-melted snow, on two sides of the valley to the north and east. Thus is formed a natural basin, sheltered on the side toward the north by its mountain bulwark, leaving its southern slope open to the rays of genial sunshine. Three large mountain streams—Soda Creek, Crystal Brook, and Spring Creek—rise at different points along the curve in the mountain range, and, converging as they flow down, join the Yampa on the town site. These streams furnish a never-failing supply of pure water, and, with a group of sixty varieties of hot, warm, and cold mineral springs, make this valley one of the most remarkable natural watering-places in the world. The first settlement was made in the valley in July, 1874, by Mr. James H. Cranford, the present manager of the springs. Since that time a flourishing town containing churches, schools, libraries, banks, newspapers, and other adjuncts of civilization, has sprung into existence. The town and vicinity offer many attractions to the enterprising settler, as well as to the tourist, the sportsman, and the invalid. The climate during the open season—*i.e.*, from April until late in December—is ideally temperate, clear, balmy days and cool nights being the rule. The springs, one hundred and forty in number, yield an exhaustless supply of water, but they have not been fully developed yet. They range in temperature from 40° to 103° F., but none of them appears to have been subjected to a complete analytical examination. Among the prominent ingredients are soda, magnesia, iron, and sulphur. The waters have been found useful in rheumatism and skin diseases, and were resorted to by the Indians for many years before the appearance of the pale face in this region. A large bath-house with swimming pool and numerous bath-rooms has been built to utilize the water from the hot springs. *James K. Crook.*

STEAPSIN. See *Pancreas*.

STEATOMA.—By many writers this term is used synonymously with lipoma; but by others it is applied to a hard variety of this tumor, in which the fat cells are of small size and the amount of connective-tissue reticulum relatively large. Such tumors resemble bacon in their gross appearances and have been designated by German authorities "Speck-tumor." In the majority of cases such tumors arise from the atrophy of the fat cells in any ordinary lipoma, and the characteristic appearance and consistence of the growth are, therefore, to be regarded as the result of secondary changes. Other writers apply the term steatoma to any variety of fibrolipoma, and the designation has even in a few instances been transferred to fibromata. By other writers still, atheromata, sebaceous cysts, and dermoid cysts, as well as retention cysts of varying origin containing fatty or pultaceous material, are also called steatomata. The varied and indefinite use of the term would appear to offer good reasons for its abandonment. *Aldred Scott Warthin.*

STERIFORM. See *Formaldehyde*.

STERILITY IN THE MALE. See *Sexual Organs, Male, Diseases of.*

STERILITY IN WOMEN.—

"If a woman do not conceive, and wish to ascertain whether she can conceive, having wrapped her up in blankets, fumigate below, and if it appear that the scent passes through the body to the nostrils and mouth, know that of herself she is not unfruitful."—*Hippocrates, Aphorism 59.*

Sterility (from στειρεος, "barren") in woman is an inability to conceive or bring forth a living child. Inability to conceive is called absolute sterility; inability to complete gestation is denominated relative sterility. It may be congenital and due to some insuperable error of conformation, or it may be acquired as the result of some local or general barrier. When a woman has never been able to conceive it is called primary sterility; when she has conceived one or more times, but is unable to conceive again, it is called secondary; when she can conceive, but is unable to carry the child to full term, it is called comparative sterility.

Prior to puberty, during lactation, and after the menopause, sterility is physiological.

The generally accepted ratio of sterility among civilized nations is eleven per cent. In primitive conditions and rural communities it is much less than in complex civilizations and in cities. Rich diet and luxury seem to be inimical to fertility; spare diet and poverty appear to increase fecundity. Sterility is rapidly increasing in the United States, especially in native-born white women. Prior to 1850 it was only two per cent. In 1900 it was twenty per cent. Among foreigners in the United States it is thirteen per cent. It is greater in the United States than in any country except France (Engelmann).

The fecundity in some parts of Europe is eight to a family; the average is five to a family. In the United States there are only two children to a family. In women who are college graduates the ratio is 1.6 to a family.

The causes of this increase of sterility are many. They are moral more than physical. Distaste for the burdens of maternity, from motives of ease and on account of the demands of society, is a prominent cause. The prevention of conception and the production of abortion are increasing ominously. The sin of Onan is making its moral and nervous wrecks. The abomination which Mme. De Staël describes as "a cobweb as regards protection and a bulwark against love" is ever more frequently employed. The marital approach is often guarded by the paraphernalia of the brothel. The secular and religious press is besmirched by advertisements of so-called emmenagogues; of sundry ingenious syringes, and other devices to thwart nature in the procreation of the species. These latter causes for sterility must be taken up by the political economist and prevented by legislative enactment. The increase of sterility from these reprehensible immoral practices, if not restricted, will be an occasion for national alarm. Mathews Duncan says:

"A healthy woman living in wedlock all of her child-bearing life under the most favorable circumstances for natural procreation, should have a family of ten. Women, under such circumstances, bearing fewer than ten, are relatively sterile, and the sterility is inversely as the number." He found the mean interval between marriage and the birth of the first child to be seventeen months; and that the likelihood of conception proportionately decreased thereafter. Only twenty-five per cent. of women bear the first child after four years of wedlock. A woman, therefore, who has been married three years without conception, and where no means to prevent it have been resorted to, may be presumed to be sterile.

Simpson out of 1,252 marriages found 1 in 8.5 unfruitful. Ansell, in the British peerage, found 1 in 6½. Engelmann among college graduates, 1 in 3½. Duncan says the average for Great Britain is 1 in 10, which may be taken as the general average.

In all sterile matrimonies it must be borne in mind that the male may be at fault. Gross, in 192 instances, found the male to be at fault in 16⅔ per cent. Kehrer, in 40 cases, found 31.5 per cent. Emil Ries estimates 30 per cent. Vedder, of Christiania, in 310 examples, found 70 per cent. due to the male, either to impotency or azoospermia. He includes infection of the wife by gonorrhœa, but this should not be included in an estimate of essential male sterility. Gonorrhœa in the male, resulting in double epididymitis and occlusion of the vas deferens, is the greatest factor. Surgical relief from this asexualization of men is much to be desired.

Assuming that from one-third to one-half of all childless marriages are due to the male, the woman should not bear the reproach until a microscopical examination of the semen of her partner is made, to determine the absence or presence of living, healthy spermatozoa.

CAUSATION.—Any cause which prevents the meeting of virile spermatozoa with a perfect ovule in the genital passages of the woman and their further fixation and retention in the uterus until gestation is completed, will result in sterility. These causes may be generalized as follows:

I. Incapacity for perfect copulation.

II. Inability of spermatozoa to enter the uterus, or anything that may prevent the occurrence of fixation after insemination of an ovule.

III. Imperfect ovulation or tubal impediments.

IV. Failure of the uterus to retain the embryo.

V. Sexual incompatibility.

VI. General diseases or diatheses.

Anatomically, these causes are found to be malformations or pathological conditions of (*A*) vagina; (*B*) uterus; (*C*) Fallopian tubes; (*D*) ovary.

(*A*) *Vagina.*—Absence, incomplete development or atresia of the vagina; imperfect hymen and congenital narrowness or shortness of the vagina; adherent labia minora; abnormal communication between the vagina and the bladder, rectum, or urethra; vicious insertion of vagina; double vagina, transverse hermaphrodism; vaginismus or dyspareunia from any cause; laceration or relaxation of the perineum; vaginitis, genital fistulæ; elephantiasis and tumors of the pudenda; prolapsus of uterus and vagina.

(*B*) *Uterus.*—(*a*) Cervix: Atresia or stenosis of the os or cervical canal; hypertrophy of the whole or of one of the segments of the cervix; elongated cervix; contracture of cervical canal from injudicious use of caustics or improperly performed trachelorrhaphy; endocervicitis.

(*b*) Corpus: Flexions, or versions; neoplasms; inflammation of the endometrium; infantile uterus, uterus unicornis or bicornis; non-development of cavity from arrested development of Müller's canals; subinvolution, hyperinvolution, or atrophy after labor or curettage.

(*C*) *Fallopian Tubes.*—Congenital absence or impermeability; closure of fimbriated extremities by gonorrhœa or other inflammation; salpingitis; destructive secretions; inflammatory impermeability of canal; peritoneal adhesions causing mechanical flexures; occlusion due to pressure of new growths.

(*D*) *Ovary.*—Absence, or imperfect development; acute or chronic oöphoritis; cystic degeneration; neoplasms; prolapsus of ovary; embedding adhesions.

I. Incapacity for Copulation.—The abolition of this function, which is usually essential for insemination, is, if permanent, an absolute bar. Insemination is not dependent upon sexual desire or sexual pleasure. It may occur in totally frigid women, or in those who have a positive disgust for the act. Pregnancy may occur if the genital passages are clear, when copulation is performed by force, as in rape, under anæsthetics, alcohol, or other drug narcosis. The deposition of semen on the pudenda, without intromission, has been known, indubitably, to have produced conception.

However, in sterility, any abnormality about the vulva and vagina should be detected. Imperforate hymen, adhesion of the labia, and atresia of the vagina are quite obvious causes.

Vaginismus, by its spasmodic contracture of the sphincter of the vagina, may incapacitate the woman for the marital relation. Dyspareunia, from vulvitis, vulvar hyperæsthesia, urethral caruncles, and pelvic inflammatory diseases, may interfere with coitus to such an extent as to preclude conception, although the woman is potentially fertile. Due care in eliciting the history and making the examination will disclose one or more of the many causes of this painful intercourse. An unusually short vagina may not retain the semen, or it may be violently evacuated by involuntary vaginismus of the upper part of the vagina (Storer). Relaxations of the vulvar orifice from laceration of the floor of the pelvis may also allow the semen to escape prematurely. The extreme acidity of a profuse leucorrhœa from a vaginitis is destructive to the spermatozoa, which require an alkaline medium.

II. Inability of the Spermatozoa to Enter the Uterus, or the Presence of Some Condition which does not Permit Fixation to Occur after the Insemination of an Ovule.—Formerly it was supposed that flexures of the uterus at or near the cervix offered a mechanical obstruction to the entrance of the spermatozoa; but it is now generally believed that if the obstruction, so called, will allow the exit of the menstrual flow, it will also allow the entrance of the spermatozoa. The sterility in flexions of the uterus are due to the attendant endometritis, the discharges from which may mechanically wash away or destroy the spermatozoa. Furthermore, the altered state of the uterine mucous membrane, in cases of this nature, will not permit fixation to occur.

While atresia or stenosis may prevent entrance of seminal fluid, the thick, tenacious plug of mucus, in cases of endocervicitis, more often acts as a barrier.

Conicity with elongation of the cervix prevents insemination because the cervix does not rest in the pool of semen bathing the posterior fornix of the vagina. The same difficulty exists when the cervix is either anteflexed or retroverted; in other words, the spermatozoa are shut off from the opportunity of entering the uterus by their ciliary movements. In uncomplicated retroversion a restoration of the uterus to its normal position may lead to the occurrence of pregnancy after years of unfruitfulness.

Anteflexion, associated with dysmenorrhœa, is often found in barren women. Sims' observation, that nearly half of the women with dysmenorrhœa are barren, means that the barrenness usually depends upon some pathological process causing the dysmenorrhœa. In anteflexion the pathology is that of an atrophic endometritis, usually associated with imperfect development. The painful menstruation is dependent upon the faulty desquamation of the endometrium and the resulting coagulation of the blood. In these cases of flexion it is not, as was formerly taught, the obstruction to the outflow which causes the dysmenorrhœa, but rather the associated endometritis; for when the latter is cured, as it may be by divulsion and curettage, the dysmenorrhœa disappears. Such a cure of the endometritis, furthermore, means the reproduction of a new and healthy endometrium, and so favors the cure of the sterility.

Fibroid tumors were found to be the cause of sterility in 18.3 per cent. (III). Here, again, we may refer the sterility to the hypertrophic endometritis which accompanies the growth of these tumors; for the ovum cannot effect an attachment to the wall of the uterus during the progress of such an inflammation. In brief, then, whenever the uterus is at fault in a case of sterility, it will be safe, in the majority of instances, to attribute the cause of such sterility to an endometritis.

III. Imperfect Ovulation and Tubal Impediments.—Absence and faulty development of the ovary and oviduct are rare without congenital absence or malformation of some other part of the genital apparatus. Arrest of the function of the gland may ensue from acute or chronic inflammations, from cystic degenerations that are complete and bilateral, and also from obliteration of the glandular structures by new growths.

Inflammatory sequelæ of infections ascending to the peritoneum are the most important causes of sterility arising in the adnexæ. The ovary may be prolapsed or placed beyond the reach of the infundibulum, or it may be surrounded with inflammatory exudate so that extrusion of an ovule is impossible. The tubes may be, as seen very commonly in abdominal work, glued up at the abdominal ostia by inflammatory exudate. The fimbriæ may be so distorted that they cannot come in contact with the ovary. Intraperitoneal bands of adhesions sometimes cause a narrowing of the lumen of the Fallopian tube. The endosalpinx, after inflammation, is commonly desquamated of its ciliated epithelium. The spermatozoon cannot make its way to the ovary, nor the ovule to the uterus. If perchance they should meet and fertilization ensue, tubal pregnancy is likely to occur. The tubes, after serious inflammation, may remain permanently occluded.

Any one or more of the conditions enumerated above are thus seen to be potent in the production of sterility by interference with ovulation and with the transit of the ovum. They may result from clinically mild infections, which, after resolution has taken place, may leave the patient, except as regards the sterility, in good health.

The comparatively recent recognition of the ravages caused by gonorrhœa in woman affords strong confirmation of Tait's contention that practically all women who have suffered from gonorrhœal infection of the tubes are sterile. Witness the notorious sterility of prostitutes, which is largely due to this cause. The point of greatest importance is to determine what proportion of these patients are hopelessly so, and what proportion may be relieved by conservative surgical operations. It is for the future to determine whether laparatomy is indicated for the cure of sterility alone. The lesions resulting from gonorrhœa comprise perhaps the largest group of the mechanical causes of sterility.

IV. Failure of the Uterus to Retain the Embryo.—This particular one of the procreative phenomena does not come under the scope of this inquiry. Habitual abortion, however, should always arouse the suspicion that one or both parents are infected with syphilis; and if other facts seem to bear out this view, active antisyphilitic treatment should be inaugurated. The results of such treatment are often very satisfactory.

Early abortions are very frequent. Ninety per cent. of child-bearing women abort once or oftener. One out of twelve pregnancies is said to end in abortion. It may be caused by trauma, by emotional violence, or by pelvic and general disturbances. The underlying cause may reside in either the father, the mother, or the fœtus.

Endometritis and laceration of the cervix are perhaps the most frequent, curable, local causes.

V. *Sexual Incompatibility.*—There is an intangible, unknowable something which causes sterility in the apparent absence of any pathological condition whatever, and this something, for want of a more exact term, we call incompatibility. Husbands and wives, each of whom has previously been fruitful with another mate, or each of whom at some subsequent period becomes fruitful when joined to another mate, will live together for years and yet will have no children. History furnishes the notable example of Augustus and Livia, and the well-known instance of Napoleon and Josephine. A satisfactory explanation is the despair of science. This form of infertility has been noticed in the breeding of animals.

VI. *General Disease, or Weakness.*—Obesity, with its attendant anæmia, is often the cause of sterility. It is presumed that the ovule is imperfectly matured. The rheumatic or gouty diathesis probably acts by nutritional defects, as does syphilis. Chronic alcoholism sometimes is causative through depreciated vitality. Unhygienic occupation and excessive wear and tear may prevent conception. A depressed state of the nervous system may suspend ovulation temporarily; hardships, grief, great mental anxiety, shock, unhappy marital relations, are mentioned as causes. Neurasthenia and certain nutritional neuroses render conception unlikely.

Tuberculous subjects are not necessarily infertile. Gestation greatly increases well-being, but parturition and lactation render the victim susceptible to the ravages of the disease. Prolonged lactation grants the woman partial immunity from conception, and is frequently used for that purpose, at the expense of both mother and child.

Prognosis is notoriously uncertain. Removal of palpable causes gives a fair prospect of success, sufficient to justify any reasonable effort, but a full statement of the improbabilities should be made to the patient. Sometimes when every discernible obstacle has been removed, sterility still persists. One should not, however, give a positive opinion that the case is a hopeless one unless some malformation presents an insuperable bar.

Conception has been known to occur under most unfavorable circumstances. Pregnancy constitutes a serious complication in fibroid tumors, and sometimes in carcinomata. It has occurred in cases of vesico-utero-vaginal fistula. Koeberle's remarkable case of abdominal pregnancy occurring through a small fistula, after vaginal hysterectomy, where a portion of the ovary was left, is unique.

Treatment.—A minute and painstaking search for the cause or causes of this condition is essential to any therapeutic attempt. If no appreciable cause is found in the woman, or before any elaborate plan of treatment is instituted if the cause is found, the presence and viability of spermatozoa should be determined. Men are loath to have an examination made that may fix the responsibility on them. In order to obtain a specimen for examination an ingeniously framed excuse, if necessary, may be made to the woman for an examination shortly after coitus.

Male potency being assured, the physician should then proceed to correct or remove any and all abnormalities possible in the genital canal, and also to remedy any systemic faults which may exist. Vulvar or vaginal impediments should be removed and the copulative tract put in a healthy state. Displacements of the uterus are to be corrected by appropriate means. Lacerations should be repaired, if necessary.

General hygienic measures are to be employed where necessary, with especial attention to anæmia and the diatheses. Higher education is unpropitious for a race of mothers. Great sexual moderation should be enjoined. Abstinence for a period of months, or, if need be, a complete separation for the same length of time, is often followed by conception. Such a separation gives an opportunity for a spontaneous cure of certain slight pathological states, and affords a much-needed sexual rest. Hyperinvolution and ill-developed uteri are treated by intra-uterine galvanism. Great persistence is required in this and all other treatment for sterility.

The former practice of treating an atrophic endometritis, in anteflexion, by simply dilating the cervix has now given place to divulsion of the cervix and subsequent curetting. This plan of treatment is applicable to the majority of cases of endometritis which complicates so many pelvic disorders and upon which sterility so frequently depends. The results obtained are quite satisfactory. Excessive acidity is overcome by alkaline injections before congress.

In the operative treatment of tubal and ovarian disease causing or associated with sterility, conservative surgery is indicated wherever possible and has yielded very happy results in some instances. When child-bearing is desired, the surgeon is justified in exercising much latitude in saving and repairing structures. The justification in invading the peritoneum for tubal sterility unaccompanied by symptoms of disease, is an open question. Goffe has operated four times upon the uterine adnexa through the vagina for the uncomplicated symptom of sterility, and has been rewarded by living children in three of the four cases. Colpotomy is quite as safe now, from a surgical standpoint, with asepsis and expertness, as many of the recognized operative methods on the uterus for sterility were three decades ago.

The frequent cure of the associated sterility, while incidental, has been observed by every operator who has done conservative operations on the internal organs of generation. The following list of conservative procedures mentioned by Kelly will indicate the many checks to conception which might be removed:

1. The release of adherent tubes.
2. The opening or resection of closed tubes.
3. The emptying, cleansing, and sterilization of inflamed tubes.
4. The amputation of diseased tubes.
5. The exsection of diseased or of strictured tubes.

Conservative operations on the ovaries comprise puncture or excision of a small cyst, resection of diseased portions, and release from embedding adhesions. A prolapsed ovary should be sewn back on top of the broad ligament and in relation with the infundibulum.

Before deciding upon an intrapelvic operation for the relief of certain pathological conditions, all the facts should be plainly set before the patient and her husband, in order that they may determine intelligently whether they are willing to incur the discomfort and danger, though slight, of an operation, the result of which is more or less problematical.

Artificial Conception.—This ingenious thought of Sims had for its basis the mechanical obstruction, in the cervix, to the further advance of the spermatozoa. It may be asserted that wherever this passage is sufficiently patulous to allow the nozzle of a syringe to be introduced for purposes of artificial impregnation, the spermatozoa are likely to effect an entrance unaided.

Of the fifty-five efforts made by Sims in two years only one resulted in conception, and that ended in an early miscarriage. A few other cases have been occasionally reported, but the procedure has never had the sympathy of the profession and has practically been abandoned.

Aside from the economic consideration of the importance of sterility to society, it must be borne in mind that it may be the cause of unspeakable disappointment and sorrow to the babeless bosom, and the mother-love will cry out in despair, "Give me children or I die."

William D. Haggard.

STERNUTATORIES, or errhines, are substances which, when applied to the nasal mucous membrane, cause sneezing and increased secretion. Properly speaking, there is a distinction between the two terms, errhine being used to denote an agent which increases the nasal secretions, while a sternutatory causes sneezing only. But as the act of sneezing is almost always accompanied by increased secretion, the distinction between the two classes of remedies is practically without a difference.

In former times sternutatories were much more commonly employed than they are at present, and the older writers were wont to lay great stress on the efficacy of these agents in the treatment of many apparently dissimilar conditions. Their use was recommended (1) to restore suspended respiration; (2) to effect the expulsion of foreign bodies from the air passages; (3) to increase the secretion of the nasal mucus or of the tears, or to expel accumulated mucus from the sinuses; (4) to awaken the action of the encephalon, restore sensibility, or excite uterine action. At the present time remedies of this class are out of fashion, and the only applications to which they are put are to excite sneezing for the sake of the pleasurable sensations that it causes, to increase the nasal secretions in the dry stage of coryza, and to clear the nasal passages and the adjacent sinuses of accumulated mucus. It is possible, however, if the present tendency of attributing many and diverse morbid conditions to the score of nasal reflexes should prevail, that future generations will restore the sternutatories to their ancient rank among the most prized of therapeutic agents.

The list of substances which have been employed at one time or another for the purposes above enumerated is as long as the moral law, and embraces nearly every drug which can be reduced to a fine powder, and even many gases, such as ammonia. To enumerate only a few of them, we have rosemary, lavender, peppermint, spearmint, white and black hellebore, stavesacre, mustard, euphorbium, betonica, ginger, iris, the peppers, calomel, bismuth, the alkaline carbonates, ipecac, tobacco, sweet marjoram, and a host of others. At present this list is practically restricted to half a dozen substances, the chief of which are tobacco, ipecac, veratrum album, quinine, camphor, and cubebs. Tobacco snuff is seldom employed now, except as a luxury, but the others just mentioned enter, one or all, in varying proportions, into the composition of the different catarrh snuffs prescribed by physicians or sold as proprietary remedies.—*From the first edition of the* HANDBOOK.

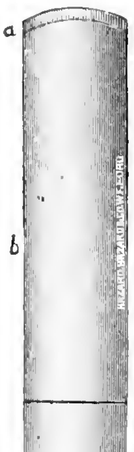


FIG. 4484.—Laennec's Stethoscope. *a*, Plug; *b*, *c*, sections; *d*, aural extremity.

STETHOMETER. *See Respiration.*

STETHOSCOPES.—HISTORICAL SKETCH.—The credit of having invented the stethoscope has been variously attributed to Hippocrates, Bayle, Hook, Laënnec, and others. It is certain, however, that Laënnec was the first to make the idea practically useful. He hit upon it accidentally, by using a roll of paper which he was holding in his hand. His first instrument was a cylinder of paper compactly rolled and kept in shape by paste. The stethoscope subsequently adopted was a cylinder of wood an inch and a half in diameter and a foot long, perforated longitudinally by a bore three lines wide, and hollowed out into a funnel shape at one end to the depth of an inch and a half. A plug of wood fitted into this hollowed extremity with a perforation through it of the same diameter as that of the rest of the tube. This was used in auscultating heart sounds. It was discarded in stethoscopes made at a later date. The instrument was made in two sections for convenience of carrying. Piorry introduced a more slender instrument, with ivory cap, and later this was altered and made of wood only. An instrument in which the pectoral end was trumpet-shaped was devised by Dr. Williams, of London, about 1843. Since then a large number of monaural stethoscopes have been devised, and descriptions of them are to be found scattered through various medical publications. They have been made of metal, wood, hard rubber, papier-maché, and other materials, used either alone or in combination. Most of these stethoscopes are hollow, the bore of the tube being pretty uniform throughout, except at the pectoral extremity, where it is expanded and bell-shaped. Solid wooden stethoscopes have also been devised, but these are more especially useful in conveying percussion sounds when the method of auscultatory percussion is practised. The monaural instruments do not differ from one another in any important particular. A few are combination instruments, having a percussor and pleximeter attached, or a clinical thermometer, a female catheter, etc., hidden away in them. Among others who have devised monaural stethoscopes may be mentioned Quain, Stokes, Arnold, Barclay, Elliottson, Dobell, Loomis, Burrow, Clark, Cammann, and Ferguson.

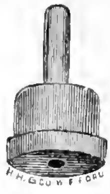


FIG. 4485.—Plug of Laënnec's Stethoscope.

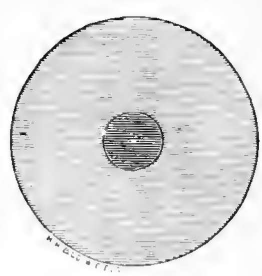


FIG. 4486.—Actual Diameter of Laënnec's Stethoscope.


FIG. 4487.


FIG. 4488.


FIG. 4489.

FIGS. 4487, 4488, AND 4489.—Monaural Stethoscopes.

M. Landouzy, of Paris, in 1850, constructed a stethoscope with a bell-shaped chest-piece, with a number of flexible tubes attached, by which several observers at once could auscultate. A single tube was designed for each person, but by the use of two tubes it became a binaural instrument. It was necessary to hold the tubes in the ears by the hands, and it was not found to be of much practical use. Many years previously Dr. Williams, of London, had been accustomed to use a binaural stethoscope made of two metal tubes attached to the bell of an ordinary stethoscope, and with flat ear-pieces. This conveyed sound with increased intensity, but was inflexible, clumsy, and awkward of application. The double stethoscope of Dr. Leared, shown in the Great International Exhibition of 1851, was a great improvement. It is made entirely of gutta percha. The two tubes are attached at one extrem-

FIG. 4490.—Intercostal Solid Cedar Stethoscope.

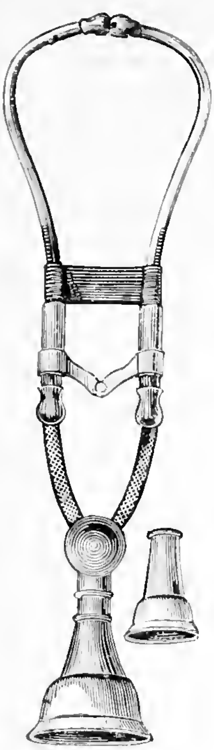


Fig. 4491.—Cammann's Binaural Stethoscope.

ity to a bell-shaped chest piece, and at the other to ear pieces similar to those of the monaural stethoscope. These tubes being separated and applied to the ears, exerted a certain amount of pressure by their own elasticity. To use this instrument ordinarily in practice, however, would require three hands, one for each ear-piece, and another to manage the pectoral end. In 1851 Dr. Marsh, of Cincinnati, patented a double stethoscope. This had a membrane stretching over its objective end, and two gum-elastic tubes leading from the chest piece to the ears. In this instrument the ear-pieces were inconvenient, and the sounds conveyed were muffled and confused. These circumstances rendered it of little value.

Dr. G. P. Cammann devised a binaural stethoscope which, after considerable labor and expense, was perfected in 1852. He was familiar with the instruments of Landouzy and Marsh, and his stethoscope, therefore, was not a new invention, but was, and is now, the best instrument of the kind devised. It is light, durable, easily carried, and a good conductor of sound. The attachment of a rim of soft rubber to the chest piece, as devised by Dr. Snelling, is of advantage in some cases in applying it more closely to the inequalities of the chest. Oval chest-pieces are also made, which enable the end of the stethoscope to be pressed into the intercostal spaces. In most of the instruments now made the rubber band which served to draw the two tubes together is replaced by a spring. In the latest improvement the spring is placed in the screw which binds the tubes together (Fig. 4495).

A considerable variety of flexible stethoscopes are now in use. The credit of having first used one is probably due to Dr. Pennock, of Philadelphia. They may be generally described as consisting of a chest-piece, long flexible rubber tubes, and round ear-pieces. The ear-pieces are held in place either by being firmly pressed into the meatus, or by a spring passing over the head or under the chin. A flexible stethoscope was devised by Mr. Brown, in which the ear-pieces are oval. When placed in the ear, with the long diameter vertical, they are said to remain readily in position. The differential stethoscope of Scott Alison is similar in mechanism to Cammann's, but has two chest pieces, one for each ear, enabling the sounds from different regions of the chest to be conveyed to the two ears at the same time. The hydrophone is another instrument devised by Alison. It consists of an india-rubber bag about the size of a large watch and filled with water. Another inventor had previously constructed a wooden instrument filled with water, but it was not practically useful. Alison found that when water was interposed between two conducting media, sound was conveyed to the ear with increased intensity. The hydrophone may be employed as an instrument by itself, or in aid of the stethoscope.

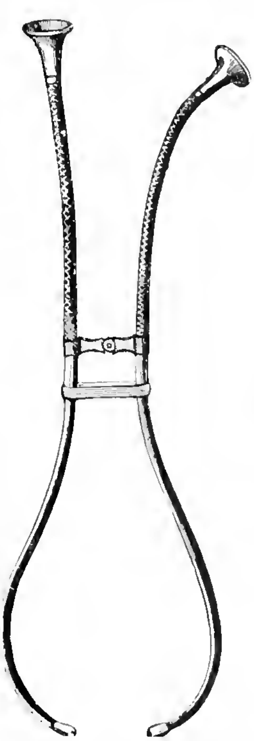


Fig. 4492.—Scott Alison's Differential Stethoscope.

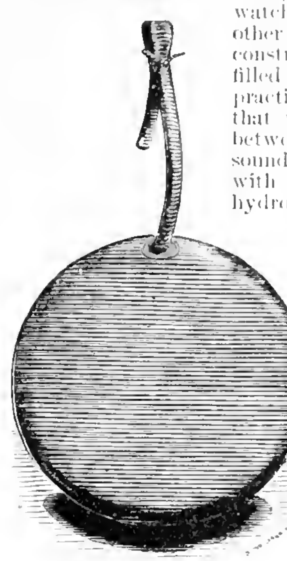


Fig. 4493.—Alison's Hydrophone.

Dr. McBride has devised for use in auscultatory percussion a solid binaural stethoscope of hard rubber, with chest piece sufficiently small to fit in the intercostal spaces. Dr. Constantin Paul devised a stethoscope with two flexible tubes leading to the ears, and a hollow chamber in the chest-piece connected with a rubber bulb by a long flexible tube. If the air in the hollow chamber is exhausted the instrument is held firmly against the chest. A modification of the chest-piece of Cammann's binaural stethoscope, which can be screwed on in place of the usual chest-piece, has been devised by the writer. In the pectoral end is an air chamber, which is completely closed by pressure against the chest. Connected with this chamber by a small tubular opening is a rubber bulb, through which the sound-conducting tube passes. By pressure upon this bulb, when the instrument is held in position, the air is exhausted in the hollow chamber and the stethoscope is held firmly to the chest wall.

Dr. Heineman, of New York, has devised an attachment to the binaural instrument, in which, by an admirably arranged piece of mechanism, the stethoscope is held firmly against the chest by means of a metal rod extending from the chest-piece to the chin, and both hands are left free.

Dr. T. O'Kelly has devised a similar arrangement of a metal rod surmounted by an india rubber cushion upon which the forehead rests, thus enabling the stethoscope to be held firmly in position.

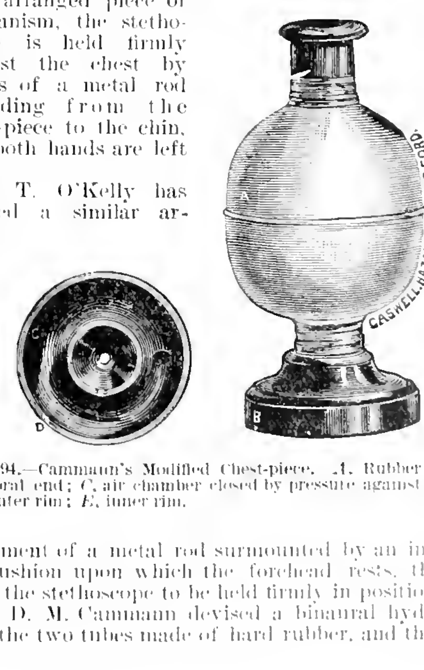


Fig. 4494.—Cammann's Modified Chest-piece. *A*, Rubber bulb; *B*, pectoral end; *C*, air chamber closed by pressure against the chest; *D*, outer rim; *E*, inner rim.

Dr. D. M. Cammann devised a binaural hydrophone with the two tubes made of hard rubber, and thin hard-rubber caps at the aural extremities. The pectoral extremity is covered by a diaphragm of soft rubber, and the instrument is filled with water by means of a faucet. The chest-piece has been already described as a modification of the ordinary binaural stethoscope, and is held firmly against the chest, leaving both hands free. It is intended for use in practising auscultatory percussion.

An instrument has been devised by Dr. Solis Cohen for intrathoracic auscultation. It consists of a rubber tube attached to the binaural stethoscope, and there is a diaphragm of gold-beater's skin in a rubber capsule intervening between the two. The rubber tube passes down the œsophagus.

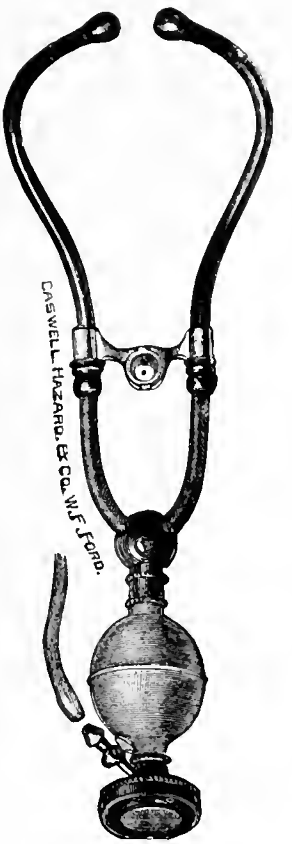


FIG. 4495. — Cammann's Binaural Hydrophone.

Dr. Bowles has devised a chest-piece which can be attached to the binaural stethoscope. It essentially consists of a diaphragm of hard rubber covering the chest-piece, which vibrates and transmits the vibrations to the instrument. It is claimed that with it sounds can be heard more distinctly.

The phonendoscope is an instrument in which there are two diaphragms with an air chamber between, and from the centre of the outer diaphragm a small rod extends, the end of which presents a small surface and, when pressed against the chest, conveys vibrations to the diaphragm.

Both of the instruments last mentioned are patented, and are made by Pilling & Sons, Philadelphia.

In addition to those already described, a number of stethoscopes have in the past ten years been put on the market. They embody no new principle and, so far as the writer is aware, do not convey sound better than the older stethoscopes, when the latter are properly constructed.

CONSTRUCTION OF STETHOSCOPES.—The rules for the proper construction of stethoscopes cannot, in the present state of our knowledge, be formulated with scientific exactness; nevertheless, a knowledge of the laws of acoustics, and of the results of the experiments of others, will aid us in constructing instruments less faulty than many of those now in use. In selecting a material, one should be chosen that, as far as possible, is light, durable, and a good conductor of sound. For the monaural stethoscope nothing has been found better than a light, firm, vibrating wood like cedar. The fibres should run in the direction of the length of the stethoscope. Mahogany, deal, and limewood answer well, but the heavier woods, as oak, beech, lignum vitæ, and boxwood, are inferior and deaden the sonorous vibrations of the bodies upon which they are applied. The quality that makes wood desirable is the same that applies in its use in violins, in sounding-boards for churches, and in the walls of concert-rooms. Other materials, although inferior, are good conductors of sound. Ebonite, a preparation of india-rubber, has the advantage of being light and durable, and easily moulded into shape. The metals, horn, papier-maché, gutta-percha, and ivory are good conductors, and have all been used for this purpose. Hollow stethoscopes are most desirable, as some sounds are conducted best through the solid walls, while others are transmitted most perfectly through the enclosed column of air. The latter is the case with the aërial sounds of the chest, the solid wall of the stethoscope acting as a sounding-board, receiving and transmitting the weakest vibrations. In the practice of auscultatory percussion, a solid wooden stethoscope or the binaural hydrophone is most useful, as sounds produced in solids are best conducted through homogeneous media; but even in this case the ordinary hollow instrument will usually be found to convey sound with sufficient intensity for all practical purposes. The bore of the stethoscope and the hollow in the chest end should not be too large, else there will be caused a confused reverberation of sound; nor should the wall of the stethoscope be of great thickness, both on account of superfluous weight and because the weaker vibrations are thereby checked. It is best that the stethoscope should be of one material throughout and in a solid block. This is not essential, however, and in the binaural instrument is not possible. Theoretically the breaking of continuity, by having it in several pieces, would impair the conducting power; but practically the difference is found not to be as great as might be expected. Flexible stethoscopes, in which the tubes are of soft rubber, or of wire covered with some pliable material, are useful in some cases, but the sounds are modified by reverberation, especially when the tubes are long and with large hollows. The length recommended by Laënnec was one foot divided in two for convenience of carrying. This is unnecessarily long, and six inches is now the usual length. The length of the binaural instrument, from ear to chest-piece, varies from ten or twelve to sixteen or seventeen inches. Most of the binaural instruments have two chest-pieces, one small and narrow, the other trumpet-shaped, which can be screwed on at pleasure. The modified chest-piece may also be used, and can be screwed on in the same way. The smaller end can localize sounds best, and is easier of application to the chest; the larger is more useful in examining the chest rapidly. The edges should not be too sharp, but rounded off both toward the circumference and toward the centre. The ear-piece of the monaural stethoscope ought to be large enough to cover the concha and to close the external meatus. It may be flat, but the most convenient form is with a depression between the circumference and the centre, the latter being considerably elevated. The binaural instruments have small circular knobs, which should not be too large nor too small. If too large, they do not fit closely and allow external sounds to enter; if too small, they cause discomfort by pressure. No instrument will suit all ears, and a stethoscope should be fitted to the ear as a shoe is to the foot.

VALUE OF THE STETHOSCOPE.—In considering the value of the stethoscope it is taken for granted that the instrument used is reliable, and that the auscultator knows how to use it. Some skilful auscultators advocate its continual use; others, equally skilful, advise that it be used only occasionally. The cause of this difference of opinion probably lies partly in difference in the acuteness of hearing and the extent of the training of different observers, and partly is a matter of habit. That the habitual use of the stethoscope does after a time render the sense of hearing less acute to the sounds heard over the chest, in immediate auscultation, is, I think, an undoubted fact. Yet the stethoscope is a valuable instrument, and although it is not always needed, often we cannot attain to a full knowledge of a case without making use both of mediate and of immediate auscultation. Often a doubtful or half-heard sound has been clearly brought out and appreciated by the use of the stethoscope; but still oftener, I think, has a sound scarcely suspected with the stethoscope been made evident by the immediate application of the ear. It requires some practice to become accustomed to the use of the stethoscope, especially to that of the binaural instrument. In the latter some sounds are exaggerated, while others are impaired, and there are not the distinctness and simplicity that are observable when we use the ear or the monaural instrument. It is an acoustic fact that sounds are better heard with two ears than with one, and virtually the double stethoscope enables us to place two ears on the chest at the same time. The modified instrument increases the intensity of sounds both by bringing the pectoral end into the closest possible contact with the chest, and by both the hollow air chamber and the rubber bulb acting as resonators. It also leaves both hands of the auscultator free. Alison's hydrophone may be used either by itself or placed between the end of the stethoscope and the chest, thereby increasing the contact and the conducting power when it is difficult to bring the inflexible end of the instrument into close apposition with the chest wall. Bowles' stethoscope is useful in listening to the posterior portions of the lungs in cases of pneumonia in which the patient cannot be turned over.

The value of the stethoscope for purposes of modesty, cleanliness, and convenience, and for examining the supraclavicular and axillary regions which cannot readily be reached by the ear, are obvious, and need only to be mentioned to be appreciated. *Donald M. Cammann.*

REFERENCES.

Laënnec: Diseases of the Chest. Translated by Forbes, New York, 1830.
Alison, Scott: The Physical Examination of the Chest, London, 1861.
Walshe: Diseases of the Lungs, London, 1871.
Aitken: Pract. Med. Edited by Clymer, New York.
Constantin Paul: Diseases of the Heart, New York, 1884.
Cammann, G. P.: New York Med. Times, January, 1855.
Pollock: Lancet, April 12th, 1856.
Hyde, Salter: Brit. Med. Journ., 1863, pp. 106, 133.
Flint: New York Med. Record, 1870, p. 235.
Williams: Lancet, November 8th, 1873.
Brown: Lancet, March 3d, 1877.
Cammann, D. M.: New York Med. Journ., January 3d, 1885, and February 27th, 1886.
McBride: Archives of Medicine, December, 1880.—Med. News, 1893, lxiii., 688.—Brit. Med. Journ., 1894, i., 919.

STILLINGIA.—U. S. P., *Queen's Root.* The dried root of *Stillingia sylvatica* L. (fam. *Euphorbiaceæ*). This is a perennial plant, with a large, tough, spongy root, and erect herbaceous or slightly woody stem, a foot or so in height, growing abundantly in the Southern States, where it has been used for about half a century.

The drug usually occurs in short transverse sections of very long, tapering, slenderly fusiform roots, about 2.5 cm. (1 in.) or less in thickness, very light, tough, and spongy; externally of a deep or occasionally a light reddish-brown, finely, shortly, and crookedly longitudinally wrinkled and incompletely annulate, especially the thicker portions, with constrictions which frequently become slight fissures; ends of the sections pinkish, very fuzzy with innumerable partly detached fine bast fibres, the bark very thick, containing scattered fine resin cells and laticiferous ducts; the wood radiate, fibrous, and porous; odor slight, peculiar; taste pungent, bitter, and acrid.

The activity of stillingia depends upon three or four per cent. of a nauseous volatile oil, a large amount of soft resin, and a fixed oil, the composition of which has not been studied, but which apparently holds an acrid substance in solution. There are considerable tannin, starch, and other unimportant constituents.

Stillingia is an emetico-cathartic, like many other plants of its family, and is said to be "alterative." Upon this property depend its principal uses, which are very similar to those of sarsaparilla, in syphilis, rheumatism, gout, etc. That its use is mildly beneficial cannot be doubted. Belonging to the same family with the castor and croton-oil plants (see *Euphorbiaceæ*), it rather actively promotes the excretions, from which result its amelioration of the above-named diseases evidently proceeds. Dose 1 or 2 gm. (gr. xv. to xxx.) two or three times a day. A fluid extract is official (*Extractum Stillingiæ Fluidum*, U. S. P.), dose 1–2 c.c. (♏ xv.–xxx.).

Henry H. Rusby.

STOMACH.—The stomach exhibits the usual four layers found in the alimentary tract, called, from within outward, the tunica mucosa, the tela submucosa, the tunica muscularis, and the tunica serosa.

The tunica mucosa is the glandular lining membrane of the stomach. In the fresh condition it is of fleshy consistence and of a pinkish color. The color of the fresh mucous membrane depends on three factors—the amount and venosity of the blood contained in its vessels, the physiological condition, and the character of the glands. In the dog, in the resting condition, the mucous membrane of the greater curvature of the stomach presents a grayish-pink appearance and is relatively opaque. After digestion has been going on for some hours, the grayishness and opacity disappear and the mucous membrane presents a rose-pink color.

If the veins are engorged, the grayish-pink tint is deepened to a chocolate-pink, which rapidly brightens on exposure to the air. The mucous membrane of the pyloric portion of the stomach is always more transparent, paler in color, and firmer in consistence than that of the fundus and corpus ventriculi.

The point of contact of the œsophageal and gastric mucous membranes at the cardia forms a somewhat zigzag line, the œsophageal epithelium extending in the form of irregular conical projections into the stomach (Schaffer) in such a manner that frequently in longitudinal sections engaging the termination of the œsophagus and the beginning of the stomach, portions of the epithelium of the former may appear as isolated patches surrounded by gastric epithelium. This irregularity of the gastro-œsophageal junction is an indication of that tendency of the œsophageal epithelium to invade the stomach and displace the glands, which in some of the lower primates, Inuus, Semnopithecus, etc., has resulted in the formation of a distinct chamber of the stomach, lined by stratified epithelium. At the summit of the musculus sphincter pylori the gastric mucous membrane is continuous with the tunica mucosa duodeni.

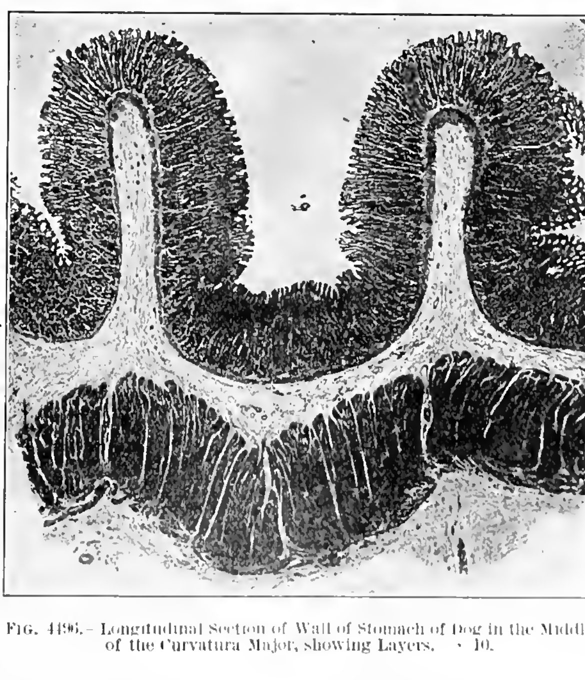


FIG. 4496.—Longitudinal Section of Wall of Stomach of Dog in the Middle of the Curvatura Major, showing Layers. × 10.

In the contracted stomach the tunica mucosa is thrown up into a series of coarse folds, the plicæ mucosæ, mainly longitudinal in direction, but with transverse and oblique connecting folds. These plicæ mucosæ involve the whole thickness of the tunica mucosa and the superficial layer of the tela submucosa. When the stomach is distended to its utmost the folds disappear. A permanent fold at the pyloric end of the stomach, caused by the projection into the cavity of the musculus sphincter pylori, forms the valvula pylori.

The whole surface of the mucous membrane in man is indistinctly marked off by irregular sulci, of varying depths, into small fields a few millimetres in width, the areæ gastricæ, giving the tunica mucosa the so-called mammillated appearance.

If the surface of the mucous membrane be examined with a lens, the close-set depressions, foveolæ gastricæ, into which the gastric glands open, may be seen. These openings are separated from one another by delicate partitions which are in the pyloric region often continued into pointed villus-like processes, projecting into the cavity of the stomach as the plicæ villosæ. Cases have been reported in which the whole inner surface of the stomach was beset with these villus-like processes. The number of foveolæ opening upon the surface of the gastric mucous membrane has been estimated by Toldt to be eighty-seven per millimetre. The total extent of the mucous membrane measured in the same individual by means of the planimeter was 76,300 sq.mm., giving 6,638,100 as the total number of foveolæ in the stomach. It seems probable, however, that the number of foveolæ is subject to considerable variation in different individuals. In a number of pathological cases reported by Einhorn, the number varied from twenty to one hundred and sixty per square millimetre.

The whole of the surface of the mucous membrane and the walls of the foveolæ gastricæ are covered with a simple cylindrical epithelium, mucigenous in function, uniform in type throughout the stomach, but differing somewhat in structural details in the different regions. The cells of this epithelium are somewhat conical in shape, but vary with the shape of the surface upon which they rest, the conical shape being more pronounced on convex surfaces. The pointed apex of the cell rests against the reticular tissue of the lamina propria mucosæ; the broad, slightly convex base of the cell is directed toward the free surface of the tunica mucosa. The adjacent surfaces of the epithelial cells are separated from one another by minute spaces, across which the cells are connected by protoplasmic intercellular bridges. The intercellular spaces are closed internally by lines of cement (*Schlussleisten* of Kohn) which connect the adjacent free edges of the cells. This cement substance is not entirely confined to the intercellular location, but, as shown by Carlier in the newt and by Bensley in man, extends over the free surface of the cell in delicate radiating lines which may easily be mistaken by an inexperienced observer for traces of a striated cuticula. The distal portion of each epithelial cell forms a cup-like cavity, the theca, which contains the specific secretion of the cell; in this case mucin or its antecedent substance. The contents of the theca are in the form of small droplets, which appear in sections of properly fixed material, stained in an alcoholic solution without exposure to water, as fine granules. If the mucin has been allowed to absorb water and go into solution, it precipitates in the form of the coarse spongy network which is usually seen in the theca of these cells. The distal portion of the theca contains very little cytoplasm, but in the proximal portion the granules are separated into groups by threads of cytoplasm which form a coarse network. The conical attached end of the cell is occupied by a delicately reticular cytoplasm containing an oval nucleus. This cyto-

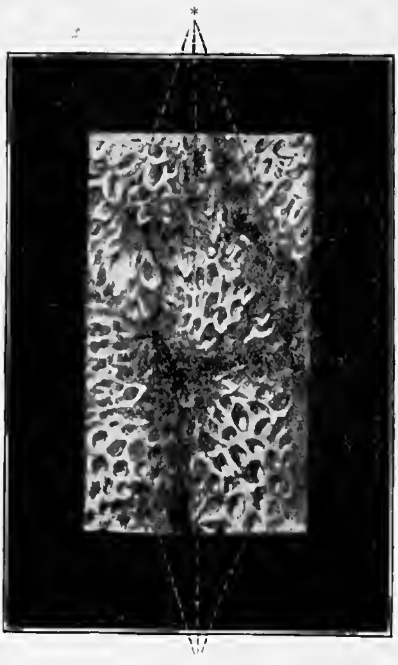


FIG. 4498.—Tunica Mucosa of the Pyloric Region, showing at * the Openings of the Gastric Foveolæ, the Villous Folds, and the Small Gastric Areas. × 16 (After W. Spalteholz, "Handatlas der Anatomie des Menschen.")

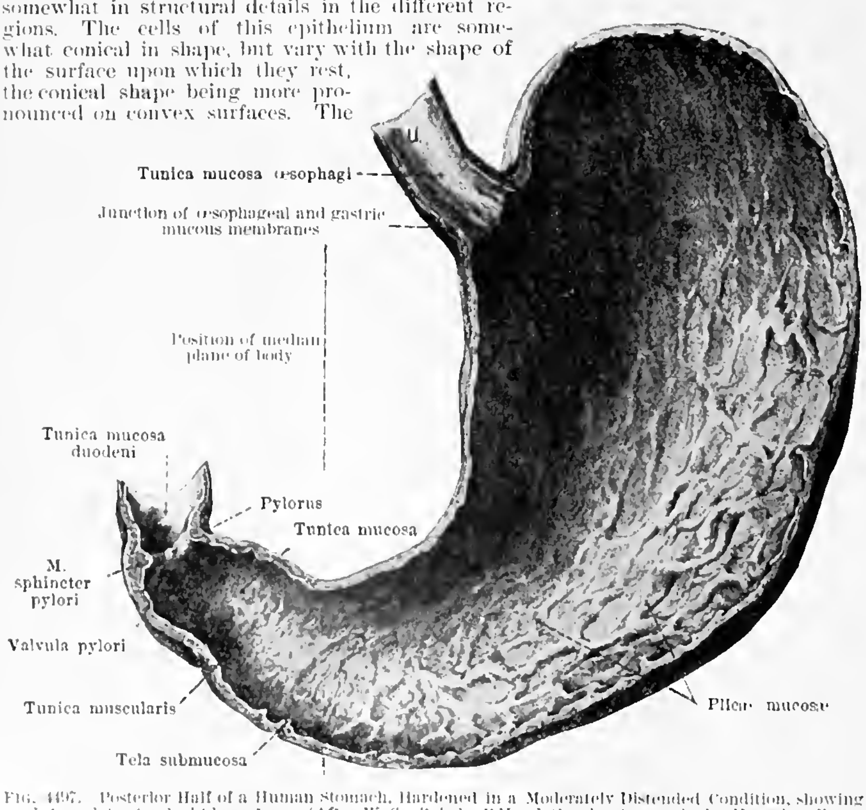


FIG. 4497. Posterior Half of a Human Stomach, Hardened in a Moderately Distended Condition, showing Internal Anatomical Characters. (After W. Spalteholz, "Handatlas der Anatomie des Menschen.")

plasm is continuous with the cytoplasmic network of the proximal portion of the theca, and frequently contains, in sublimate-fixed preparations around the base of the theca, numerous minute granules stainable in eosin or acid fuchsin.

Between the nucleus and the theca the cytoplasm stains less deeply than that in the base of the cell, owing to the presence of the structures which have been interpreted by Holmgren as similar to the canal-like structures observed by him in the hepatic cells, to which he has applied the name trophospongium.

The so-called replacing cells (*Ersatzzellen* of Ebstein) do not exist in the epithelium of the stomach, the structures which have been described under this name being, as suggested by Stöhr, in all probability, lymphocytes which have invaded the epithelial layer.

The epithelium of the foveolæ gastricæ is, as has been indicated, similar to that of the free surfaces, but on going down the foveolæ, certain changes of a transitional character make their appearance as the bottom of the depression is approached. Near the mouth of the foveola the cells are slightly imbricated at their attached ends and have a larger theca than those of the free surface. Deeper in the foveola the cells become shorter and more cubical in shape, the nucleus larger, more rounded, and richer in chromatin; the theca tends to become smaller in extent and divided into two more or less distinct masses, a proximal mass near the nucleus and a distal mass near the cavity. These smaller cells of the bottom of the crypt exhibit great activity in division, as is indicated by the presence of numerous mitoses. The cells of the surface, on the other hand, rarely divide. On this fact Bizzozero has based his theory of the mode of regeneration of the surface epithelium, according to which the cells of the bottoms of the crypts are endowed with the property of dividing and producing new cells, which by a gradual process of migrating or displacement finally reach the surface and replace the cells, which for various reasons are being constantly lost there.

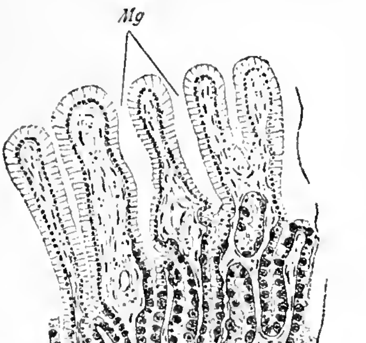


FIG. 4499.—Vertical Section through the Mucous Membrane of the Fundus Gland Region of the Stomach. × 85. *Mg*, Foveolæ gastricæ; *h*, neck of gland; *k*, body of gland; *m*, lamina muscularis mucosæ. (After V. von Ebner, in von Kölliker's "Handbuch der Gewebelehre des Menschen.")

A point of some interest is the occasional occurrence in the human stomach, on the surface of the tunica mucosa, or in the foveolæ, of epithelium of the intestinal type, that is to say, composed of cells with a distinct striated cuticula alternating with goblet cells (Schaffer, Boeckelman, Hári). There is still some doubt as to whether these patches of intestinal epithelium occur normally in the human stomach. They appear to occur most frequently in the pyloric region, but have been observed by Schaffer at the very margin of the œsophagus in the foveolæ of the cardiac glands.

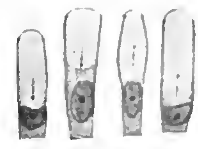


FIG. 1500.—Types of Epithelial Cells from the Gastric Mucosa of Man. (After K. W. Zimmermann. *Arch. f. mikr. Anat.*, Bonn, Bd. lii.)

The great thickness of the gastric mucous membrane is caused by the closely aggregated tubular or tubulo-acinous glands. These are of three kinds, occupying three definite regions of the mucous membrane. The *cardiac glands* (glandulæ cardiacæ) form in man a small area around the cardiac orifice of the stomach, which varies in width in different individuals and in different parts of the circumference of the cardia in the same individual, the extremes, so far recorded, being 0.5 cm. in one of Kupffer's cases, 4.3 cm. in a case described by the writer. The tunica mucosa of the fundus ventriculi, of the curvaturæ major et minor, and of the parietes anterior et posterior is occupied by the *fundus glands* (glandulæ gastricæ propriæ), that of the antrum pyloricum and the adjacent portions of the stomach, by the *pyloric glands* (glandulæ pyloricæ). The cardiac and pyloric glands are, for the most part, mucous glands of simple structure, the acid and pepsin of the gastric juice being in large measure produced by the complex fundus glands.

At the lines of junction of the various glandular zones a gradual transition from one type of gland to the next may be observed, forming thus between the cardiac and fundus zones on the one hand, and between the fundus and pyloric zones on the other hand, intermediary zones of small extent.

The tunica mucosa in the region occupied by the fundus glands differs in thickness according to the location. In man, according to von Kölliker, the thickness of the tunica mucosa is 0.37 mm. to 0.56 mm. at the cardia, 1 mm. in the middle of the greater curvature. Zimmermann gives the thickness of the mucous membrane as 1.2 mm. in a piece of mucous membrane from the fundus gland zone. In material examined by the writer, the thickness of the mucous membrane, including the lamina muscularis mucosæ, was 0.64 mm. at the beginning of the fundus glands, 0.82 mm. in the middle of the fundus ventriculi, 1.2 mm. to 1.3 mm. in the middle of the curvatura major.

The fundus glands (glandulæ gastricæ propriæ), physiologically the most important, are slightly wavy, branched tubules, placed vertically in the tunica mucosa, and so closely aggregated throughout the whole of the zone that the interglandular tissue of the lamina propria mucosæ is reduced to a minimum. Each gland is connected with a foveola gastrica by a short collecting duct (*inneres Schaltstück* of Rollett), lined by epithelium of the same type as that of the deep ends of the foveolæ.

The gland may be divided into two portions, which differ from one another in size and in the character and arrangement of their respective epithelial elements. The more superficial, narrower portion of the gland is called the neck of the gland; the deeper, wider portion, the body of the gland.

The relative lengths of the foveolæ and different sections of the glands is given by Zimmermann as follows:

Thickness of the tunica mucosa	1.200 mm.
Depth of the foveolæ gastricæ	0.256 to .325 "
Collecting duct (*Drüsenhals* of Zimmermann)	.046 to .078 "
Neck of gland (*Schaltstück* of Zimmermann)	.265 to .312 "
Body of gland	.465 to .578 "

The measurements obtained by the writer correspond very closely with those of Zimmermann as regards the length of the body of the gland, but show relatively longer foveolæ and shorter necks. They are as follows, taken from glands of the middle of the greater curvature of the stomach:

Thickness of tunica mucosa	1.200 to 1.320 mm
Combined length of foveolæ and collecting duct	.358 to .539 "
Neck of gland	.147 to .220 "
Body of gland	.414 to .526 "

The differences between these two sets of measurements possibly indicate that there is considerable individual variation in the relative lengths of the foveolæ and the necks of the glands.

The fact that the fundus glands of the stomach are composed of several kinds of cells was discovered in 1850 by von Kölliker, who described them as composed of very large mononucleated cells, located immediately beneath the membrana propria, and of smaller rounded cells which formed a complete tube around the very narrow lumen. This discovery, however, attracted little attention from histologists, and even von Kölliker himself failed to mention it in the subsequent editions of his text-book. The two kinds of cells were subsequently rediscovered in 1870, independently of one another, by Heidenhain and Rollett. The former called the chief cells and parietal cells respectively *Hauptzellen* and *Belegzellen*. By Rollett the chief cells were called "*adelomorphe Zellen*," the parietal cells, "*delomorphe Zellen*."

The descriptions of Heidenhain and Rollett differed in some important respects. The former described the neck of the gland as being composed of both chief and parietal cells, and mentioned the occasional occurrence of parietal cells under the cylindrical epithelium. Rollett denied both the existence of chief cells in the neck of the gland, which he supposed to be wholly composed of parietal

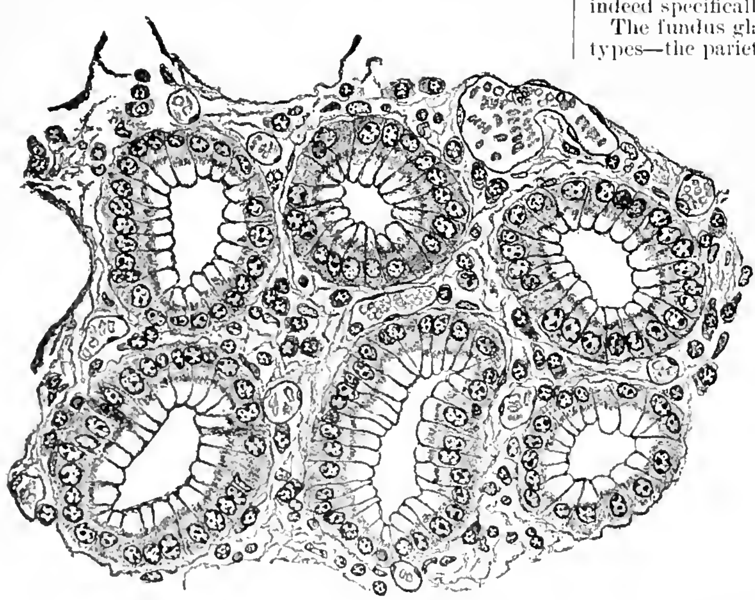


FIG. 4501.—Section Cut Parallel to the Surface of the Mucous Membrane of the Greater Curvature of the Human Stomach, Across Six Foveolæ Gastricæ, showing the Type of the Epithelium and the Tissue of the Lamina Propria Mucosæ. Note the large number of plasma cells in the latter. × 394.

cells, and the occurrence of the latter in the foveolæ. The researches of subsequent investigators, in particular those of Stöhr, have amply sustained Heidenhain in both these respects. In 1892 Bizzozero called attention to the fact that the chief cells in the neck of the gland differed somewhat from those in the body of the gland. The question as to the nature of these cells has since been investigated by Oppel, Bensley, Zimmermann, Cade, and

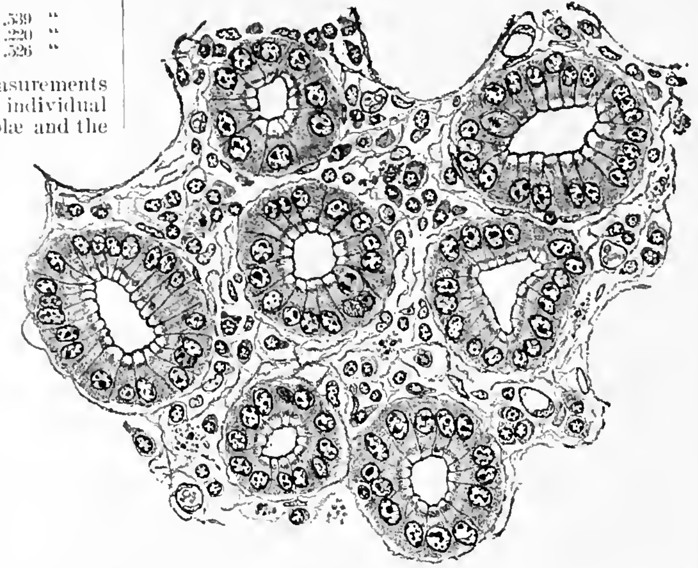


FIG. 4502.—Section Across the Foveolæ Near their Outer Ends. Note the smaller size of the foveolæ as compared with Fig. 4501; the smaller mucigenous border (theca) of the epithelial cells; the mitoses; and the larger amount of interglandular tissue. × 394.

others, and it has been shown that the transition which Bizzozero supposed to exist between the chief cells of the neck of the gland and those of the body of the gland does not occur, and that the two kinds of chief cells are indeed specifically different.

The fundus gland is composed of cells of three distinct types—the parietal cells, large, ovoidal elements projecting on the outside; the mucous cells of the neck of the gland (*Halshauptzellen* of Oppel); and the pepsin-forming chief cells of the body of the gland (*Grundhauptzellen* of Oppel).

In the body of the gland, the large, wedge-shaped or cuboidal chief cells form an almost continuous lining for the narrow lumen, the large ovoidal parietal cells being displaced to the periphery of the gland away from the lumen, with which they are only connected by narrow ductlets which pass between the adjacent surfaces of the chief cells.

In sections of fresh mucous membrane, mounted in an indifferent fluid (aqueous humor or blood serum), the portions of the chief cells of the body of the gland which border the lumen are seen to be occupied by closely packed minute refractive granules. These granules have been shown by Langley in a number of mammals and lower vertebrates to diminish in number during secretory activity and to accumulate during rest. Langley has also shown that the amount of pepsin which may be extracted from the mucous membrane is proportional to the extent of this superficial granule-filled zone of the chief cells. The granules are therefore composed of the antecedent substance of the enzyme, and are called zymogen granules. The zymogen granules in the gastric mucosa of man are exceedingly difficult to preserve, and for this reason are usually not visible in stained sections. In material fixed in alcohol or in aqueous solutions of mercuric chloride they have, as a rule, completely disappeared. They may be retained by fixation of the tissue in alcoholic solutions of mercuric chloride or in solutions containing four per cent. of formaldehyde.

In sections of tissue fixed by mercuric chloride in alcohol and stained in hæmatoxylin, or, better, in toluidine blue, the chief cell of the body of the gland exhibits two well-defined zones—a deeply stained proximal zone containing the nucleus, and a pale distal zone bordering the lumen. The relative sizes of these two zones depend on the physiological condition of the cell, the clear zone being larger in a resting cell, smaller in a cell which has been actively secreting for several hours. The cytoplasm of the basal zone stains intensely in nuclear dyes such as hæmatoxylin, toluidine-blue, thionin, methylene-blue, etc., and exhibits an indistinct radial striation, which has been interpreted by some observers as due to the presence in the cytoplasm of groups of parallel filaments (the basal filaments of Solger). The intense staining of the basal zone has been shown by the writer to be due to the presence in it of substances chemically similar to the chromatins of the nucleus. This may be shown by the employment of Macallum's microchemical tests for iron and phosphorus, both of which give distinct positive reactions, quite as intense as those given by the nuclear chromatin. There is a reciprocal relation between the amount of these substances and the number of zymogen granules bordering the lumen of the gland, the latter being formed apparently in part at the expense of the former. These substances, on the presence of which depends the deep staining character of the basal zone, may therefore be termed prozymogens. The amount of prozymogen and of zymogen present in any cell depends on the phase of physiological activity in which it happens to be, and on the specific secretory equilibrium of the cell. Macallum has shown in the pancreatic cell, and Carlier in the cells of the gastric glands of Triton, that the increase of prozymogen in the basal cytoplasm is accompanied by an exhaustion of the nuclear chromatin, indicating an actual participation of the latter in the secretory metabolism of the cell.

The transparent distal zone of the chief cells of the body of the gland, that is, the zone that is next the lumen of the gland, exhibits a finely reticular structure, the meshes of the network being of wonderful regularity and corresponding in size to the zymogen granules observable in the living cell. This reticular appearance has been interpreted by Théohari and others as due to the presence of a true cytoplasmic reticulum or spongioplasm. The more probable explanation is that the cytoplasm of the portion of the cell nearest the lumen contains innumerable small granules of zymogen, each granule enclosed in a space separated from the neighboring spaces by the continuous cytoplasm. In sections stained in alum hæmatoxylin and eosin or in toluidine-blue, the granules remain unstained and the spaces they occupy appear as tiny vacuoles, so closely aggregated that the portion of the cell in which they occur appears reticulated. The correspondence between the granules and the meshes of the cytoplasmic network may be demonstrated by staining sections of material fixed fresh in formalin or in alcoholic solution of mercuric chloride, in iron alum hæmatoxylin, or in neutral gentian. By these methods the zymogen granules are intensely stained, and it may be readily seen that each granule is enclosed in a mesh of the network.

The nucleus of the chief cell of the body of the gland is located at the junction of the two zones, is spherical in outline, and possesses one or two oxyphile nucleoli and a well-defined chromatin network.

It has been shown by the writer and confirmed by Cade that the chief cells of the neck of the gland differ in several important points from those of the body of the gland. These cells lack both prozymogens (there is no indication of basal filaments in them) and zymogen granules. In the living gland the contrast between the two portions of the gland is very striking, owing to the fact that the zymogen granules are entirely confined to the body of the gland.

The neck chief cells resemble very closely the mucous cells from salivary glands. For the most part they appear triangular when seen in longitudinal sections of the gland, the broad base of the triangle directed toward the lumen, the narrow apex toward the outside, where the cells are crowded by the presence of the parietal cells. The nucleus is located in the proximal attached end of the cell and is spherical, oval, or crescentic in outline, according to the degree of loading of the cell with secretion. The contents of the cell appear in hæmatoxylin-eosin sections clear and transparent, and exhibit a reticular structure, the large meshes of which are separated by delicate protoplasmic trabeculæ. The meshes or clear spaces in such preparations are the cavities of the cell in which the secretion is stored. Usually there is in these cells a condensation of the cytoplasm in the

FIG. 4503.—Section Across Six Fundus Glands from the Greater Curvature of the Human Stomach, Near the Outer Ends. In the chief cells may be seen the two characteristic zones: the outer zone containing basal filaments of prozymogen; the inner zone a fine network enclosing the spaces in which the zymogen granules are lodged. × 500.

middle of the cell in the form of a transverse band, incompletely subdividing the secretion into a proximal and a distal mass. The nature of the secretion contained in these cells may be determined by staining in a modified form of P. Mayer's muchæmatein solution of the following composition: Hæmatein, 1 gm.; aluminum chloride, 0.5 gm.; seventy-per-cent. alcohol, 100 c.c. The sections fastened to the slide are stained in this solution under the microscope until the mucin of the surface epithelial cells is a deep blue; the stain is then washed off with ninety-five-per-cent. alcohol, and the sections are dehydrated, cleared, and mounted in xylol balsam. In such preparations the contents of the secretion spaces of the neck chief cells, as well as the mucin of the surface cells, are stained intensely blue. A similar result is obtained by staining sections with Mayer's mucicarmine, freshly prepared and undiluted, the contents of the neck chief cells and of the theca of the epithelial cells of the foveolæ gastricæ staining in this solution intensely red. Thus the impression gained by a study of the structure of these cells that they secrete mucus is confirmed by the staining reactions.

At the junction of the neck and body of the gland for a very short distance the mucous cells and zymogenic cells are mixed with one another, affording at this place a good opportunity to compare their respective cytological characters. In a very few of the glands of the fundus the mucous cells extend right to the bottom of the gland, replacing entirely in this case the ordinary chief cells of the body of the glands. Such mucous glands contain fewer parietal cells and a larger lumen than the ordinary fundus glands. The mucous chief cells of the neck of the fundus gland of man and mammals are the homologues of the large clear cells found in the necks of the gastric glands of reptiles and anurous Batrachians, with which they correspond in position, structure, and staining characters.

The parietal cells occur in all parts of the gland, although they may be found in greatest numbers in the necks of the gland, alternating in this situation with groups of the mucous neck cells. In the body of the gland they are fewer in number, and in the foveolæ only an occasional parietal cell may be seen.

The parietal cells are of ovoidal shape with centrally placed nuclei. In the neck of the gland they have a broad surface of contact with the lumen, but in the body of the gland they are crowded to the outside of the gland, and are connected with the lumen only by narrow ductlets which pass between the adjacent surfaces of the chief cells. In each parietal cell according to Zimmermann, three zones of structure can be made out, a central mass of coarsely granular structure, containing the spherical nucleus or nuclei, for the latter are often multiple, a peripheral zone of similar structure, and an intermediate zone of finely granular structure. The differences between these various zones are best brought to view by staining sections according to Heidenhain's iron hæmatoxylin method, in which the coarse granules of the middle and outer zones stain deeply. The intermediate zone forms the free surface of the cell on the lumen or on the minute ductlets above described.

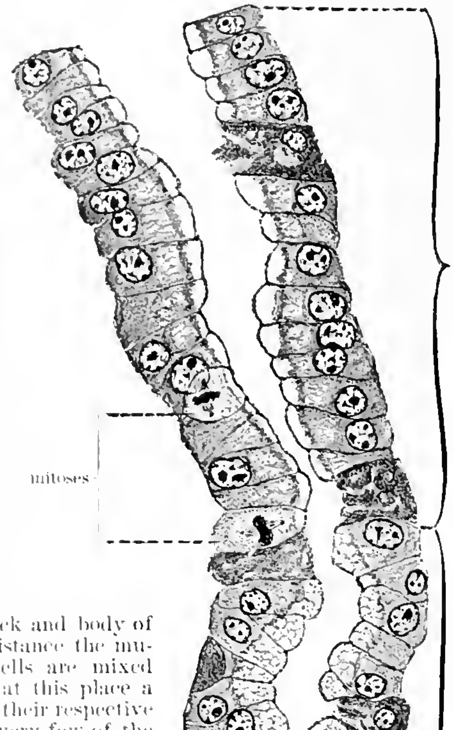


FIG. 4504. Longitudinal Section of Part of a Foveola Gastrica, of the Neck, and of Part of the Body of a Fundus Gland of the Stomach of Man. × 580.

For a long time it was thought that the parietal cells in the body of the gland were completely shut off from the lumen by a layer of chief cells. Stöhr was the first to point out that the parietal cells also came into contact with the lumen. According to him this connection was effected by the parietal cell possessing a pointed projection which penetrated between the adjacent surfaces of the chief cells and thus reached the lumen of the gland. It was not, however, until the introduction of the rapid Golgi method for the impregnation of tissue spaces that the real nature of the ductules of these cells was determined. By this means Erik Müller was able to show not only that a minute canal ran from the lumen of the gland to the parietal cell, but that the latter possessed an intricate system of branching and anastomosing secretion canaliculi. These intracellular canaliculi have since been observed by Müller, Zimmermann, and others in ordinary stained preparations, especially in sections stained by the ferric alum hæmatoxylin method of M. Heidenhain, in which the intracellular and intercellular secretion canaliculi may be readily seen. In Golgi preparations of the gastric glands the fine ductule which connects the parietal cell with the lumen of the gland is seen to divide, on arriving at the cell, into a group of fine branches, most of which penetrate the substance of the cell, in the intermediate zone of which they ramify (intracellular canaliculi); others penetrate a short distance between the parietal cell and the adjacent chief cells (intercellular canaliculi). The true intercellular character of the latter may be determined, as Zimmermann has shown, by the presence of the intercellular cement lines. The ductules of the intracellular canaliculi frequently contain transparent globules of coagulated secretion, which may also be observed in the lumen of the gland as far as its opening into the foveola gastrica.

The theory of Heidenhain that the parietal cells are the sole source of the hydrochloric acid of the gastric juice rests at present on a very insecure foundation. The argument commonly employed, that the parietal cells are absent from the pyloric glands which produce an alkaline secretion, would be equally true of the chief cells of the body of the fundus glands. Moreover, the difference in acidity of the mucous membrane of the fundus and greater curvature of the stomach of the rabbit, which, according to Langley, corresponds to differences in the number of parietal cells present, could be equally well explained by the obvious differences in secretory equilibrium of the chief cells from these two sources.

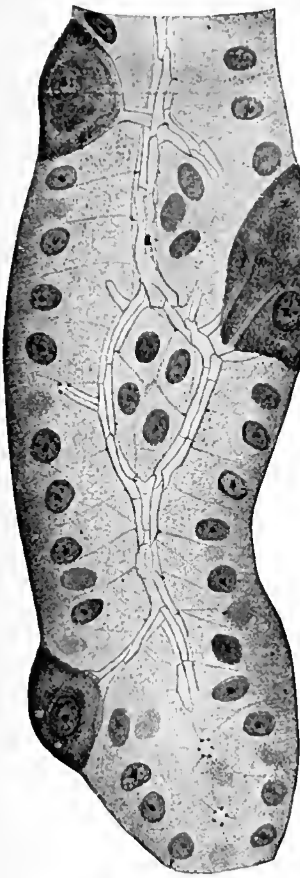


FIG. 4505.—Lower End of Fundus Gland, Chief and Parietal Cells. In the latter the intracellular ducts may be seen. (After K. W. Zimmermann, *Arch. f. mikr. Anat.*, Bonn, Bd. lii.)

The mucous membrane of the greater part of the pars pylorica is thinner than that of the greater curvature, although thicker than that of the fundus and cardia. The thickness in material examined by the writer was 0.832–0.955 mm. Near the sphincter pylori, however, it again increases in thickness to 1.3 mm., or in places as much as 1.8 mm.

The glands of the pyloric region are much less closely set than in the fundus region, and are separated from one another by a larger amount of tissue belonging to the lamina propria mucosæ.

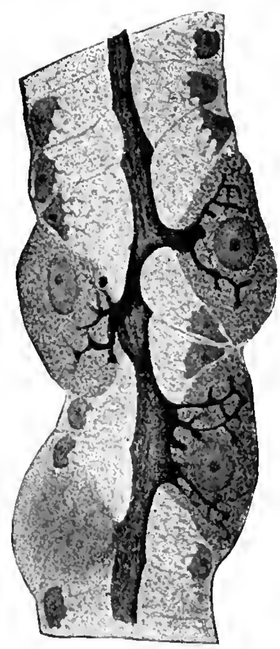


FIG. 4506.—Fundus Gland of Cat. Golgi preparation, fixed in ammonium sulphide and stained with hæmatoxylin and eosin; showing intracellular ducts of the parietal cells. (After K. W. Zimmermann, *Arch. f. mikr. Anat.*, Bonn, Bd. lii.)

The foveolæ into which the pyloric glands open are much narrower in man than in most mammals. They rapidly diminish in diameter, to become narrow tubes, which branch as they descend in the mucous membrane, and at about the junction of the middle and outer thirds of the mucous membrane receive the pyloric glands. The long tubular branches of the foveolæ in the pyloric region may be compared to the short collecting ducts of the fundus glands. In view, however, of the fact that they are lined throughout by epithelium similar in character to that of the foveolæ, it seems to me better to consider them as part of the latter.

Into the bottoms of these foveolar branches open the pyloric glands. These are composed of a varying number of branching wavy tubules, into which open short, pear-shaped acini. Both tubules and acini are lined by the characteristic pyloric gland cells. The thickness of the portions of the mucous membrane occupying the foveolæ and glands respectively, I have determined as follows:

Length of foveolæ and branches	0.441–0.476 mm.
Width of portion of tunica mucosa occupied by the glands proper	.283–.301 "

In the thicker distal portion of the pyloric mucous membrane they are as follows:

Length of foveolæ and branches..................	0.735 mm.
Width of mucosa containing glands proper........	.301 "

The narrow tubular branches of the foveolæ are lined by cells of the type of those found at the bottoms of the gastric foveolæ and in the short tubules which are intercalated between these and the neck of the glands in the fundus region. They are cylindrical cells, containing an oval nucleus and a considerable amount of cytoplasm. At the end of the cell which borders on the lumen a small theca is seen containing mucus, stainable in mucihæmatein according to the method already described.

The terminal branches of the pyloric gland are made up of large, cubical cells surrounding an obvious lumen. These cells are usually found filled with secretion which occupies the meshes of a coarse network of cytoplasm. The nucleus is situated at the base of the cell and is spherical, flattened, or crescentic in outline, according to the amount of the secretion contained in the cell.

The theory of Heidenhain that the cells of the pyloric glands are pepsin-forming elements similar in character to the chief cells of the body of the fundus gland, has been shown to be incorrect.

As has been pointed out, the chief cells contain two characteristic substances which are phases in the formation of their secretion, namely, prozymogen, a deeply staining substance found in the base of the cell; and zymo-

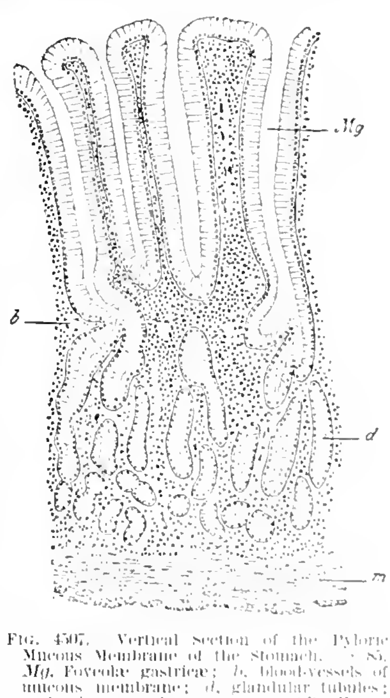


FIG. 4507.—Vertical Section of the Pyloric Mucous Membrane of the Stomach. × 85. *Mg*, Foveolæ gastricæ; *b*, blood-vessels of mucous membrane; *d*, glandular tubules; *m*, lamina muscularis mucosæ. (After V. von Ebner in von Kölliker's "Handbuch der Gewebelehre.")

gen, found in the form of coarse granules along its free surface. Neither of these substances occurs in the pyloric gland cells. The absence of the granules explains the greater transparency of the pyloric mucous membrane. On the contrary, the meshes of the coarse network seen in the pyloric gland cells are filled with a substance which stains strongly in muchæmatein or mucicarmine, when employed according to the methods indicated above. These facts, together with the strong resemblance of the pyloric gland cells to mucous cells from other sources, and the gradual transition in character from the gland cells to the cells of the superficial epithelium, indicate that the bulk of the secretion of the pyloric glands is simply mucus. What other subsidiary substances are secreted along with the mucin is at present unknown.

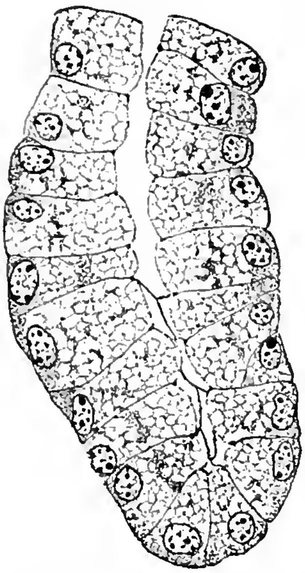


FIG. 4508.—Tubule of Pyloric Gland of Man. (Highly magnified.) Note the thin basal layer of cytoplasm; the reticular cell body containing secretion; the subdivision of the latter in some cells into proximal and distal masses.

Morphologically and physiologically the cells of the pyloric glands are regarded by the writer as the equivalents of the mucous chief cells found in the necks of the fundus glands. The same relation thus obtains between the pyloric glands and the fundus glands of mammals as between the corresponding structures in Reptilia and Anura.

The cardiac glands occupy a zone varying in width from 0.5 cm. to 4.3 cm. around the cardiac orifice of the stomach. The glands of the proximal portion of this area are much more richly branched than either the fundus glands or the pyloric glands. They are composed largely of cells similar in character to the pyloric gland cells and the mucous chief cells of the fundus glands, and like them contain a secretion which stains in mucihæmatein and mucicarmine. Some tubules are, however, formed of cells similar in type to the chief cells of the body of the fundus gland, inasmuch as they contain both prozymogen and granules of zymogen. A few parietal cells may also be present in the cardiac glands.

Toward the distal part of the zone the glands become less branched, and chief cells make their appearance regularly at their outer ends, a transition being thus gradually accomplished from the cardiac glands to the fundus glands.

The framework of the tunica mucosa is composed of reticulum, which forms a delicate network supporting and separating the glands and containing the blood-vessels, nerves, etc., of the membrane. The delicate fibrils of which this tissue is composed are condensed around the surfaces of the glands to form basement membranes for them. In the dog, according to Mall, the reticulum is especially condensed at two levels in the mucosa, one just above the lamina muscularis mucosæ, corresponding to a rudimentary stratum fibrosum (stratum compactum of Oppel); the other at the level of the necks of the glands. In man the glands reach almost to the muscularis mucosæ, so that here also the stratum fibrosum of Mall is rudimentary.

Here and there in the tunica mucosa branching bands of smooth muscle extend between the glands from the muscularis mucosæ in the direction of the free surface. These also receive a delicate investment of reticular fibrils, containing a network of fine elastic fibres.

In the meshes of the reticular framework many wandering cells occur. In the superficial portions of the mucous membrane Unna's plasma cells are especially abundant (Figs. 4501 and 4502). A few polymorphonuclear neutrophile and eosinophile leucocytes, and lymphocytes, are present, and in sections stained in polychrome methylene-blue numerous mast cells may be seen among the glands.

Solitary lymph nodules (noduli lymphatici solitarii) occur in varying numbers in the mucous membrane of the stomach. They are particularly abundant in the cardiac and pyloric regions, where they occupy the deeper layers of the mucous membrane. Occasionally they may be found in the superficial tela submucosa, in which case they are often continuous through an opening in the lamina muscularis mucosæ with the reticular tissue of the tunica mucosa.

The deepest layer of the tunica mucosa is formed by the lamina muscularis mucosæ, a double layer of unstriated muscle fibres, 50–100 μ in thickness. It consists, according to Klein, of an inner circular and an outer longitudinal layer of fibres, which intercross and pass into one another. According to Böhm and von Davidoff it is composed of three layers. Between the constituent fibres of this layer may be seen a delicate network of reticulum and a rich network of elastic fibres. The fibres of the latter, for the most part, run in a direction parallel to the muscle fibres. From both layers of the lamina come off the groups of muscle fibres referred to above, ascending in the tunica mucosa among the glands.

The tela submucosa is a loose layer of collagenic fibrous tissue, connecting the tunica mucosa with the tunica

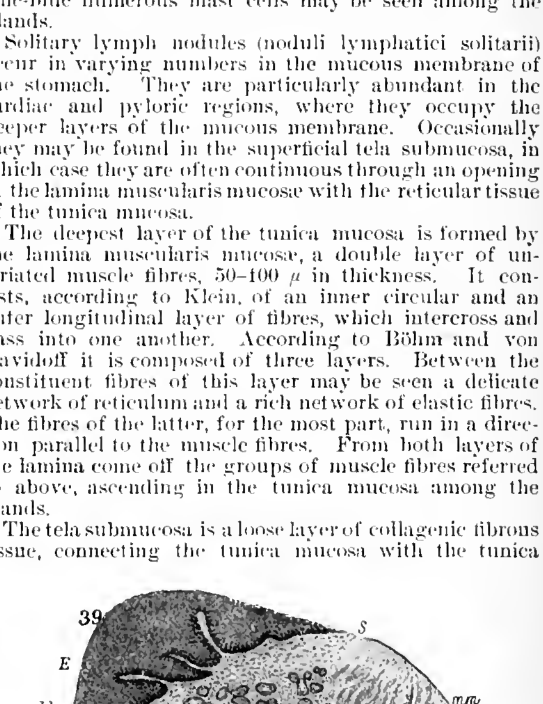


FIG. 4509.—Section through the Junction of Œsophagus and Stomach of Man, showing Cardiac Glands. × 121. *Oe*, Œsophagus; *m*, stomach; *cd*, cardiac glands; *wd*, dilated ducts of cardiac glands. (After J. Schaffer, *Sitzungsb. d. k. Akad. d. Wissensch.*, Wien, Bd. cvi., Abth. iii.)

muscularis, and containing the large blood-vessels and lymphatics and the nerves and ganglia forming the plexus of Meissner. This layer is poor in elastic fibres except in the neighborhood of the tunica muscularis, where the rich network of elastic fibres may be seen. Here and there, in the tela submucosa, are to be seen larger and smaller accumulations of adipose tissue.

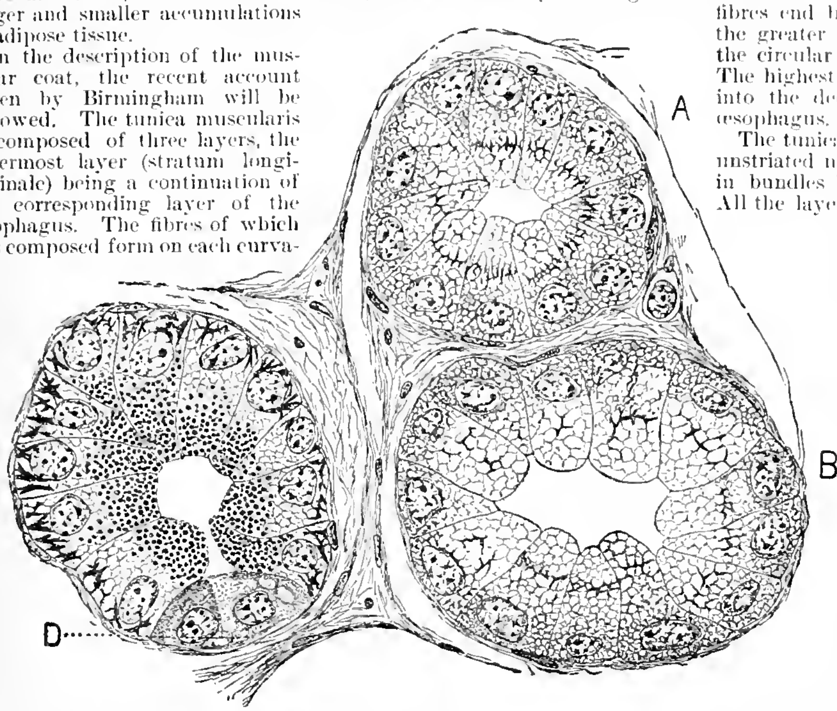


FIG. 4510.—Cross-section of Three Tubules of the Cardiac Glands of Man. × 1,000. A, Mucous tubule, showing cells in early stage of mucin formation; B, mucous tubule, showing cells in various stages of mucin formation up to complete loading; C, tubule composed of cells similar to the chief cells of the body of the fundus glands. These cells contain basal filaments (prozymogen) and zymogen granules; D, binucleate parietal cell with intracellular secretion channels. (After R. R. Bensley, '02.)

In the description of the muscular coat, the recent account given by Birmingham will be followed. The tunica muscularis is composed of three layers, the outermost layer (stratum longitudinale) being a continuation of the corresponding layer of the œsophagus. The fibres of which it is composed form on each curvature, but particularly on the curvatura minor, a well-marked layer of numerous distinct bundles. On the anterior and posterior surfaces the layer exists as a very thin sheet, the fibres being less distinctly longitudinal in places, particularly near the middle of the surfaces beneath the cardia, than in the neighborhood of the curvature (Fig. 4511). The middle layer (stratum circulare) is best developed at the pylorus, where it forms a thickened muscular ring, musculus sphincter pylori, surrounding this aperture. In the adjacent narrow portion of the stomach the fibres are also well developed, and the resulting rings are numerous and closely placed. As we pass on toward the left the layer becomes thinner and the rings correspondingly fewer, but they still form a distinct and well-defined continuous sheet, the fibres of which can be easily seen even through the peritoneum, forming very symmetrical rings, disposed at right angles to the long axis of the organ. This regular arrangement is continued as far as the region of the œsophagus, where it is interrupted. To the left of the cardia the layer is continued for some distance in the form of oblique fibres, which radiate from the right side of the œsophageal opening above, downward, and to the left on the two surfaces of the stomach. These fibres, becoming more and more oblique, are continued above into the superficial circular fibres of the lower end of the œsophagus. The internal layer is composed, like the middle layer, of circular and oblique fibres; but while the oblique fibres are but slightly developed in the middle layer, they form an important part of the internal layer. Beginning as a series of circles at the summit of the fundus, it extends in the form of a layer of rings, disposed at right angles to the axis of the stomach, as far as the cardia. Beyond this it is continued by a number of fibres—the well-known oblique muscular fibres of the stomach—which radiate from the left side of the œsophageal opening, downward, and to the right on both surfaces of the stomach, some of them reaching almost as far as the antrum pylori. These fibres end by turning abruptly toward the greater curvature and passing into the circular fibres of the middle layer. The highest of these oblique fibres pass into the deeper circular fibres of the œsophagus.

The tunica muscularis is composed of unstriated muscle fibres bound together in bundles by delicate reticular tissue. All the layers of this coat contain many elastic fibres forming networks, the meshes of which are elongated in the direction of the long axis of the fibres.

Between the strata is a thin layer of collagenic connective tissue, containing numerous blood-vessels and the nerves and ganglia of the plexus of Auerbach.

The peritoneal coat of the stomach (tunica serosa) consists of collagenic tissue, composed of crossing and intercrossing fasciculi and containing elastic fibres. The free surface is covered by a layer of flat, irregularly shaped nucleated endothelial cells, which give to the external surface its smooth, glistening appearance. Under the endothelium is a thin layer of connective tissue, containing in its deeper half a network of fine elastic fibres. The deeper layers of the tunica serosa, formed of connective tissue composed

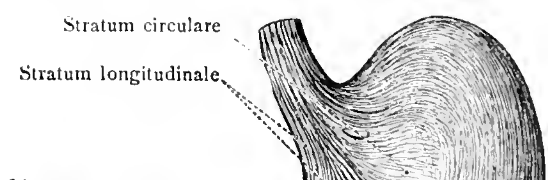


FIG. 4511.—The Superficial Layers of the Tunica Muscularis of the Stomach. Stratum longitudinale. (After C. Toldt, "Anatomischer Atlas," Zweite Auflage.)

of loosely interlaced fasciculi of collagenic fibrils and a few elastic fibres, contain the blood-vessels and nerve bundles.

The blood-vessels of the stomach are derived from all three branches of the arteria cœliaca, which form arterial arches along the curvaturæ minor et major, from which the smaller branches to the organ are derived. That

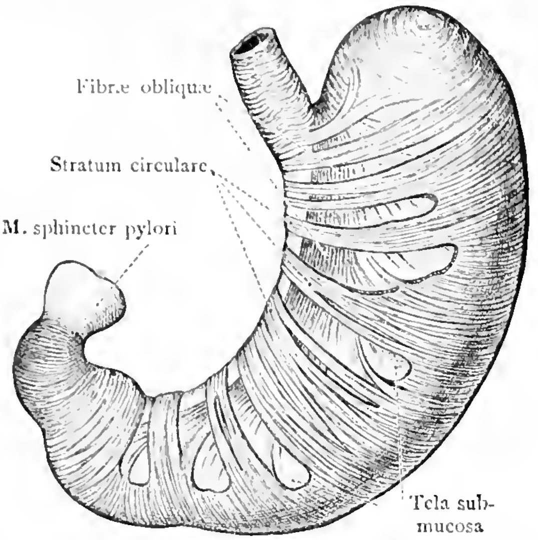


FIG. 4512. The Middle and Internal Layers of the Tunica Muscularis of the Stomach. Stratum circulare and fibræ obliquæ. The stratum circulare has been removed in places. (After C. Toldt, "Anatomischer Atlas," Zweite Auflage.)

along the lesser curvature is formed by the union of the right gastric branch (arteria gastrica dextra) of the arteria hepatica with the left gastric artery (arteria gastrica sinistra); that of the greater curvature, by the union of the right and left gastro epiploic arteries (arteriæ gastro-epiploicæ dextra et sinistra) derived from the hepatic and splenic arteries. In addition, the fundus ventriculi receives a number of short branches (arteriæ gastricæ breves) from the arteria lienalis. The large vessels formed by these anastomoses may be compared, according to Mall, to the vascular arches of the mesenteric arteries.

From the arches thus formed branches come off which penetrate the tunica muscularis at the curvatures, and are distributed in the tela submucosa of both surfaces of the organ. These branches in the submucosa are, in the dog, according to Mall, of various sizes, being smallest and most numerous in the pyloric region and fundus, largest in the middle zone. They pass in a circular direction around the stomach, branching and anastomosing freely to form a fine plexus of vessels, located at about the middle of the tela submucosa. From this plexus vertical branches arise which pass through the lamina muscularis mucosæ at very regular intervals and supply the mucous membrane. As soon as the bases of the glands are reached, each of these vessels breaks up into radiating branches (the stellate arteries), which in some animals form a second plexus within the deepest portion of the mucous membrane.

From these stellate arteries arise numerous capillaries which form a dense network with elongated meshes, surrounding the gastric glands from the bases to their necks. As the capillaries approach the openings of the glands, they begin to collect into larger vessels, which in turn communicate with a plexus of veins located under the epithelium. Thus the deeper layer of the mucous membrane receives the blood in a more arterial condition than do the superficial layers.

The subepithelial venous plexus is composed of small vessels which form a network of meshes surrounding the foveolæ near the openings. From this plexus larger veins pass vertically to join the subglandular plexus at the outer edge of the mucous membrane just internal to the lamina muscularis mucosæ. From this second venous plexus branches pass to the tela submucosa, which join one another and communicate finally with the submucous plexus of large veins. The veins which form the submucous plexus correspond in their distribution very closely to the vessels of the arterial plexus. Each large artery has, as a rule, two accompanying veins, the smaller arteries one. The arteries are, as a rule, more superficial than the veins and smaller in size.

The tunica muscularis is supplied, to a limited extent, along the greater and lesser curvatures by branches which come from the arteries as they pass through to the submucosa. The great bulk of the muscular coat, however, is supplied with blood by means of recurrent branches from the plexus of vessels in the submucosa. These branches pass directly outward from the submucous plexus through the stratum circulare, to the intermuscular layer, where they form a plexus the meshes of which are for the most part elongated in the direction of the fibres of the stratum longitudinale. From this plexus and from the recurrent arteries which form it are given off branches which break up into capillaries in the muscular layers. The circular coat receives, in addition, numerous branches directly from a plexus lying between the tela submucosa and the tunica muscularis.

All the veins leave the stomach in company with the arteries.

The lymphatics of the stomach begin as comparatively

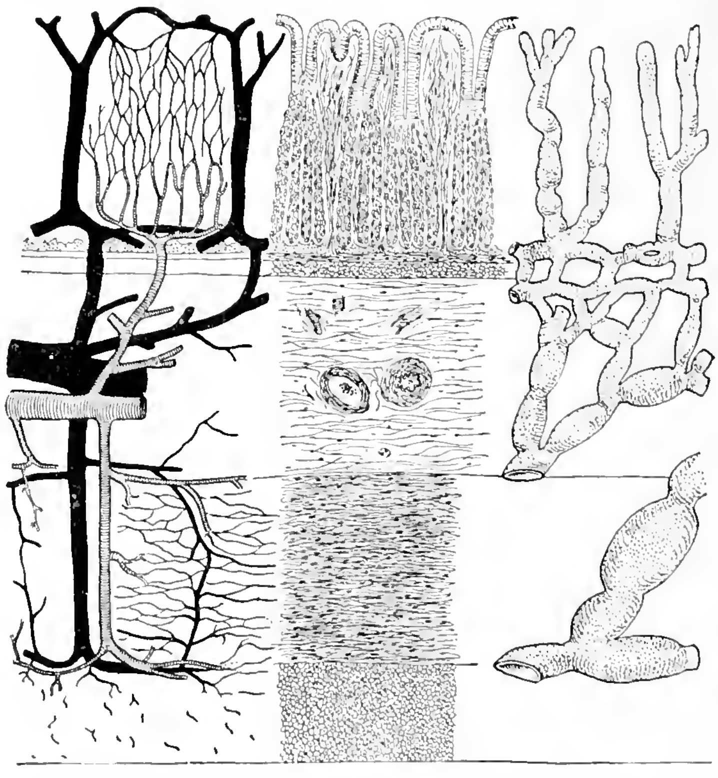


FIG. 4513. Three Sections of the Stomach Wall of the Dog, Placed Side by Side to show the Situation of the Blood and Lymph Vessels in the Different Tunics. × 70. Veins black; arteries striated; lymphatics dotted. (From A. Oppel, '96, after F. P. Mall.)

wide, blind, capillary tubes beneath the epithelium of the stomach. These pass somewhat irregularly outward and join to form larger trunks, which communicate with a fine network of lymphatic vessels located in the mucous membrane between the lamina muscularis mucosæ and the bases of the glands. This plexus (plexus mucosus) in turn communicates by means of vessels which pass at right angles through the lamina muscularis mucosæ with a second plexus located in the inner part of the tela submucosa. This plexus is composed of large vessels with many valves. From it arise many irregular branches which anastomose and pass through the substance of the submucosa to join the large collecting branches. The latter, in turn, communicate by large branches which pass through the circular muscle with the intermuscular plexus, the large vessels of which run toward the lesser curvature. For further details as to the arrangement of the large lymphatic vessels of the stomach, see the article on the *Lymphatic System*.

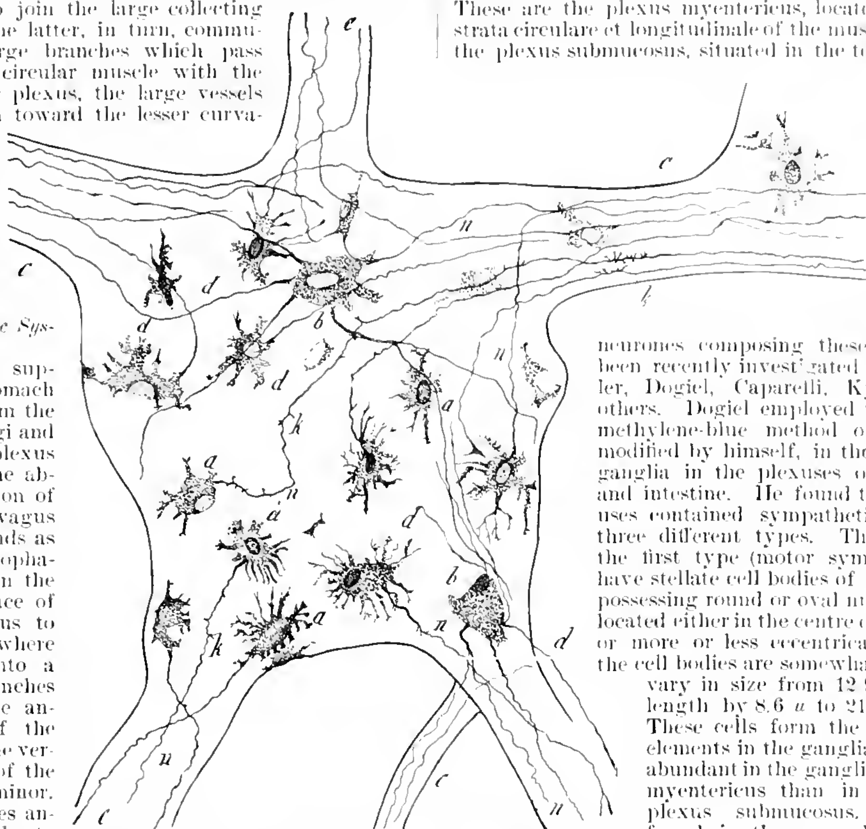


FIG. 4514.—Ganglion from the Plexus Myentericus of the Small Intestine of Man. *a*, Cell bodies of neurones of the first type (sympathetic motor neurones); *b*, neurones of the second type; *c*, nerve bundle. (After A. S. Dogiel, '99.)

The nerve supply of the stomach is derived from the two nervi vagi and from the plexus cœliacus. The abdominal portion of the nervus vagus sinister descends as the chorda œsophagea anterior on the anterior surface of the œsophagus to the stomach, where it divides into a group of branches located on the anterior face of the viscus, near the vertical portion of the curvatura minor. These branches anastomose freely to form the plexus gastricus anterior. From this plexus come off branches which radiate over the anterior face of the stomach. These branches run in the tunica serosa for a longer or shorter distance, but finally penetrate the muscular coats to terminate in the intrinsic plexuses of the organ. The right vagus goes in large part to the ganglion semilunare dextrum, but contributes some branches to the plexus gastricus posterior, distributed on the posterior face of the organ.

The sympathetic nerve supply is derived from the plexus cœliacus by means of fibres which accompany the several branches of the arteria cœliaca. The plexus gastricus superior accompanies the arteria gastrica sinistra, but also receives communicating branches from the right vagus, and from the plexus hepaticus, which reach the stomach in company with the arteria gastrica dextra. Some of the branches of the anterior gastricæ plexus accompany the rami œsophagei of the left gastric artery to the cardia; others descend upon the anterior and posterior surfaces of the stomach beneath the peritoneum, anastomosing on the left with the branches of the plexus lienalis which accompany the arteriæ gastricæ breves to the fundus, on the right with the branches of the plexus hepaticus which accompany the arteria gastrica dextra. Additional fibres from the hepatic and splenic plexuses accompany the arteriæ gastroepiploicæ dextra et sinistra respectively and are distributed to the greater curvature. The nerve fibres from all these sources, after a longer or shorter course in the tunica serosa, penetrate the muscular coats and join the intrinsic nerve plexuses of the organ.

The stomach, like the intestine, contains two characteristic nervous plexuses formed of branching and anastomosing bundles of non-medullated nerve fibres, forming a fine network with ganglia at the nodal points. These are the plexus myentericus, located between the strata circulare et longitudinale of the muscular coat, and the plexus submucosus, situated in the tela submucosa. The former plexus furnishes the motor supply to the tunica muscularis, the latter supplies the lamina muscularis mucosæ.

The structure of the neurones composing these plexuses has been recently investigated by Cajal, Müller, Dogiel, Caparelli, Kytmanow, and others. Dogiel employed the *intra-vitam* methylene-blue method of Ehrlich, as modified by himself, in the study of the ganglia in the plexuses of the stomach and intestine. He found that these plexuses contained sympathetic neurones of three different types. The neurones of the first type (motor sympathetic cells) have stellate cell bodies of angular shape, possessing round or oval nuclei, which are located either in the centre of the cell body or more or less eccentrically. Many of the cell bodies are somewhat flattened and vary in size from 12.9μ to 34.4μ, in length by $8.6\ \mu$ to $21.5\ \mu$ in width. These cells form the most frequent elements in the ganglia, and are more abundant in the ganglia of the plexus myentericus than in those of the plexus submucosus. A few are found in the nerve bundles which connect the ganglia with one another. From each pole of the cell body come off four to six or ten to twenty short, wide, somewhat flattened dendrites which a short distance from the cell subdivide into several more or less flattened short branches, which in turn divide and subdivide in a similar manner. According to Dogiel the terminal branches of these dendrites anastomose directly with similar dendrites belonging to other neurones of the same character. This direct continuity is, however, denied by La Villa and von Kölliker, who maintain that the apparent anastomoses seen by Dogiel are superposed but independent dendrites. Each of these neurones possesses, according to Dogiel, a single axone, which arises commonly from the cell body itself, but sometimes from a dendrite, by means of a thick cone of origin. This axone is a thin, smooth, or slightly varicose filament which traverses a greater or less extent of the ganglion and enters one of the connecting nerve bundles through which it courses to a second or third ganglion, in some cases even returning to the ganglion in which it took its origin. From this axone come off numerous extremely fine collaterals which leave the plexus in the groups of fibres distributed to the muscle coat. Finally, these axones break up into several fine varicose fibres which also terminate in the muscular layers, of which they appear to form the motor supply.

The neurones of the second type have somewhat larger cell bodies than the foregoing, and occur in much smaller numbers. Each cell body contains a moderately large, round, or oval nucleus with one or two nucleoli. From the poles of the cell body come off from three or four to as high as six or ten dendrites, which have the appearance of moderately thick fibres, and which presently divide into several thin branches. The latter do not terminate within the ganglion as do the dendrites and neurones of the first type, but enter the connecting nerve bundles, whence, after frequent subdivision, they pass into those small nerve bundles which traverse the stratum circulare tunicæ muscularis to connect the plexus myentericus with the plexus submucosus. In the latter, according to Dogiel, these dendrites may be often followed for considerable distances, and may be seen to pass into the mucous membrane, where they form the plexus of nerves surrounding the glands. The axone of the neurone of the second type begins in a more or less thick hillock on the cell body or on one of the dendrites and has the form of a nodulated, long, slightly wavy fibre, from which numerous collaterals similar to but shorter than the dendrites come off. The mode of ending of these collaterals and of the axone itself Dogiel does not describe, except to point out that the latter may be traced into the connecting bundles of fibres to a second ganglion.

The neurones of the third type resemble in many respects those of the second type. The dendrites form a richly branching system of very fine threads, which, in their finer ramifications, may be distinguished with difficulty from axones. These fine branches form a very rich plexus within the ganglion in which the cell body is located. The axones from these cells pass out by a nerve bundle to a second ganglion or to several successive ganglia. Their ultimate fate is unknown.

Among the nerve fibres ending in the ganglia, Dogiel distinguishes two kinds, one of which he regards as of sympathetic, the other of cerebrospinal origin. The fibres of the first kind are extremely thin, smooth, or slightly varicose threads, which do not differ in any respect from the axones of the neurones of the ganglia of the plexus. These fibres enter a ganglion by a nerve bundle, describe a more or less tortuous course among the nerve cells of the ganglion, and break up on their way into much thinner varicose fibrils, which in turn subdivide into a number of extremely fine end fibrils, which are beset with numerous round and oval varicosities. These end fibrils form an extremely close, intercellular plexus within the ganglia, without coming into direct contact with the cell bodies, from which they are always separated by the capsular cells. The second kind of fibres is distinctly coarser than the preceding and exhibits large, round, and spindle-shaped varicosities. In some cases Dogiel was able to trace these fibres through the longitudinal muscle coat and to demonstrate their continuity with medullated fibres. These fibres enter a ganglion from one of the connecting nerve bundles and may, in favorable preparations, be traced a considerable distance through the ganglion. In its course through the ganglion it gives off two to six or more varicose collateral branches, and ultimately breaks up into several similar fibrils. Both the collateral and the terminal branches go to the cell bodies of the ganglia, penetrate the capsules, and terminate in a number of fine varicose fibrils around the cells.

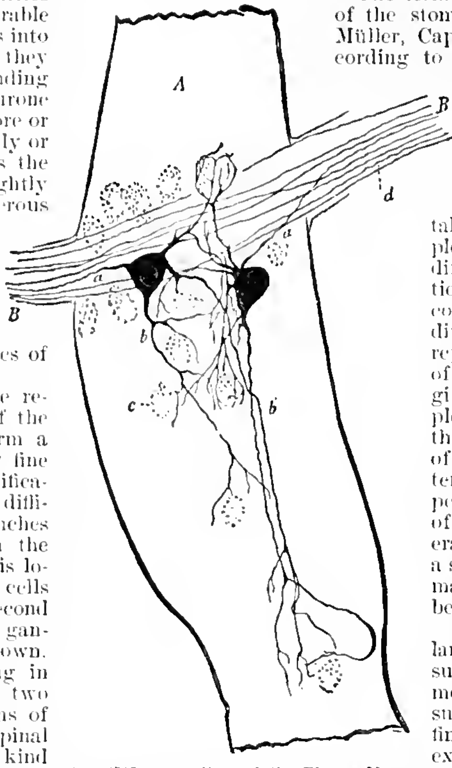


FIG. 4515.—Ganglion of the Plexus Myentericus of the Guinea-pig, showing the Cell Bodies of Neurones of Dogiel's Third Type. *a*, Axone; *b*, dendrites, some of which form a plexus around other cell bodies. (After A. S. Dogiel, '95.)

The stellate cells described by Cajal, Müller, and others, on the walls of the small blood-vessels and on the membrana propria of the glands, are regarded by Dogiel as connective-tissue cells.

As the foregoing description indicates, the exact relations of the nerve fibres which enter the stomach wall and of the axones and dendrites of the sympathetic neurones of the two principal plexuses, to the terminal organs in the walls of the stomach, are still doubtful, with the exception of the nerve supply to the muscle coats, which seems to be derived from the axones of the neurones of Dogiel's first type.

The terminations of the nerves in the walls of the stomach have been studied by Berkley, Müller, Caparelli, Kytmanow, and others. According to Müller, who employed the rapid Golgi method in the study of the nerves of the stomach and intestine, the muscular coats contain an extremely large number of nerve fibres, partly in the form of end fibres, partly as larger or smaller nerve bundles. These take their origin from branches of the plexus myentericus, which run in a direction at right angles to the direction of the muscle fibres. From these come off branches which follow the direction of the muscle fibres. The repeated subdivision and intercrossing of the branches of these nerve bundles give rise to a very fine intramuscular plexus of fibres. The termination of the fine terminal twigs takes the form of a group of branches, each of which terminates in a minute spherical or pear-shaped swelling on the surface of a muscle cell. There may be several of these swellings in the course of a single terminal nerve filament, which may thus supply successively a number of muscle fibres.

A plexus of fine nerve fibres, to a large extent derived from the plexus submucosus, exists in the mucous membrane. Cacciola distinguishes a subglandular plexus and a plexus of finer fibres surrounding the glands and extending as far as the free surface of the mucous membrane.

According to Müller the nerves terminate by free, often swollen extremities, under the cylindrical epithelium, or between the pointed proximal ends of the cells. Kytmanow, using the methylene-blue method, was able to trace the nerve terminations through the basement membrane into the glands, where they terminate by each dividing into a group of coarsely varicose filaments, which penetrate between the cells of the glands and lie in close contact with both the surfaces of the parietal and chief cells.

The stomach is developed as a spindle-shaped dilatation of the primary endodermal canal, which may be recognized in very early embryos. The stomach is at this early stage vertical and median in position. In embryos of 5 mm. length there is already an indication of the greater and lesser curvatures, and in the 12.5 mm. embryo these are well formed, the greater curvature being directed backward and slightly toward the left; the lesser curvature forward. Owing to the increase in length of the œsophagus and stomach, the latter has descended from its primary position above the septum transversum into the abdominal cavity. The stomach at this stage is connected with the abdominal walls both dorsally and ventrally by a double layer of mesoderm, forming the mesogastrium anterius and the mesogastrium posterius. The former extends from the septum transversum to the umbilicus and contains between its two layers the developing liver, of which it subsequently forms the tunica serosa. The portion of the mesogastrium anterius between the liver and the anterior abdominal walls forms the falciform ligament (ligamentum falciforme hepatis); that between the liver and the lesser curvature of the stomach becomes the lesser omentum. The final position of the stomach is reached by a gradual shifting of the upper end of the organ from its median position toward the left side, and a rotation of its axis in such a way that the primary right side of the stomach becomes the posterior face, the primary left side the anterior face; and the fundus of the stomach becomes directed to the left. During this process the mesogastrium posterius undergoes a more rapid development than is necessitated by the changing position, forming an elongated pouch, which hangs down ventral to the rest of the intestine, and forms the great omentum (omentum majus). The portion of the cœlom enclosed between the two layers of the elongated mesogastrium posterius becomes the lesser peritoneal sac, or bursa omentalis.

From the visceral layer of the mesoderm are developed the three outer layers of the wall of the stomach as well as the tissue of the lamina propria mucosæ. The epithelial elements of the stomach, including the gastric glands, are derived from the endoderm.

The development of the gastric glands has been investigated by Kölliker, Laskowsky, Brand, Toldt, Sewall, Salvioli, Ross, and others. On account of the difficulty of obtaining human material in a sufficiently good state of preparation, most of the work along this line has been done on the stomachs of lower mammals.

According to Toldt, the endodermal layer of the stomach in the cat embryo of 2.5 cm. body length is still composed of a single layer of small pyramidal or conical cells, the nuclei of which are placed at different levels. Of these he recognized two kinds: one of these has its broader end directed toward the inner surface of the stomach and contains a large oval nucleus near the free border; the other kind of cell has the broader base directed toward the attached side of the epithelium. Both of these cells extend through the whole thickness of the epithelium, which is thus unstratified, though he points out that in poorly preserved material the impression of stratification might easily be obtained. In somewhat older cat embryos, up to 5 cm., the condition is much the same, except for the greater number of cells of the second type mentioned above in the epithelium. In cat embryos from 5 cm. body length upward, the structure of the epithelium is modified by the appearance in it of the rudiment of the gastric glands. Concerning the formation of the latter two views exist. According to one group of observers, including Kölliker, Brand, and Sewall, the determining factor in the formation of the gastric glands is the irregular growth of the mesodermal stratum. This, according to Brand, is accomplished by the growth of villus-like processes covered with epithelium. By the coalescence of the bases of these villi shallow pits are formed which are the rudiments of the glands. A similar description of the origin of the glands is given by Sewall, except that he describes the gland processes as short ridges instead of villi. According to Toldt and Ross, the formation of villi has nothing to do with the development of the glands, which they regard as wholly intra-epithelial in origin. Toldt recognized the rudiments of the glands in cat embryos of from 5.3 to 6.8 cm. body length in the form of single scattered cells of spherical or ellipsoidal shape located between the bases of the cylindrical cells, which at this stage make up the gastric epithelium. In addition to their characteristic location, these cells are distinguished from the other cells by their coarsely granulated protoplasm and greater opacity. In places several such cells could be seen so grouped together as to leave little doubt that they had arisen by division of the single isolated cell. Such groups often contained a minute circular vacuole-like space, the future lumen of the gland. This group of cells assumes gradually, by increase of its elements, an elongated shape, and an opening to the surface is obtained by displacement of the overlapping cylindrical cells. The displacement of the bases of the latter by the growing gland rudiment causes the inner ends of the epithelial cells immediately surrounding the gland to converge toward the opening, forming in this way the first indication of the gastric foveola. The further development of the glands consists in the increase in length and number of the gland tubules and the differentiation of their specific glandular elements. The increase in length of the glands soon causes them to project beyond the epithelial layer into the subjacent mesoderm. The increase in number of the glands in the course of development is accomplished in part by the formation of new glands in the epithelium, in part by the branching and subdivision of those already existing.

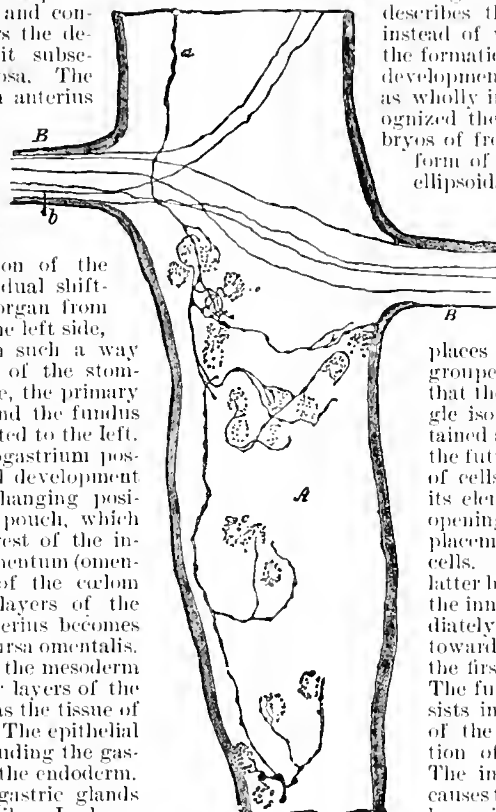


FIG. 4516.—*a*, Nerve fibres of Dogiel's second type which end in a ganglion of the plexus myentericus (guinea-pig) in pericellular groups of branches; *A*, ganglion; *B*, nerve bundle. (After A. S. Dogiel, '95.)

The differentiation of the specific cellular elements of the glands occurs, according to Toldt, at a somewhat late stage of development. In cat embryos of 13-14 cm. body length—that is, shortly before birth—he found the majority of cells forming the glands still undifferentiated. In the deeper part of the glands, however, a few larger richly granular parietal cells could be seen.

The recent account of the development of the gastric glands, given by Ross, practically confirms Toldt's observations in all essential details. These two observers are agreed as to the non-participation of the villus-like ridges of the developing stomach in the formation of the glands.

R. R. Bensley.

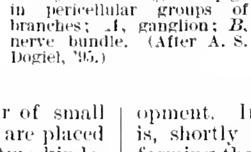


FIG. 4517. *A*, An isolated chief cell of the fundus gland of the cat showing the termination of a nerve fibre in a group of branches around the cell; *B*, a parietal cell of the same animal; vital methylene-blue staining. (After K. A. Kytmanow, '96.)

REFERENCES ON THE STRUCTURE OF THE STOMACH.

Bensley, R. R.: The Structure of the Mammalian Gastric Glands. Quart. Journ. Micr. Soc., London, N. S., vol. xli., 1898, pp. 361-389.—The Cardiac Glands of Mammals. Amer. Journ. Anat., Baltimore, vol. ii., 1902, pp. 105-156.

Berkley, H. J.: The Nerves and Nerve Endings of the Mucous Layer of the Ileum as shown by the Rapid Golgi Method. Anat. Anz., Jena, vol. viii., 1893, pp. 12-19.

Birmingham, A.: The Arrangement of the Muscular Fibres of the Stomach. Journ. Anat. and Physiol., London, vol. xxxiii., 1899, pp. 22-30.

Bizzozero, G.: Ueber die schlauchförmigen Drüsen des Magendarm-kanals und die Beziehungen ihres Epithels zu dem Oberflächenepithel der Schleimhaut. Arch. f. mikr. Anat., Bonn, vol. xlii., 1893, pp. 82-152.

Boeckelman, W. A.: Untersuchungen zur pathologischen Anatomie des menschlichen Magens in Fällen von Ileus und Carcinoma bei bekannter chemischen und motorischen Funktion. Ztschr. f. klin. Med., Berlin, vol. xliv., 1902, pp. 128 *et seq.*

Brand, E.: Beiträge zur Entwickelung der Magen- und Darmwand. Inaug. Dissert., Würzburg, 1877.

Cade, A.: Études de la constitution histologique normale et de quelques variations fonctionnelles et expérimentelles des éléments sécréteurs des glandes gastriques du fond. Arch. d'anat. micr., Paris, vol. iv., 1901, pp. 1–86.

Cacciola, S.: Sulla distribuzione dei nervi dello strato glandulare della mucosa dello stomaco, con. 3 fig. Quattro Casi di Neoplasma ec. Padova, Proserpini, 1886.

Capparelli, A.: Die nervösen Endigungen in der Magenschleimhaut. Biol. Centralbl., Leipzig, vol. xi., 1891, pp. 27–30.

Carlier, E. W.: Changes that Occur in Some Cells of the Newt's Stomach during Digestion. Cellule, Lierre and Louvain, vol. xvi., 1899, pp. 403–461.

Dogiel, A. S.: Zur Frage über die Ganglien der Darmgeflechte bei den Säugethieren. Anat. Anz., Jena, vol. x., 1895, pp. 517–524. Ueber den Bau der Ganglien in den Geflechten des Darmes und der Gallenblase des Menschen und der Säugethiere. Arch. f. Anat. u. Physiol., Leipzig, Anat. Abth., Jahrg., 1899, pp. 130–158.

Ebstein, W.: Beiträge zur Lehre vom Bau und von (?) den physiologischen Funktionen der sogenannten Magenschleimdrüsen. Arch. f. mikr. Anat., Bonn, vol. vi., 1870, pp. 515 *et seq.*

Edelmann, R.: Vergleichend anatomische und physiologische Untersuchungen über eine besondere Region der Magenschleimhaut (Cardiadrüsenregion) bei den Säugethieren. Deutsche Ztschr. f. Thiermed., Leipzig, vol. xv., 1889–90, pp. 165–214.

Einhorn, M.: A Further Contribution to Our Knowledge of the Histology of the Gastric Mucosa in Pathological Conditions of this Organ. Am. Journ. Med. Sci., Philadelphia, 1902, pp. 1–19.

Härt, P.: Ueber das normale Oberflächen-Epithel des Magens und über Vorkommen von Randsaumepithelien und Becherzellen in der menschlichen Magenschleimhaut. Arch. f. mikr. Anat., Bonn, vol. lviii., 1901, pp. 685–726.

Heidenhain, R.: Untersuchungen über den Bau der Labdrüsen. Arch. f. mikr. Anat., Bonn, vol. vi., 1870, pp. 368–406.—Ueber die Pepsinbildung in den Pylorusdrüsen. Arch. f. d. ges. Physiol., Bonn, vol. xviii., 1878, pp. 169–71.

Hemmeter, J. C.: Ueber die Histologie der Magendrüsen. Arch. f. Verdauungskr., Berlin, vol. iv., 1898, p. 23.

His, W.: Anatomie menschlicher Embryonen. I. Embryonen des ersten Monats., Leipzig, 1880.

Kölliker, A. von: Mikroskopische Anatomie, ii. Bd. Spezielle Gewebelehre, Leipzig, 1. Hälfte, 1850, 2. Hälfte, 1854.

Kupffer, C.: Epithel und Drüsen des menschlichen Magens. Festsch. d. aerztl. Ver. München, etc., 1883, pp. 27–46.

Langley, J. N.: On the Changes in Pepsin-Forming Glands during Secretion. Journ. Physiol., London, vol. ii., 1879–80, pp. 281–301. On the Histology of the Mammalian Gastric Glands and the Relation of Pepsin to the Granules of the Chief Cells. Journ. Physiol., London, vol. iii., 1880–82, pp. 269–291.

Laskowsky: Ueber die Entwickelung der Magenwand. Sitzungsb. d. k. Akad. d. Wissensch., Math.-Naturw. Cl., Bd. lviii., Wien, 1868, 2. Abth., pp. 137–143.

Macallum, A. B.: On the Distribution of Assimilated Iron Compounds, Other than Haemoglobin and Haematins, in Animal and Vegetable Cells. Quart. Journ. Micr. Soc., London, vol. xxxviii., N. S., 1895, pp. 175–274. On the Detection and Localization of Phosphorus in Animal and Vegetable Tissues. Proc. Roy. Soc., London, vol. lxiii., 1898, pp. 467–479.

Mall, F. P.: The Vessels and Walls of the Dog's Stomach. Johns Hopkins Hospital Reports, Baltimore, vol. i., pp. 1–36.

Mayer, P.: Ueber Schleimfärbung. Mitth. a. d. Zool. Station zu Neapel, Leipzig, vol. xii., 1897, pp. 303–330.

Müller, E.: Zur Kenntniss der Labdrüsen der Magenschleimhaut. Biol. Fören. Forhandl., Verhandl. d. biol. Ver. in Stockholm, vol. iv., 1892, No. 8, 10 pp. Zur Kenntniss der Ausbreitung und Endigungsweise der Magen-, Darm- und Pankreasnerven. Arch. f. mikr. Anat., Bonn, vol. xl., 1892, pp. 390–408.

Negrini, F.: Intorno allo sviluppo e struttura della mucosa gastrica del majale. Gior. di anat. fisiol. e patol. d. animali, Pisa, vol. xviii., 1886, pp. 121–148.

Oppel, A.: Lehrbuch der vergleichenden mikrokopischen Anatomie der Wirbelthiere. Theil I., Der Magen, Jena, 1896.

Ramón y Cajal, S.: Sur les ganglions et plexus nerveux de l'intestin. Compt. rend. d. Soc. de biol., Paris, Serie 9, vol. v., 1892–93.

Ross, M. J.: The Origin and Development of the Gastric Glands of Desmognathus, Amblystoma and Pig. Biol. Bull., Lancaster, vol. iv., 1893, pp. 66–95.

Rollett, A.: Ueber die blinddarmförmigen Drüsen des Magens. Med. Centralbl., Nos. 21 and 22, pp. 325 and 337.

Salvioli, Dr.: Quelques observations sur le mode de formation et d'accroissement des glandes de l'estomac. Internat. Monatschr. f. Anat. u. Physiol., Leipzig, vol. vii., 1890, pp. 71–80.

Sewall, H.: The Development and Regeneration of the Gastric Glandular Epithelium during Foetal Life and after Birth. Journ. Physiol., London, vol. i., 1879, pp. 321–334.

Solger, B.: Ueber den feineren Bau der Glandula submaxillaris des Menschen mit besonderer Berücksichtigung der Drüsengranula. Festschr. z. 70. Geburtstag Carl Gegenbaur, vol. ii., 1896, pp. 179–218.

Stöhr, P.: Zur Kenntniss des feineren Baues der menschlichen Magenschleimhaut. Arch. f. mikr. Anat., Bonn, vol. xx., 1882, pp. 221–245.

Théohari, A.: Étude sur la structure fine des cellules principales de bordure et pyloriques de l'estomac à l'état de repos et à l'état d'activité sécrétoire. Arch. d'anat. micr., Paris, vol. iii., 1899, pp. 11–34.

Toldt, C.: Die Entwickelung und Ausbildung der Drüsen des Magens. Sitzungsb. d. k. Akad. d. Wissensch. Math.-Naturw. Cl., vol. lxxxii., Wien, 1880, Abth. iii., pp. 57–128.

La Villa, S.: Estructura de los ganglios intestinales. Rev. trimest. microg., Madrid, vol. ii., 1897, fasc. 3 and 4.

Zimmermann, K. W.: Beiträge zur Kenntniss einiger Drüsen und Epithelien. Arch. f. mikr. Anat., Bonn, vol. iii., 1898, pp. 546–551.

STOMACH AND ŒSOPHAGUS. (SURGICAL.)—I. THE SURGERY OF THE ŒSOPHAGUS.—*Methods of Examination.*—The *x* rays are very useful in locating bone; also coins and other metallic foreign bodies. It is usually best to take a skiagraph, in order to determine the exact relations of the foreign body. The fluoroscope is occasionally very useful, and the surgeon may sometimes even attempt to extract the foreign body with forceps while he looks through the fluoroscope. An œsophageal diverticulum may be shown by the *x*-rays, if the patient has previously swallowed capsules of subnitrate of bismuth. If the bismuth enters the diverticulum, it will coat it so that the pouch will cast a shadow in the *x*-rays. A bougie containing a piece of metal on a small metallic chain may, in some cases, enter the diverticulum and cast a shadow with the *x*-rays.

The most common method of examining the œsophagus is with the exploratory sound. A flexible bougie with an ivory tip will locate an obstruction, whether it be a foreign body or a stricture. In an adult, it is best to make an examination of this kind without ether. If ether is not employed, we can keep the patient sitting up; and he can help us by swallowing the instrument when directed to do so, and can also aid us somewhat in locating the obstruction. In a child, it may be necessary to give an anæsthetic. The bougie should be passed as follows, when the patient is not anæsthetized:

He sits up and rests his head against a chair-back, a bed-rest, or the chest of another person. The surgeon stands in front of him. The patient's head is thrown back and held securely by an assistant. When the patient is a child, it will be necessary to hold the arms also. The mouth may be gagged open with a bit of wood or a cork, but I usually dispense with a gag and simply wrap the forefinger which is to be inserted with some gauze. The instrument is warmed and smeared with glycerin, and is passed into the rear of the pharynx, the surgeon drawing the tongue forward and holding it with a towel. Drawing the tongue forward draws the larynx a little forward also, and enables the instrument to pass more readily over the glottis. In some cases it is necessary to guide it over with the index finger of the left hand.

As soon as the instrument strikes the back of the pharynx, the patient will attempt to vomit; but the slight respiratory obstruction met with here should not deter one, although, of course, if there is violent respiratory difficulty the instrument must be at once withdrawn, because of the fear that it may have entered into the larynx. After it strikes the back of the pharynx it should be pushed on steadily but lightly, and the patient should be directed to swallow. The passage of the instrument will thus be greatly aided. When the instrument is blocked by an obstruction, one must not attempt to force it, but should hold it gently in contact with the obstruction. If this is only spasmodic, the spasm may relax and let the instrument pass. If the obstruction is organic, it will not relax. We should always remember, however, that an organic stricture may be associated with a spasm above it, and therefore that we may be blocked by spasm before reaching the true seat of disease. If we are in doubt as to whether we are dealing with a pure spasm or with an organic stricture, the administration of an anæsthetic will solve the doubt; for a pure spasm relaxes when the patient is anæsthetized, so that the instrument is allowed to pass, but an organic stricture does not relax. The average distance from the incisor teeth to the cardiac opening of the stomach in the adult is, according to Maylard, from fourteen to sixteen inches.

The *œsophagoscope* (Fig. 4518) has been used for many years by Mikulicz, but it is only of late that its real value has become recognized by the profession at large. In fact, in this country the appreciation of this seems to date from the visit of Gottstein, Mikulicz's assistant, about a year ago. The œsophagoscope is undoubtedly a useful instrument. With its aid one may see a tumor, an ulcer, a foreign body, varicose veins, or a strictured area; and may remove in some cases a foreign body and in others a tumor for examination. Of course, in order to use the instrument well a man must be specially trained, and good results can be obtained only by an expert; but the same assertion is true of the use of the ophthalmoscope, the laryngoscope, and the cystoscope. Any one can learn to use the œsophagoscope, but only an expert will use it really well. One great lesson in its use is to be very gentle and never to force it, and, if it is obstructed by spasm, to wait for the spasm to subside before urging it onward.

When one has decided to use this instrument, he should first employ a sound to locate the situation of the obstruction. The pharynx, the larynx, and the upper part of the œsophagus are then cocainized with a ten-per-cent. solution of cocaine. The patient lies upon the table, on his right side, the clothing about his neck and his chest being loosened. His head rests upon a pillow, being bent back so far that a straight line through the mouth would enter into the œsophagus. He is told to raise his left hand if he feels pain and wishes the instrument withdrawn, and he is ordered to breathe quietly and regularly. Then the tongue is drawn forward and the tube is introduced into one side of the mouth and carried into the pharynx. As the patient swallows, the instrument passes down to the desired point. Then the plunger is withdrawn and the panelectroscope is inserted, throwing light to the bottom of the tube. Any mucus present is swabbed away with pieces of gauze caught in forceps; the region of disease is carefully studied, and, if thought desirable, a piece of tumor is removed. A note on the use of this instrument may be found in *American Medicine*, October 25th, 1902, in the editorial comment on general surgery; and the instrument is fully described by Gottstein in his "Technik u. Klinik der Oesophagoscopie."

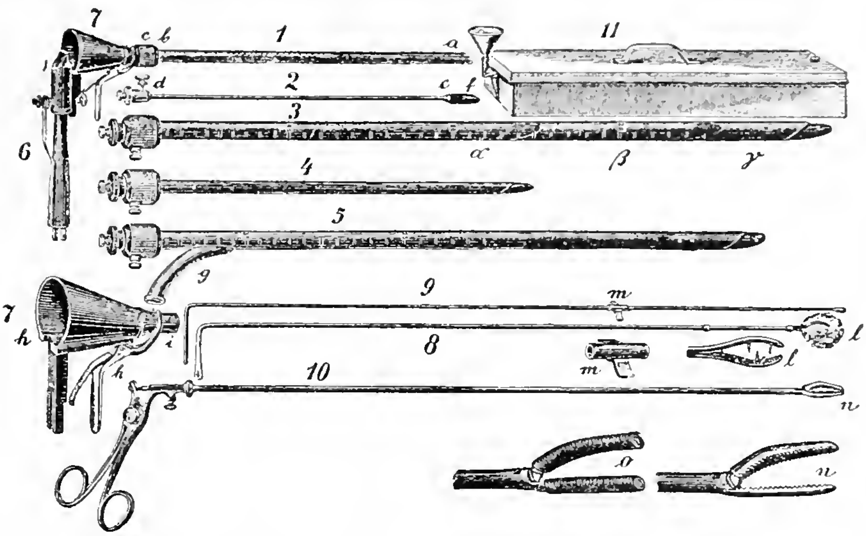


FIG. 4518.—Gottstein's Œsophagoscope. *1*, Œsophageal tube with oblique end (*a*), with hard-rubber ring (*b*), with bayonet catch (*c*); *2*, mandrel for the tube with screw at the upper end (*d*), fitting into the bayonet catch, and a hard-rubber olive point at the lower end (*e*), bevelled on the side (*f*); *3*, œsophageal tubes of different lengths (26, 36, and 46 cm.) and 14 mm. in diameter; *4*, children's size of tubes, 10 mm. in diameter; *5*, tubes with outflow tube (*g*) at the upper end; *6*, Casper's panelectroscope; *7*, the intermediate piece between the tube and the panelectroscope—external end (*h*), internal end (*i*), handle for detaching it from the tube (*k*); *8*, sponge-bearer with double teeth (*l*); *9*, sound with a rider (*m*); *10*, forceps with rough jaws (*n*), or covered with rubber (*o*); *11*, hot-water pan.

OPERATIONS ON THE ŒSOPHAGUS.

Internal Œsophagotomy.—By this operation one divides a fibrous stricture. The method of performing it is to pass an instrument known as an œsophagotome. In order that this may be passed, the channel of the stricture must be large enough to admit the instrument. After the latter has passed through the stricture, the blade is protruded and the instrument is withdrawn. From forty-eight to seventy-two hours after the operation, the surgeon begins to effect distention by means of bougies. Gussenbauer performs internal œsophagotomy by making an opening in the œsophagus above the stricture, and then, through this opening, cutting the stricture by means of a tenotome. Internal œsophagotomy may be productive of dangerously severe hemorrhage and is occasionally followed by infective processes—for instance, by empyema. It should never be attempted for malignant obstruction.

Electrolysis.—Electrolysis has been much improved by Fort and others. It should not be used for malignant obstruction, but may be of great benefit in cicatricial stricture. It will fail, however, if the stricture is very hard. It is probable that several applications will be necessary in most cases, after which bougies should be used for a considerable length of time.

External Œsophagotomy.—External œsophagotomy may be performed through the neck by what is known as cervical external œsophagotomy; or it may be performed through the mediastinum—the intramediastinal method. External œsophagotomy may be done for the purpose of treating a cicatricial stricture of the œsophagus, either directly—as in Gussenbauer's method—or indirectly—as in Abbe's string-saw method. It may also itself directly divide a stricture. The chief use of the operation, however, is to remove foreign bodies, when these are lodged above the lower third of the œsophagus. If the foreign body has been in the œsophagus over twelve hours and has sharp edges, attempts to extract it through the mouth should not be made, but external œsophagotomy should be performed at once.

The incision is usually made on the left side, the cut being at the anterior edge of the sterno-cleido-mastoid muscle, and running from half an inch above the sterno-clavicular joint to the level of the superior border of the thyroid cartilage. The muscles are retracted, in some cases the omohyoid is divided, the trachea is drawn forward, great care is taken to avoid the recurrent laryngeal nerve, and the gullet is exposed. If a foreign body is palpable, the incision is made upon it; otherwise a bougie is introduced, and the gullet is opened upon that.

After the foreign body has been removed, there is a question as to how the wound should be managed. It seems certain that it should not be closed without any drainage. In fact, some surgeons do not close it at all, but simply pack it with gauze. It is wiser to suture the mucous membrane with stitches of silk or chromicized catgut, to run a piece of gauze down to the suture line for drainage, and then to suture the muscles and the skin, the gauze drain being removed within two or three days.

For the first twenty-four hours after the operation the patient is given no food by the mouth, but is fed by the rectum; and rectal feeding is continued as a supplement to mouth feeding until sufficient food can be taken by the mouth to meet the needs of the organism. After twenty-four hours small amounts of liquid may be given by the mouth, and more and more should be given each day until the full quantity can be taken. Frequently there is a little leaking through the mucous membrane.

FIG. 4519. — Coin-Catcher and Sponge probang.

Intramediastinal Œsophagotomy.—Weir, Quenu, Rehn, and others have given much thought to the matter of reaching dense strictures below the arch of the aorta. Rehn endeavored to reach such a stricture by a posterior operation, but he found the difficulties and dangers to be insurmountable. He made an incision over the angles of the ribs, between the inner edge of the scapula and the spines of the vertebræ, resected parts of several ribs, separated the pleura, and felt for the œsophagus. At the present time the operation does not seem justifiable.

Œsophagostomy.—In this operation the œsophagus is exposed and opened as in cervical œsophagotomy, but the edges of the œsophageal opening are sutured to the skin. A tube, somewhat resembling a tracheotomy tube, is inserted and tied in place; and when one desires to feed the patient, a long tube of less diameter than the retained tube is passed through the latter into the œsophagus.

Excision of Diverticula.—I have never performed this operation, but have assisted Professor Hearn to perform it. Whenever possible, a bougie should be carried into the sac. Then ether should be given, and the sac exposed and tied off with a catgut ligature. The sac is extirpated beyond this ligature and the stump is sutured. In Dr. Hearn's case the diverticulum was cut off, the mucous membrane was sewed with a continuous suture of catgut, the muscular layer was closed with interrupted sutures of silk, a piece of gauze packing was carried down to the mucous membrane, and the other tissues were sewed with silkworm gut. No leaking took place, and the wound completely healed within twelve days. Several other cases have been reported.

Œsophagectomy.—By this term is meant the resection of a portion of the œsophagus. In the cervical operation an incision is made in the neck to expose the œsophagus, and this incision is identical with that for internal œsophagotomy. After the gullet has been exposed, it is separated completely from the surrounding parts, the diseased area is excised, and the lower end of the gullet is sutured to the skin. This is a very difficult operation, and is of questionable utility.

De Quervain has performed this operation in one case, and has collected thirteen other cases from literature. He maintains that the operation is justifiable in some cases, viz., those in which there is malignant disease involving the œsophagus only, and in which the lower margin of the growth is above the aorta and the upper margin is at least 20 cm. from the teeth.

Occasionally, though rarely, a preliminary œsophagostomy may be performed, but preliminary gastrostomy is much to be preferred to preliminary œsophagostomy. When a preliminary gastrostomy is performed, healing of the œsophagus is greatly favored. When preliminary gastrostomy has been performed, and œsophagectomy is carried out whenever it is possible, the upper end of the lower part of the gullet should be sutured to the wound; but if this cannot be done, a ligature should be tied about that part of the œsophagus, and it should then be dropped back into the wound.

This author maintains that the patient is much better off with a gastric fistula than with a contracting cicatrix of the gullet, which will be sure to establish itself if the ends are brought together. In cases in which the ends cannot be brought together, there will, of course, be a salivary fistula from the upper end of the œsophagus (*Arch. f. klin. Chir.*, 1898, Bd. lxviii., Hefte 1-4). By some surgeons an attempt has been made to extirpate the œsophagus by what is called endothoracic resection; but at the present time the operation is not to be recommended.

Œsophagoplasty.—After a portion of the œsophagus has been resected for cancer, an attempt may be made to reconstitute the canal by von Hacker's method of œsophagoplasty. Maylard describes this operation as follows: "The operation is performed in two stages. After excision of the part, two flaps of skin are raised on each side. These are carried backward and united above and below to the cut ends of the œsophagus. This constitutes the first stage. The second consists in detaching these flaps from their bases and folding them over, so as to complete the canal. The stitching is completed around the œsophagus, above and below, and they are united together down the median line" ("The Surgery of the Alimentary Canal," by A. Ernest Maylard).

Foreign Bodies in the Œsophagus.—When a foreign body has passed into the œsophagus, the surgeon should endeavor to obtain information as to its size, its nature, its shape, and its weight; and he should then seek to locate its point of lodgment. The point at which a bone or a metallic body has lodged may be determined by using the *x*-rays; the location of other kinds of foreign bodies by using the œsophageal sound; and the position of both classes of articles by using the œsophagoscope. In employing the sound it may be necessary to give ether; this is seldom required for an adult, but usually for a child, a nervous woman, or a lunatic.

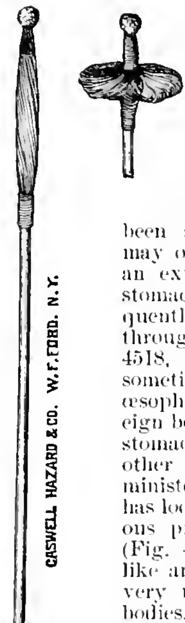


FIG. 4520.—The Bristle or Umbrella Probang.

When a soft foreign body has been swallowed, external manipulation may occasionally alter its shape to such an extent that it will pass on into the stomach or be coughed up. Not infrequently the foreign body may be reached through the mouth with forceps (Fig. 4518, 10), and these manipulations are sometimes much aided by employing the œsophagoscope. Small and sharp foreign bodies may often be carried into the stomach by swallowing mush, bread, or other food of a similar nature. To administer an emetic when a foreign body has lodged in the œsophagus is a dangerous procedure. The horse-hair probang (Fig. 4520) is an instrument that opens like an umbrella as it is withdrawn; it is very useful in extracting some foreign bodies. The coin-catcher (Fig. 4519) is also a very useful instrument. Occasionally, when it is impossible to pull a foreign body up through the mouth, it is advisable to push it down into the stomach. This may be done with such a body as a small coin that, we feel sure, will ultimately pass through the intestinal canal.

It is never proper to permit a foreign body to remain in the œsophagus until ulceration occurs; neither is it right greatly to prolong efforts to extract a foreign body through the mouth, and such efforts should not be made at all if ulceration is believed to exist. When a patient has a foreign body lodged in the œsophagus, and there is no ulceration, the surgeon should make one careful and thorough attempt to remove it through the mouth; and if this attempt fails, he should at once proceed to operate. If he thinks that ulceration exists he should operate. Long retention means probable ulceration.

If the point of lodgment is anywhere within the upper two-thirds of the œsophagus, external œsophagotomy should be performed; if it is in the lower third, the stomach should be opened. Then either the foreign body

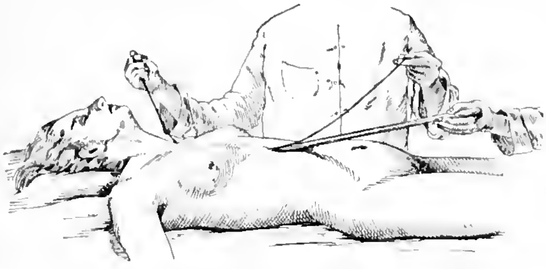


FIG. 4521.—Abbe's String-saw Operation. Method of using the bougie and string. (Abbe.)

should be drawn down into the stomach and thus removed, or else a whalebone bougie should be passed from the mouth into the stomach, a string should be tied to the bougie, and pieces of fluffed-up gauze should be fastened to the string. As the string is pulled, the foreign body is extracted. If the bougie cannot be passed from the mouth into the stomach, it may perhaps be carried from the stomach into the mouth.

Cicatricial Stricture of the Œsophagus.—In almost every case—at least for a certain length of time—gradual dilatation is employed, the largest bougie that will readily pass being used. The bougies with olive-shaped tips are not used, but the conical semisolid elastic instruments are employed. The bougie should be retained for several minutes and should be passed every second or third day. Each time it is passed it should be retained in the stricture longer than on the preceding occasion. As soon as it is found that the instrument begins to pass easily, a larger one should be employed. Gradual dilatation will be successful only if the stricture occupies a limited portion of the œsophagus.

Symonds inserts a tube through the stricture, leaves this in place until it becomes loose, then inserts a larger tube, and so on, the patient being fed through the retained tube. In some cases, when gradual dilatation from above is impossible, a gastric fistula is made, the patient swallows a shot to which a silk thread is fastened, the thread is brought out through the fistulous opening in the stomach and fastened to a bougie, and the dilating instrument is drawn up through the œsophagus.

I have already pointed out that a cicatricial stricture of the œsophagus is often associated with swelling and spasm, and that if a gastrostomy is performed the swelling and spasm abate, because of rest. In this way a stricture previously impassable may become passable. Some surgeons have employed forcible dilatation by way of the mouth or through an opening in the stomach. Electrolysis is used by Fort and some others.

We have already discussed the operations of internal and external œsophagotomy. If there is a dense stricture in the thoracic portion of the œsophagus, and this stricture is not dilatable, one should treat it by Abbe's method. Abbe performs gastrotomy, passes a conical rubber bougie carrying a silk thread from the stomach into the mouth. The end of the string is grasped and withdrawn, the stricture is made tense by introducing a conical bougie from below, and the string is drawn tight. One end of the silk emerges from the mouth and is carried back into the pharynx, and the other end comes out of the opening in the stomach. The string is moved rapidly to and fro and divides the stricture. After the division of the stricture, the silk is withdrawn and full-sized bougies are passed. In some cases Abbe opens the stomach and also the œsophagus above the stricture, and brings one end of the string out of each wound (Figs. 4521 and 4522).

Ochsner has devised an operation in which he draws a small, soft-rubber drainage tube, caught up in the middle with a thread, through the stomach wound and into the stricture. When traction is made upon this tube it becomes smaller; and it is made smaller by traction until its size is sufficiently diminished to allow it to enter the strictured portion of the œsophagus. The tube is drawn out by its free ends, and increasing sizes of tubes are employed.

Carcinoma of the Œsophagus.—This disease is necessarily fatal. Operations done for it are really only palliative, as œsophagectomy is not a satisfactory procedure. The patient is given a soft, bland diet, in small quantities at a time and very often. When there begins to be distinct trouble in swallowing even this food, a soft bougie should be carefully passed every third or fourth day, or a Symonds tube should be inserted; or œsophagostomy may be performed below the growth, if this is possible, or gastrostomy should be done.

II. SURGERY OF THE STOMACH.—The operative surgery of the stomach is to a very great extent distinctly modern, although gastrotomy has now and then been performed from time immemorial, and gastrostomy was practised as long ago as the time of Sedillot. The direction of surgical thought toward operative possibilities in this region seems to have begun in 1875, when many experiments upon animals were made to show that resection of the stomach is a thoroughly possible operation. It was in 1876 that Gussenbauer and Winiwarter made a series of experiments upon dogs, and maintained that the surfaces of the stomach, when sewed together, have a tendency to heal by first intention, and, further, the very important fact that the mucous membrane near the wound is not digested by the gastric juice. They resected the stomachs of seven dogs, and, as Dr. Keen says in his Cartwright Lectures, showed that a partial resection may be successfully accomplished; that the resulting stricture does not interfere with the motor or secretory power of the stomach; and that pyloric resection does not permit of a too early escape of food into the intestine, or of the regurgitation of the intestinal fluids into the stomach. Kaiser and, shortly after, Gussenbauer performed gastrectomy upon dogs, and obtained better results than their predecessors because they employed antiseptic methods with more care (Arthur E. Barker).

These and numerous other experiments upon animals have not only indicated that extensive operations may be performed upon the stomach with the retention of life and the repair of damage, but have pointed the way to the various refinements of technique that are found to be such valuable accessories in securing a successful result. In this field of surgery the principles of Lister have secured a notable triumph.

The above-cited experiments gave a stimulus to human visceral surgery, and in 1877 Billroth successfully sutured

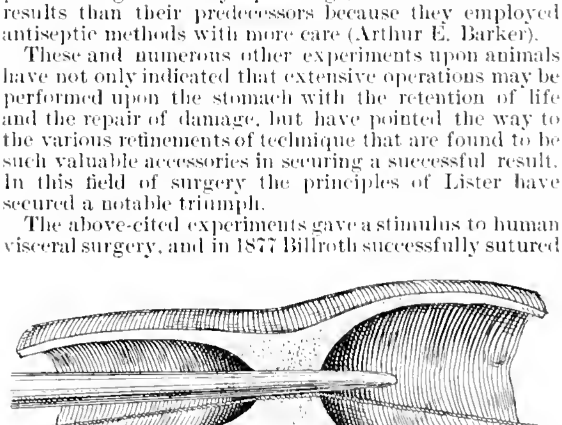


FIG. 4522.—Abbe's String-saw Operation. String dividing the œsophageal stricture kept tense by bougie. (Abbe.)

a wound in the stomach. From that time to this stomach operations have multiplied, until it is now considered proper to open the stomach, not only for the removal of foreign bodies or to secure ingress for food by a permanent artificial mouth when there is obstruction of the œsophagus or of the cardiac end of the stomach, but also to remove ulcerations, to separate constricting adhesions, to extirpate malignant tumors, to arrest hemorrhage, to side-track a malignant tumor or a fibrous constriction by the operation of gastro-enterostomy, to diminish the size of a distended stomach by placing numerous tucks in its wall, and even to remove the entire stomach—any of which operations may be done with the retention of life and digestive capacity. The number of cases of disease of the stomach in which operation is now performed is simply amazing, and may be especially gathered from a study of the reports of Professor Mikulicz, of Breslau; Professor Weir, of New York; Dr. Doyen, of Paris; Dr. Mayo, of Rochester, Minn.; Mr. A. W. Mayo Robson, of Leeds, England; Professor Keen, of Philadelphia; Prof. Arthur E. Barker, of London, and many others.

The surgery of the stomach may be presented to the reader in two ways: First, by describing in detail the different operations upon the stomach and setting forth the morbid conditions to which they should be applied; and, secondly, by discussing the surgical treatment of certain diseases of the stomach. In an article such as this, neither of these methods can be followed purely; it will be necessary first to discuss a number of the particular operations, and next to consider the surgical treatment of certain special conditions.

The operations to be considered are.

1. Gastrorrhaphy, or the suturing of a wound or a perforation in the stomach.

2. Gastrolysis, or the separating of perigastric adhesions.

3. Gastropexy, or the lifting of a stomach that has dropped downward, and the fastening of it in a normal position.

4. Gastroplication, or the diminution of the size of a dilated stomach by making tucks in its wall.

5. Gastrotomy, or incision of the stomach, followed by the subsequent closing of the wound.

6. Gastrostomy, or the making of a more or less permanent opening into the stomach—an opening that is usually employed for the purpose of administering food.

7. Gastro-enterostomy, or the making of a permanent opening between the stomach and the duodenum or the ileum.

8. Gastrogastrostomy, or the making of a permanent opening between two portions of the stomach itself, when there is a constriction existing between the two portions; and gastroplasty, an operation performed for the same purpose and similar to pyloroplasty.

9. Pyloroplasty, a procedure for enlarging the calibre of a strictured pylorus.

10. Gastrectomy, or the excising of the stomach wall—called partial gastrectomy when a portion of the wall is removed, and called complete gastrectomy when ablation of the entire stomach is practised.

11. Pylorectomy, or the excising of the pyloric end of the stomach and of the gastric end of the duodenum.

12. Jejunostomy, the making of a permanent fistula in the jejunum.

1. *Gastrorrhaphy.*—The term gastrorrhaphy should really be employed only to mean the suturing of a wound or perforation of the stomach wall. It has, however, been employed as synonymous with gastroplication, a usage of the term that is very objectionable.

A wound in the stomach is more easily managed and can be more firmly and securely closed than can a wound in the intestine. The blood supply, as Dr. Mayo points out, is excellent, and is derived from different sources; the mucous membrane of the stomach is thick. The stomach is fairly well fixed, the gastric juice is antagonistic to bacteria and the sutures can be firmly placed and are not apt to cut out. In doing this, it is necessary to bear in mind certain general principles:

The needle that is employed should be fine and round, and not one with a spear shaped or an edged point. A flat needle is very objectionable.

Fine sterile silk is the best suture material. Whereas it is permissible to use catgut to close the mucous membrane, it is not proper to use catgut to close the wound in the other coats. Strong gut is too large in diameter, it may be wiry and may cut when tied, it swells more or less after insertion, the stitch holes may leak, and it is of doubtful cleanliness; it is, therefore, an improper material.

Some surgeons advocate first closing the mucous membrane by means of a continuous suture of catgut. This method has its advantages. If this is done leakage in the suture line of the outer coats is prevented for many hours after the operation. Some have maintained that it is objectionable to use a mucous-membrane suture at all, because it may permit of infection of the coats beyond it and prevent the satisfactory drainage of an infected suture line. As a rule, it is satisfactory to close the stomach wound simply with inversion sutures of silk; but Halsted's plan is safer. Inversion sutures are caught in the submucous coat, but do not penetrate the mucous membrane. They should be about one-sixth of an inch apart; and when the ordinary Lembert stitches are used, it is advisable to employ from two to four layers of them, in order to secure an unleaking suture line. Whenever possible, these sutures should be introduced in the direction in which the blood-vessels run. Before tying them some surgeons scarify the peritoneal surface of the wound edges, believing that by so doing they expedite union. It is not necessary to trim the edges of a bullet wound or of a perforated ulcer, because the area of contusion or thrombosis can, in such cases, be deeply inverted and closely covered over.

The knots are tied firmly, but never tightly. To tie them tightly means either that there will be some cutting of the suture, or that there will be subsequent necrosis about the stitch hole, with loosening of the suture and probable infection. I believe that tying stitches too tightly is a most powerful predisposing cause of wound infection.

Interrupted sutures are better than the continuous suture; and the continuous inversion suture should not be used, except as a final stitch over previous layers of interrupted sutures. The continuous suture makes irregular lines of traction and unequal apposition of surfaces. If one part breaks or loosens, the whole suture line gapes, and there is much greater probability of leakage than when well-applied interrupted sutures are used.

Halsted's principle of suturing is the correct one; that is, that each stitch must catch up a portion of the fibrous submucous coat. The Halsted mattress sutures, when applied with care, will certainly approximate the margins of a stomach wound so that they will give broad surfaces for union, and will make such even pressure and give such thorough closure that even a single line of sutures is practically safe. Professor Halsted has employed the following method with great satisfaction for many years: When feasible he uses three rows of sutures. The inside row is continuous and includes the mucosa and submucosa and the edge of the serosa. The middle row is continuous, interrupted here and there. The outside row is made with mattress sutures. In other words, Halsted uses the Czerny suture with an outside row of mattress sutures. Halsted's method is the safest and hence the best. The various sutures that may be used upon the stomach will be found described in detail in the article on *Intestinal Surgery*. The chief of these are the Lembert suture, Cushing's right-angle suture, Gussenbauer's suture, Czerny's suture, Wölfler's suture, Bishop's suture, and Halsted's mattress suture.

When a gap in the stomach wall is too large to invert, or when, because of great thickness of the edges of the opening or of the existence of dense encompassing adhesions, the edges cannot be turned in, some other course must be followed. In some cases union has been secured by first suturing the mucous membrane and then the other layers of the stomach wall, just as we would suture an ordinary wound, without inversion. Another method, and a better one, is to use such a suture and then cover the suture line, after the plan of Senn, with a portion of omentum that is still left attached to the great mass of the omentum, or with a separate omental graft. In some cases an opening in the wall of the stomach has been successfully closed by sewing over it a graft of omentum, without suturing the opening at all or by pushing a piece of omentum through the opening, just as a cork is pushed into a bottle. If it is found impossible to close the wound in the stomach by any of these plans, then the wound must be surrounded by iodoform gauze, in order to protect the peritoneal cavity from infection; a drainage tube must be carried down to the opening, and a gastric fistula must be deliberately formed. At a later period this fistula will probably heal of itself; but if it does not do so, it can be closed by a plastic operation.

When a surgeon deals with a wound of the stomach, he should always be alive to the possible existence of a wound of the posterior wall; and, in order to determine whether or not such a wound exists, he should tear through the gastrocolic omentum and inspect the posterior wall. If a wound is found in this situation it should be sutured according to the ordinary rules. When there has been a wound of the posterior wall of the stomach the pancreas must be inspected to see if it has been injured, and it is usually advisable to make posterior drainage of the lesser peritoneal cavity.

After the operation of gastrorrhaphy a piece of gauze should be carried down to the suture line, and should be retained for at least twenty-four hours. Such a manœuvre never does any harm; it aids in the formation of adhesions that will eliminate the stomach wound from the peritoneal cavity; and, if leakage does occur, it gives exit to it and thus probably saves the patient's life. I utterly disbelieve in the propriety of closing a wound of the stomach without drainage.

2. *Gastrolysis.*—By this operation we separate or partially extirpate perigastric adhesions. Such adhesions are far more common than was once thought, and are frequently productive of much suffering. They may result from traumatism, from tuberculosis, or from syphilis, but are most commonly due to fibrous thickening about an ulcer of the stomach, or to gall stones or cholangitis.

Such adhesions may attach the stomach to the gall bladder, to the gall ducts, to the omentum, and to other parts. The pain produced by them is particularly appreciated on taking food, and is usually relieved on lying down. They may also cause constriction of one of the orifices of the stomach, and usually induce the condition that Calwell named adhesion dyspepsia. Mayo points out that dilatation is often present, but, unlike what occurs in the dilatation due to ulcer, there are few symptoms of ordinary indigestion.

When such a condition is suspected to exist, we should, after opening the abdomen, follow the advice of Bird (*Inter-Colonial Medical Journal of Australasia*, December 20th, 1900) and inspect first the region of the gall bladder, in which such adhesions are most commonly met with, and then the other neighborhoods in which they may exist. When the adhesion is trivial, is very slender, or is in the form of a narrow band, we can simply separate it; and when this is done, most patients will be cured and practically all will be benefited. When an adhesion is very firm and long, it may be necessary to ligate it at each end and excise it. In separating adhesions the bleeding is generally so slight that ligation is rarely necessary. In severe cases in which the adhesions constrict the pyloric outlet of the stomach, gastro-enterostomy should be performed, the anterior operation being employed for posterior adhesions and the posterior operation for anterior adhesions. Always remember that adhesions may mark the site of an unhealed ulcer, and if they do so the ulcer should be treated surgically.

3. *Gastropexy.*—When the stomach droops the condition is known as gastroptosis; and this may exist alone or in association with the drooping of other abdominal viscera. When the stomach droops it passes into a more or less vertical position. The condition is not at all unusual in women, and its frequency may be estimated from the report of Steele and Francine that, in the Medical Dispensary of the Hospital of the University of Pennsylvania, sixty-three cases of gastroptosis have been recognized during the last two years.

When gastroptosis exists, the supports of the stomach are elongated. These supports are the gastrohepatic omentum and the gastrophrenic ligament. Duret advocates treating such cases by suturing the stomach to the peritoneum of the anterior abdominal wall. In view of the fact that dilatation of the stomach is a frequent secondary consequence of gastroptosis, some surgeons advocate gastro-enterostomy as the proper operation. If the liver likewise droops, it should certainly be lifted back to its place and sutured.

The most promising operation is that devised by Henry D. Beyea (*Pennsylvania Medical Journal*, November, 1902). He describes his operation as follows:

Make an incision three inches long, midway between the ensiform cartilage and the umbilicus. Place three transverse rows of interrupted silk sutures, from above downward and from right to left, through the gastrohepatic omentum, and another series through the gastrophrenic ligament. Tie these sutures, and thus form a broad transverse fold, or plication, in each ligament, that will shorten the ligamentous supports and lift the stomach into its normal position. Beyea says that seven cases have been operated upon, up to the present time, by himself and other operators. Six of these cases have now been observed for from sixty-five days to three years after the operation. In every patient the symptoms have been completely relieved and the health has been remarkably improved.

4. *Gastroplication.*—In this operation we seek to diminish

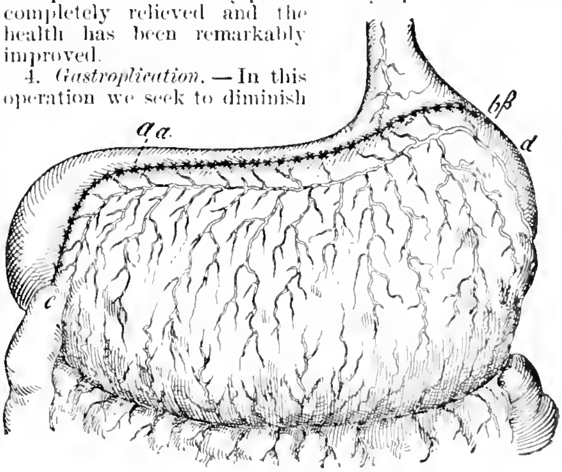


FIG. 4523.—Bircher's Method of Gastroplication. (Keen.)

the size of a dilated stomach by taking tucks in its wall. The term gastrorrhaphy has likewise been employed to designate this operation; but, as before stated, the name gastrorrhaphy should be restricted to the suturing of a wound or a perforation.

Gastroplication has been used to prevent the perforation of an ulcer, but its chief use is in dilated stomach. Clearly, however, when this dilatation is due to pyloric obstruction, such an operation must fail of effect, because it does not remove the cause of the difficulty; therefore when dilatation of the stomach is secondary to pyloric obstruction, that obstruction should be abolished by some of the methods subsequently to be considered, or gastro-enterostomy should be performed. The operation of gastroplication, if employed at all, should be restricted to cases of dilatation due purely to muscular atony, in which the digestive powers are at a low ebb because of the atony.

Different methods have been employed. One is to turn the greater curvature upward upon the lesser curvature and suture the two together (Fig. 4523). Two broad and lengthy layers of the anterior wall may be sutured together, or a very great number of small areas may be approximated by inversion sutures. Brandt, for instance, employed over two hundred sutures in one case.

The value of this operation is very questionable; and we lean to the view of Wölfler that, as the causative condition, whatever it may be, remains untouched, the dilatation will probably be reproduced.

5. *Gastrotomy.*—Gastrotomy means the making of an incision into the stomach and closing the incision at the termination of the operation. Gastrotomy is employed for exploration, for the removal of a foreign body from the stomach, for the arrest of hemorrhage, to permit of the dilatation of a stricture of the œsophagus or of a stricture of the pylorus, or to facilitate the removal of a foreign body from the œsophagus. This operation was performed now and then even in ancient times. In 1532 Matthias, of Brandenburg, successfully removed a knife from the interior of the stomach. The stomach is opened in the following manner:

The abdominal incision is usually made in the median line above the umbilicus. If we are operating for a foreign body in the stomach, when the organ is exposed the foreign body should be located by palpation; and if the body is sharp, every precaution should be taken to prevent injury during the manipulation. Jacobson gives us the sound advice that in dealing with a sharp body with one blunt end, the blunt end should be located first.

The portion of the stomach to be incised is then brought out of the wound and surrounded with gauze. An incision transverse to the long axis is now made, preferably with scissors. Any bleeding vessels are caught with forceps, the foreign body is removed, mucus and blood are eliminated from the interior of the viscus by gentle sponging, its wall is inspected to see that it has not been seriously damaged, bleeding vessels are ligated, the stomach wound is sutured in accordance with the directions given under the heading of gastrorrhaphy, the stomach is restored to its proper position, a small piece of gauze is carried down to the stitch line for drainage, and the abdominal wound is closed.

If operating for the arrest of hemorrhage from the stomach, after the anterior wall has been incised the interior of the stomach is explored with an electric-lighted endoscopic tube and the bleeding point is located. If it is in the anterior wall, it is treated through this incision. If it is in the posterior wall, an opening is torn through the gastrocolic omentum; a finger is passed up into the lesser peritoneal cavity, and the portion of the posterior wall at which the bleeding point is located is inverted with the finger, so that it may be readily recognized through the anterior incision. Then the vessel is ligated or sutured, as the surgeon may elect. After ligating a bleeding point or suturing it with a portion of the stom-

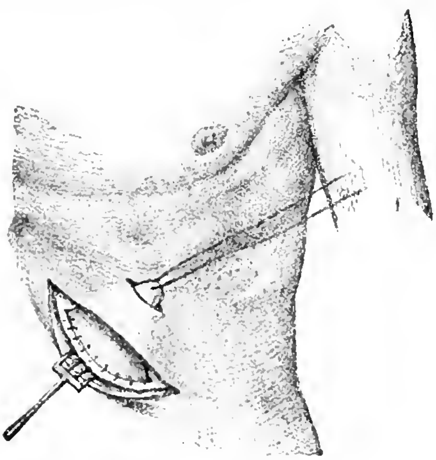


FIG. 4524.—The Ssabanejew-Franck Method of Gastrostomy. (Meyer.)

ach wall, apply several inversion sutures to the overlying part of the stomach surface. The operation as employed for the removal of a foreign body in the œsophagus is described in the section on the œsophagus.

The operation of gastrotomy is the antecedent to the performance of Abbe's string-saw operation for stricture of the œsophagus—a procedure that will be found described under the heading "Cicatricial Stricture, etc.," on page 477. The operation of gastrotomy is likewise a necessary antecedent to the performance of Loreta's operation of digital divulsion of a stricture of the pylorus. If gastrotomy has been employed for the arrest of hemorrhage, it should usually be associated with gastroenterostomy, which latter operation will put the stomach at rest after the hemorrhage has been checked.

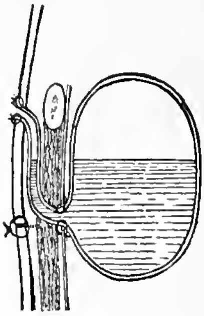


FIG. 4525.—Section to show the Line of the Stomach Wall after the Performance of Gastrostomy by the Ssabanejew-Franck Method. (Meyer.)

6. *Gastrostomy.* — Gastrostomy means the making of a permanent opening into the stomach. This opening is used for the introduction of food. The operation was first performed by Sedillot in 1849. It is usually employed in cases of malignant stricture of the œsophagus, is occasionally used in cases of very marked fibrous stricture of the œsophagus, and has been employed on persons suffering from obstructing cancer of the pharynx, on the victims of œsophageal diverticula, and on individuals who have swallowed corrosive liquids and to whom swallowing is difficult or impossible and in whom stricture is certain to arise. At the present time it would scarcely be used in œsophageal diverticula. In only one instance have I ever employed the operation for anything except malignant disease. That case was one of fibrous stricture of the œsophagus associated with great spasm. The stomach was opened with the intention of distending the stricture from below, or of cutting it by the Abbe string-saw method. This was, however, found to be impossible; therefore the operation of gastrostomy was performed. The results in this case were remarkable. In a few weeks it became possible to pass bougies from above; and subsequently, when the stricture was well dilated, the gastrostomy opening was allowed to close. In such a case as the above, gastrostomy is of benefit, not only by enabling the patient to take sufficient food to maintain his strength, but also by giving complete rest to the strictured area and thus relieving spasm and promoting the absorption of inflammatory exudate.

The operation of gastrostomy has been condemned by many surgeons on the ground that it is extremely fatal; and, as a matter of fact, when performed late in a case of malignant disease, it is very fatal. At this late period the patient is already exhausted, the shock of the operation may be profound, the wound heals badly, and the patient's tissue resistance is at such a low ebb that infection is quite likely to occur. Gastrostomy should not be reserved for cases *in extremis.* When a man is nearly dead, the operation is almost sure to be fatal; and even if passed through successfully, it will prolong the sufferer's life for but a short time. It ought to be performed much earlier, or not at all. As J. B. Murphy says, gastrostomy has no place as a last resort and should only be used in cases without pronounced constitutional symptoms (Chicago *Medical Recorder*, June 15th, 1902). When done at an earlier period, it gives the greatest possible ease and comfort, and may prolong the life of a cancer patient for weeks or months. Mikulicz's rule appeals to us as being a sound one; *i.e.*, when the patient shows a progressive loss of weight and when he begins to develop difficulty in swallowing semisolids and liquids, then the operation should be performed. Then it can be done with the greatest safety, and then it will give the greatest relief and the greatest prolongation of life. When the operation is done at this time, it usually relieves the patient of much distress and uneasiness; it enables him to take plenty of food, thus counteracting weakness and depression; and, in fact, after an early gastrostomy there is, as a rule, a very distinct gain in weight.

When cases are operated upon early it is usually safe to give a general anæsthetic; but when the case is at all advanced or when the patient is weak, a local anæsthetic should be used. I have done the operation with ease and safety under local anæsthesia; in fact, when the hæmoglobin of the blood is distinctly below fifty per cent., I always elect to do it under local anæsthesia.

In performing this operation the surgeon must so do it as to prevent subsequent leakage of the gastric contents. If the fistula leaks, the fluid, as it flows over the surface, will produce irritation and inflammation of the skin and harassing annoyance to the patient. When gastrostomy was performed according to the old methods, leakage inevitably happened. By all of these old methods the stomach was fixed to the abdominal wall and opened a few days later. A large opening was made; the fistula thus formed enlarged, rather than contracted, and leakage took place.

Modern operations are much more satisfactory. The operation that is the most satisfactory in the majority of cases is the one known as the Ssabanejew-Franck method. Ssabanejew devised this operation in the year 1890; and some three years later Franck practised the same method, without being aware of his predecessor's labors. In order to perform this operation an incision is made at the border of the left ribs, and a cone of the stomach is drawn out through this incision. This cone should be at least an inch and a half in length. About an inch above the rib borders a second incision is made through the skin, and the bridge of skin between the two cuts is undermined with a blunt instrument. The base of the stomach cone is sutured to the parietal peritoneum, and the apex is caught with forceps, pulled under the undermined skin, made to emerge through the second opening above the border of the ribs, and sutured there. The incision in the abdomen is then closed. The apex of the cone may be opened at once; and whenever it is desired to feed the patient, a tube may be introduced. This fistula does not leak; it has no tendency to contract, and it is not necessary to wear a tube permanently. It is an admirable operation; it can be very easily and quickly performed; there is no danger of sepsis from the escape of the contents of the stomach, and no buried sutures are employed. It is not, however, applicable to all cases. When the stomach is shrunken and contracted, or when it is very adherent at some portion, one will not be able to pull out a cone an inch and a half long; and if a cone of this length cannot be obtained, one should not do the operation. In two cases I have taken the cone beneath the muscles, as well as beneath the skin; but I question the necessity of this modification.

A. W. Mayo Robson declares himself eminently satisfied with Franck's operation. He, however, employs it in a

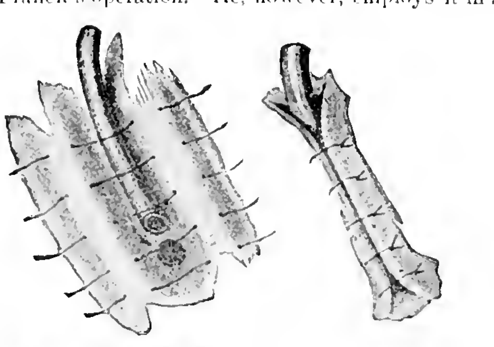


FIG. 4526.—Witzel's Gastrostomy. (Esmarch and Kowalzig.)

somewhat modified form. He makes a vertical incision, an inch and a half in length, over the outer third of the left rectus muscle. This incision commences three-quarters of an inch below the costal margin. He then separates the fibres of the rectus, by blunt dissection, to the same extent as the external incision, and afterward divides the posterior portion of the rectus sheath and the peritoneum by an incision an inch in length. He brings a cone from the cardiac end of the stomach up through the wound, and has it held upward by an assistant while the base of the cone is sutured to the parietal peritoneum. He next makes a transverse incision, half an inch in length, through the skin, one inch above the upper end of the

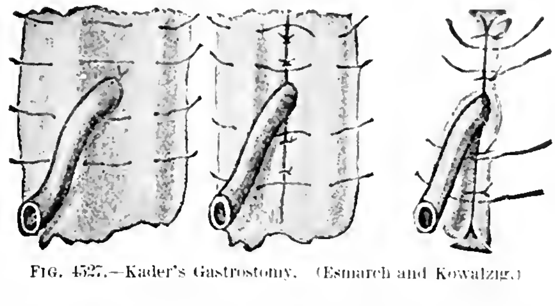


FIG. 4527.—Kader's Gastrostomy. (Esmarch and Kowalzig.)

first incision; undermines the skin between the two openings; introduces a pair of forceps through the upper incision; catches the cone of stomach, and draws it to and a little beyond the second opening, where it is retained between two harelip pins. This portion of the cone completely fills the second opening, and no stitches are necessary. The lower opening is then sutured.

Unless early opening of the stomach is necessary, the surgeon should wait twenty-four hours, in order that a protective barrier of lymph may be thrown out. When the stomach is opened it is done by passing a tenotome between the pins. After the opening is made, a soft-rubber catheter—from No. 8 to No. 12—is inserted, and is retained for a few days. When it is desired to feed the patient a funnel is attached to the catheter. After a few days the catheter is removed, and is then introduced temporarily whenever food is required.

In Witzel's method of gastrostomy (Fig. 4526) a cone of the stomach wall protrudes into the lumen of this viscus, and leaking is thus antagonized. The operation is performed as follows:

The preferable incision is a vertical one through the rectus muscle of the left side. The cardiac end of the stomach is exposed and drawn out, and a very small opening is made, into which a rubber tube about the size of a lead-pencil is introduced. A part of this tube, where it lies upon the wall of the stomach, is buried in the stomach wall by stitching two folds of this wall over the tube with Lembert sutures. The free end of the tube emerges from the wound, and the surface of the stomach about the tube is sutured to the parietal peritoneum. The abdominal wound is then closed. The end of the external portion of the tube is now clamped and the dressings are applied. Food may be administered immediately after the operation, if it is desirable.

I do not like this method as well as Franck's operation. In the first place, it is necessary to use intra-abdominal sutures. There is also some danger of leakage; and the fact that the tube crosses the surface of the stomach may, as it did in one case, cause the formation of an hour-glass constriction.

Kader's operation is employed when, because of the small size of the stomach or of adhesions of this viscus, it is impossible to obtain a sufficiently large cone to perform the Franck operation. I have used Kader's method with great satisfaction. It may be regarded as a modification of Witzel's operation, and is performed as follows:

A three-inch incision is made two fingers' breadths below and parallel with the border of the left lower ribs; or, which is preferable, a vertical incision is made through the left rectus muscle. A fold of the wall of the stomach is drawn forward; a small incision is made, as in Witzel's operation; and the tube is pushed into the stomach for a distance of two inches (Fig. 4527). This tube is then fastened to the stomach wall with a single catgut suture; and a Lembert suture is placed on each side of the tube, each suture raising and uniting a fold about half an inch in width and making a groove about three quarters of an inch in width. When the sutures are tied, longitudinal folds are formed. A portion of the stomach wall is turned inward and surrounds the tube. Over this first fold other folds are made, usually two in number. Then the stomach is stitched to the parietal peritoneum and to the posterior portion of the rectus sheath. The abdominal wound is closed, the other end of the tube emerging from it. In cases in which the stomach is very much contracted it may be necessary to open the viscus within the abdomen, because it will be found impossible to pull it up sufficiently to open it extraperitoneally.

The operation of the younger Senn, of Chicago, is advocated by a number of surgeons. He, too, makes a valve of the stomach wall; and the opening thus formed does not leak during the digestion of food, and may be opened by the passage of a tube when we wish to administer food.

I regard the Franck operation as the easiest, safest, and most satisfactory when it can be performed; when it cannot, I prefer the method of Kader.

7. *Gastro-enterostomy.*—Gastro-enterostomy is the operation of making an anastomosis between a portion of the small intestine and the stomach. It was first suggested in 1881 by Nicoladoni, and was first performed by Wölfler, in the same year (Fig. 4528). The anastomosis may be, and usually is, made between the stomach and the jejunum, and then the correct name of the procedure is gastrojejunostomy. It may, however, be made between the stomach and the duodenum, and is then known as gastroduodenostomy. We shall consider particularly gastrojejunostomy.

The operation of *gastrojejunostomy* may be performed when there is pyloric obstruction, malignant or non-malignant in character; when there is ulceration of the stomach, especially if associated with hemorrhage; when perigastric adhesions produce adhesion dyspepsia; when there is dilatation of the stomach from any cause; when there is grave indigestion that is unamended by ordinary means; and when there is congenital hypertrophy of the pylorus. In dilatation due to simple muscular atony, the operation, as we have previously stated, is of no value. When dilatation and hypertrophy are associated with spasm of the pylorus, the operation is not indicated. Its employment in uncorrectable indigestions has been suggested by Hartmann and warmly advocated by Keen. When the surgeon is dealing with cancer of the pylorus he must choose between pylorectomy and gastro enterostomy. When he is dealing with non-malignant stricture of the pylorus, he must frequently choose between pyloroplasty and gastro-enterostomy. In a case of non-malignant stricture of the pylorus, if the pylorus is accessible and if the plastic operation is possible, we should prefer pyloroplasty, as it keeps the parts in a natural condition and saves the patient from some not improbable post-operative complication.

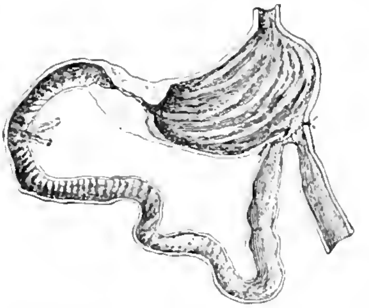


FIG. 4528. Wölfler's First Method of Gastro-enterostomy. (Esmarch and Kowalzig.)

In cancer, if the adhesions are not too extensive, if the growth is not disseminated into near by or distant viscera, and if it is found possible to remove the associated lymphatic glands, pylorectomy is usually performed in preference to gastro-enterostomy; in fact, we may say that in early cases of cancer of the pylorus pylorectomy is to be preferred, and that in very advanced cases gastro enterostomy is of no use. It is rather in the medium type of cases that gastro-enterostomy should be employed; *i.e.*, in persons in whom the growth from the pylorus is irremovable, but who have not yet passed into advanced cachexia and exhaustion.

In a non-malignant case of stricture of the pylorus gastro enterostomy may produce a permanent cure. It frequently relieves the acidity; it enables the stomach to empty itself more rapidly, and thus prevents fermentation and gives rest to the organ. After the operation the motor power of the stomach usually increases, the secretory power often improves, and some stomach digestion usually occurs. As a rule, a certain amount of bile flows into the stomach after the performance of gastro-enterostomy. This was noted in most of Weir's cases. It seems, however, to do no particular harm unless it is present in quantity, or unless it has difficulty in flowing out again. If hyperacidity exists the operation commonly has the effect of causing a lessening or a disappearance of free hydrochloric acid. Of course, even in non-malignant cases the operation sometimes fails of effect.

One of the most valuable effects produced by gastro-enterostomy in either malignant or non-malignant obstruction is the return of regular bowel movements. The operation is, of course, infinitely more serviceable in non-malignant than in malignant cases. In a malignant case it may be followed by a rapid gain in weight; but this gain is only temporary. If, after the performance of gastro-enterostomy, there be marked and prolonged gain in weight, we should be justified in concluding that the disease was not cancer.

The mortality of the operation has been regarded as very high; but when we analyze the figures, we find that it is very high in malignant and not very high in non-malignant cases. In cases of malignant disease the mortality is frequently in the neighborhood of forty per cent.; even in the hands of Mikulicz it has been thirty-two per cent. The Mayos (William and Charles) report ninety-eight gastro-enterostomies with nine deaths, the mortality in malignant cases having been twenty per cent. and in non-malignant cases six per cent. This high mortality in malignant disease is due to the fact that the operation is frequently done too late, when the patient is exhausted and near to death. It should not be done on cases *in extremis*, and, as before stated, should be employed when the case is too far advanced for pylorectomy, but is not very cachectic or much exhausted.

The period of prolongation of life produced by the operation in malignant disease is doubtful. It may be a few weeks, a few months, or a year or more. It is, however, rarely more than a few months. Because of the short prolongation of life and the very high mortality, many surgeons have questioned the value of gastro-enterostomy in malignant disease; but it undoubtedly makes the patient more comfortable. It allays pain; it stops the harassing hunger and torturing thirst; it causes a return of normal bowel movements; and it makes life at least bearable. As Keen says, it is not so much a question of how long a patient lives as how he lives.

In non-malignant cases the mortality is very low. Karle, of Turin, reported twenty-three operations without a single death; and Karle and Fantine estimate that the mortality from operations in non-malignant cases is under four per cent. In such cases the operation is often positively curative; and in nearly all cases it will, at least, give definite and prolonged relief.

There is a fundamental difference in methods of performing this operation, in the fact that the anastomosis may be made upon the anterior wall of the stomach or upon the posterior wall (Figs. 4531–4536). Each method has its advocates. The anterior operation may be performed more readily and quickly; and its advocates maintain that, if it is properly performed, it is safer and more satisfactory than the posterior. In some cases the anterior operation must be performed because the posterior wall cannot be reached. The advocates of the posterior operation maintain that the anterior operation is more liable to be followed by a vicious circle; that the cone of stomach pulled down occasionally compresses the large intestine and produces obstruction; that the posterior operation has very little tendency to be followed by a vicious circle; and that, whereas it takes somewhat longer to do, it is a question whether the mortality is distinctly higher. Further, it is well known that if a button is used in the anterior operation, this mechanical appliance is far more apt to remain in the stomach than if the posterior operation is performed.

Whichever operation is selected, the stomach should be washed out daily for several days preceding its performance. The abdomen should be cleansed at least forty-eight hours before the operation; and during the operation the patient must be carefully protected from cold by being wrapped in blankets and being surrounded with hot-water bottles.

The first incision in the abdominal wall should be small, in order to permit of exploration, so that the surgeon may determine whether gastro-enterostomy is to be performed at all and what method is to be employed. The abdominal incision is then enlarged. If speed is not a vital point in the case, the simple suture without mechanical aid should be selected; if speed is a vital element, one should use a Murphy button, bearing in mind that there is a possibility that this button may be retained. I would do no operation by means of the forceps of La Place or O'Hara, because forceps turn in a very large septum after previously bruising it, and consequently expose a large bruised, raw surface to infection. I am persuaded that operations by means of forceps are more apt than are operations by other methods to be followed by sloughing or by obstruction of the anastomosis opening. Personally, I perform, in most cases, a posterior gastro-enterostomy, effected by a simple suture if the patient's condition is good, and by a Murphy button if haste is imperatively necessary.

A great many operations have been devised, but only a few of the most valuable will be mentioned here.

After-effects of Gastro-enterostomy.—The effects of this operation upon the motor power, the secretory function, and the digestive capacity of the stomach have been referred to previously. Certain pernicious conditions may also ensue; for instance, in a few cases ulcer has formed in the intestine, being apparently due to the extreme acidity of the gastric juice. Neumann suggests that this complication may be cured by making a temporary fistula, and keeping it open until the excessive acidity of the gastric juice has disappeared.

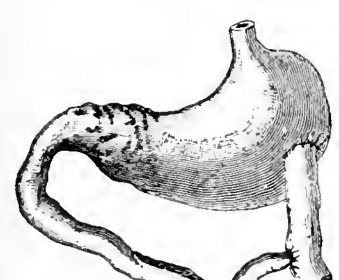


FIG. 4529.—Wölfler's second Method of Gastro-enterostomy. (Esmarch and Kowalzig.)

The most common ill-consequences of gastro-enterostomy are constriction of the new opening, and vomiting, due to regurgitation from the duodenum or to the establishment of what is known as a vicious circle. In every case the new opening contracts to some extent, and occasionally it absolutely closes. The lesson to be drawn from this is that the opening made should be of considerable size. When the stomach is very much dilated at the time of operation, the contraction of the opening is sure to be notable as the viscus shrinks; hence the greater the dilatation, the larger should be the opening. Contraction of the opening is indicated by burning pain, nausea, and it may be regurgitation of small quantities of bile (Mayo).

In some patients, after gastro-enterostomy the fluid from the stomach passes into the proximal loop of intestine and distends it, and the distal loop undergoes collapse. The collection of fluid in the proximal loop may be due to the retention of the secretions that normally enter into that loop, with the addition, it may be, of the passage of a certain amount of material from the stomach through the strictured pylorus. Such a condition may be brought about by the abolition of peristaltic movement in the proximal loop; by the constriction of the distal loop, through an adhesion, a twist, or a kink; or by the formation of a spur, which prevents the passage of material from the proximal into the distal loop.

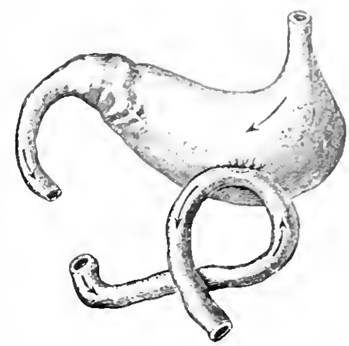


FIG. 4530.—Lücke's Method of Gastro-enterostomy. (Esmarch and Kowalzig.)

The term vicious circle means that the contents of the stomach enter into the duodenal loop and are then returned to the stomach, with bile, pancreatic juice, and other contents of the duodenum. George Ryerson Fowler (*Annals of Surgery*, November, 1902) opposes the use of the term vicious circle, and prefers to say regurgitation, or, better still, reflux, when he wishes to indicate the passage of bile and pancreatic secretion, as well as that of the contents of the jejunum, into the stomach. As previously stated, after every operation of this sort some bile enters into the stomach; but if only a small amount enters, it produces no harm, and the condition will practically amend itself; and even if a considerable quantity enters the stomach it causes little trouble if it readily passes from the stomach into the distal loop. Sometimes there is slight and temporary vomiting, which after a time passes away. At other times the vomiting is extremely serious, and may even hurry the patient to death. Because the vomited matter seemed to be chiefly composed of bile, the trouble has been attributed purely to the presence of bile; but A. W. Mayo Robson maintains that the presence of bile alone is not sufficient cause for the vomiting, and neither is the presence of pancreatic juice. He says that the real cause of the vomiting is not definitely understood. If this vomiting is trivial, it may often be controlled by frequently washing out the stomach and by temporarily abandoning mouth-feeding; but if the vomiting is severe, it is usually met by performing an additional anastomosis between the portion of the duodenal loop above the anastomotic opening and a portion of the jejunal loop below this opening. In the older operations of gastro-enterostomy, the contents of the duodenum inevitably passed into the stomach through the anastomotic opening. They then mixed with the other stomach contents and entered the distal loop. In the perfecting of the modern operations of gastro-enterostomy, the constant effort has been to avoid this complication; for instance, Wölfler, in his second method, cut the jejunum across, implanted the end in the stomach, and fixed the end of the duodenal portion into the efferent portion (Fig. 4529). Lücke so arranged the loop for anastomosis that the peristaltic wave would be in the same direction in the stomach and in the distal portion of the loop (Fig. 4530). The following methods will be described: anterior gastro-enterostomy as practised by Mayo, of Rochester, Minn.; and von Hacker's method of posterior gastro-enterostomy.

In regard to the use of simple sutures or of some mechanical appliance, each operation must be considered on its own merits. The operation with the Murphy button can be done in about fifteen minutes. The surgeon should be certain that the two halves of the button are tightly forced together, and supplementary sutures will then not be necessary. The button may pass during the second week, but rarely does so until the third. In one of my cases of posterior gastro-enterostomy it did not pass until the ninetieth day. Sometimes it does not pass at all, and this complication is said to be particularly apt to occur after anterior gastro-enterostomy; although, strange to say, the retention of the button seems rarely to produce harm. The opening made by the button is sometimes scarcely large enough, and is particularly apt to contract to an unfortunately small size if the stomach is very much dilated. In using the button, we may employ the purse-string suture around the central tube, as Murphy does, or follow the plan of Karle, which is to make a small incision, insert the button, and put a small stitch on each side of the central tube, thus saving time and handling. I do not believe that the button operation is desirable if the anterior gastro-enterostomy is employed. Mayo Robson advocates the use of a bone bobbin. If the anterior operation is employed, I believe that simple suturing is desirable or that Robson's bone bobbin should be used.

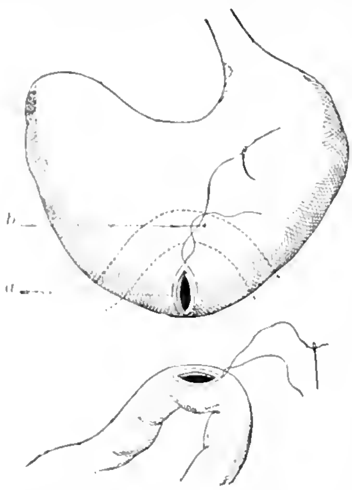


FIG. 4531. Showing Proper and Improper Locations of the Opening in Gastro-enterostomy. (From Dr. William J. Mayo, in *Annals of Surgery*, August, 1902.) *a*, Proper position, which leaves no pouch; *b*, usual position, which leads to the formation of an intragastric pouch.

Anterior Gastro-enterostomy.—Mayo says that the anterior method has certain distinct advantages. It does not open the lesser peritoneal cavity, as does the posterior operation; it can be done with a smaller incision and less exposure; and, hence, it is safer and simpler. Mayo prefers it to the posterior, and says that a careful examination of literature does not show the frequency of the ill-effects so often attributed to it. As a matter of fact, the reports of the Breslau Clinic show the best results from the anterior operation. Mayo employs the anterior operation if the mesentery is short or contains much fat, or if the vascular loop running to the transverse colon from the superior mesenteric artery is small, "bringing the opening in the posterior layer of the gastrocolic omentum in close proximity to it" (*Annals of Surgery*, August, 1902). Some operators maintain that as the stomach shrinks the transverse colon will be pressed upon or constricted, but this will not happen if there is plenty of slack. That regurgitant vomiting is not common even after the anterior operation is shown by the fact that Czerny had but one fatal case out of sixty-five operations. Mayo had two cases of vomiting in thirty-one gastro-enterostomies, each case having been controlled by lavage. In twenty non-malignant cases he did not have a single instance of vomiting.

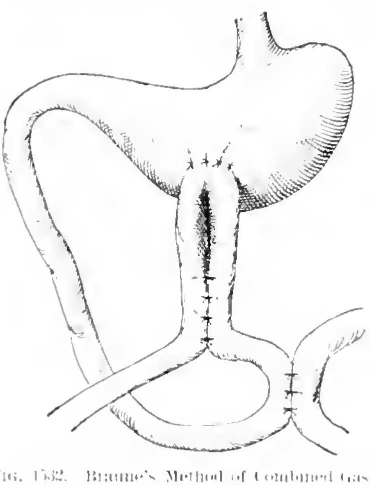


FIG. 4532. Braune's Method of Combined Gastro-enterostomy and Entero-enterostomy.

The operation should be done without a button, if the condition of the patient is good; with a button, if haste is necessary. The button is probably more apt to be retained in the anterior than in the posterior operation.

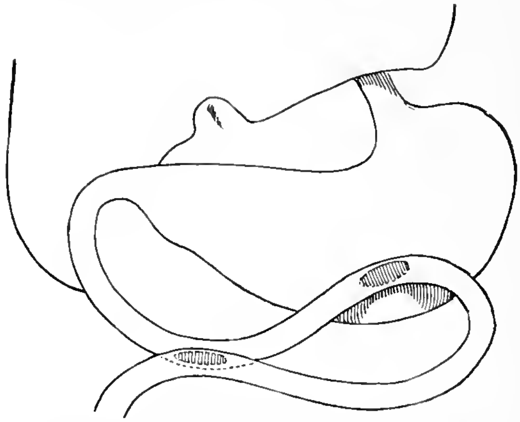


FIG. 4533. Jaboulay's Method of Combined Gastro-enterostomy and Entero-enterostomy.

A portion of the anterior wall of the stomach toward the pylorus is selected. Mayo tells us not to go too near the pylorus, because to do so means early invasion by cancer. The opening must be as near the pylorus as it is safe to go without the apprehension of involvement. Mayo's rule is, place the opening near the greater curvature, one inch above the inferior border. When it is so placed, traction will draw down the stomach so that the anterior surface becomes the inferior. The opening will be at the most dependent portion of the stomach pouch, the stomach will empty itself readily, gravity will prevent the entrance of bile, and a vicious circle will not be established (Fig. 4531).

The origin of the jejunum is next sought for, and a coil about fourteen inches in length is obtained. This is so attached to the stomach that peristalsis in the coil and peristalsis in the stomach run in the same direction. If the button is used, it is applied as in an ordinary in-

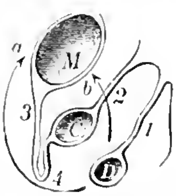


FIG. 4534.

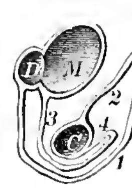


FIG. 4535.

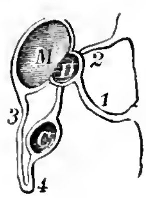


FIG. 4536.

Diagrams of Gastro-Enterostomy.

FIG. 4534.—*M*, Stomach; *C*, colon and small intestine in normal position; *1*, mesentery; *2*, mesocolon; *3*, gastrocolic ligament; *4*, great omentum; *a*, Wölfler's procedure; *b*, von Hacker's procedure. (Esmarch and Kowalzig.)

FIG. 4535. Wölfler's Antecolic Gastro-enterostomy. (Esmarch and Kowalzig.)

FIG. 4536. Von Hacker's Retrocolic Gastro-enterostomy. (Esmarch and Kowalzig.)

testinal anastomosis; if simple suturing is employed, it is done as Halsted directs.

Weir is a believer in the plan of Braune and Jaboulay, *i.e.*, the performing of entero-anastomosis, as well as gastro-enterostomy. He performs anastomosis, by means of a Murphy button, between the efferent and the afferent coils. Rutkowski associates a temporary gastrostomy with gastro-enterostomy, carrying a small tube from the stomach incision well into the jejunum. The gastric juice at once passes from the stomach, alongside of the

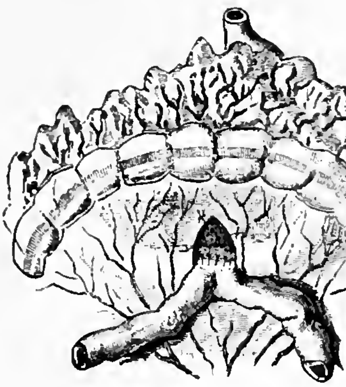


FIG. 4537.—Von Hacker's Method of Posterior Gastro-enterostomy. (Esmarch and Kowalzig.)

tube, into the bowel; and the patient can be fed without danger. Ten days after the operation the gastrostomy wound is allowed to heal.

Posterior Gastro-enterostomy (von Hacker's Operation).—This operation was first devised by von Hacker. It is the preferable operation when the posterior wall of the stomach can be readily reached. Mayo prefers the posterior method for a thin subject with a long mesocolon.

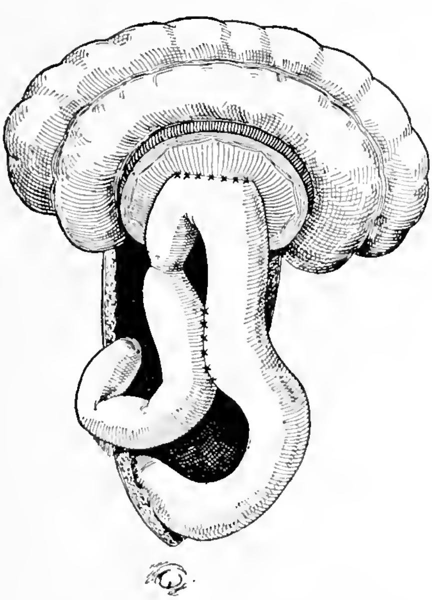


FIG. 4538.—Gastro-enterostomy; Method of Dr. George Ryerson Fowler. (*Annals of Surgery*, November, 1902.)

The bowel is attached to the part of the stomach that is the most dependent when the patient is recumbent. There is less probability of regurgitation of bile than in the anterior operation, and there is a ready passage of food. The bowel is not apt to kink, and if a button is used it is more certain to be passed.

In this operation the great omentum and the transverse colon are lifted upward, a small opening is torn through the transverse mesocolon, and the posterior wall of the stomach is thus reached. A cone of the stomach should be sutured to the margins of the opening in the transverse mesocolon (Fig. 4537). The point in the jejunum at which the anastomosis opening is to be situated is about twelve inches from the beginning of the jejunum. If we have plenty of time the simple suture is used to effect the union; but if it is necessary to has-

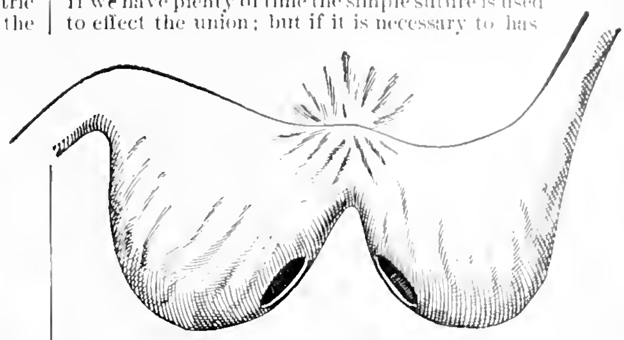


FIG. 4539.—Wölfler's Method of Gastro-gastrostomy for Hour-glass Stomach. (Keen.)

ten, we should use the Murphy button. If the button is used, it is not necessary to stitch the stomach to the opening in the transverse mesocolon. George Ryerson Fowler associates posterior gastro-enterostomy with entero-anastomosis, and cuts off absolutely communication between the stomach and afferent loop by circumclusion

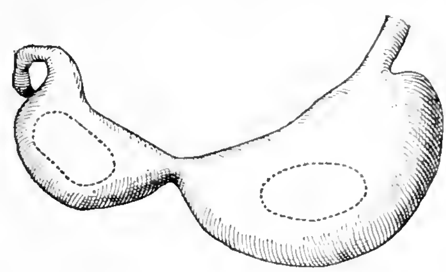


FIG. 4540.—Watson's Method of Gastro-gastrostomy.

of the afferent limb of the jejunum between the anastomotic openings by a silver-wire ligature (*Annals of Surgery*, November, 1902). (Fig. 4538.)

An ingenious method of gastro-enterostomy is that by the elastic ligature. It was devised by Dr. Theodore A. McGraw and has been practised successfully by him and by others. Dr. McGraw says that this method "is unequalled in the rapidity of its execution, its efficiency, and its safety, although it does not accomplish its pur-

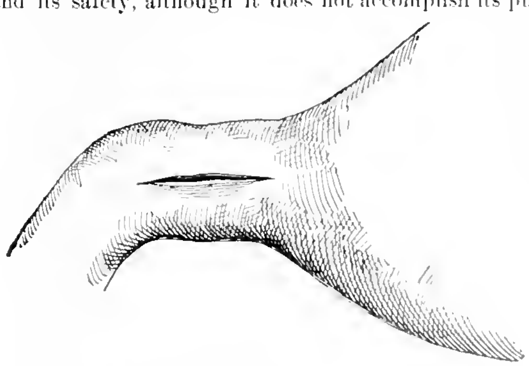


FIG. 4541.—The Heineke-Mikulicz Method of Pyloroplasty. The longitudinal incision. (Keen.)

pose until after the lapse of two or three days" (*New York Medical Journal*, January 26th, 1901). The material used is rubber cord 2 mm. in diameter. One end is shaved thin and passed through the eye of a worsted needle. The intestine and the stomach wall are brought in contact and are sewed together by a number of Lembert sutures in a line. The needle carrying the rubber cord is carried into the stomach and brought out again, the space included being about 5 or 6 cm. in length. It is then entered into the intestine and brought out in a like manner, and the ends are tied "tightly and firmly in a square knot." The ends of the ligature are cut short and are tied together with silk. Lembert sutures are inserted above.

In this operation the ligature cuts through in two or three days, and when it cuts through tissues which are adherent, infection is prevented, and the cord passes away.

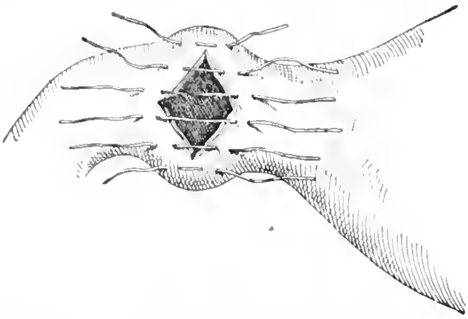


FIG. 4542. The Heineke-Mikulicz Method of Pyloroplasty. Incision stretched at a right angle to its axis and sutures inserted. (Keen.)

Gastroduodenostomy.—This operation has been strongly advocated by some operators; notably Jaboulay and Mikulicz. The pyloric end of the stomach is anastomosed to the anterior portion of the duodenum. In order to perform the operation successfully, the duodenum must be movable. Of course it is never suited to malignant disease, and cannot be performed when the pylorus is adherent. The great advantage of the operation is that the anastomotic opening is above the bile and pancreatic ducts, and hence regurgitation does not occur.

8. *Gastroplasty and Gastro-gastrostomy.*—The condition known as hour-glass stomach may be relieved by the performance of Watson's gastro-gastrostomy (*i.e.*, the anastomosis of the portion of the stomach on one side of the constriction with the portion of the stomach on the other side of the constriction); or of Watson's gastro-gastrostomy; or by gastroplasty (the making of a longitudinal incision through the constricted portion, followed by traction upon the sides of this incision, so that it becomes transverse; and the application of sutures so as to maintain it in this transverse or vertical position). The constriction is thus diminished or abolished. Gastroplasty is the preferable method.

9. *Pyloroplasty* (the Heineke-Mikulicz Operation).—For cicatricial stricture of the pylorus, the older method of Loreta has been practically abandoned, because after

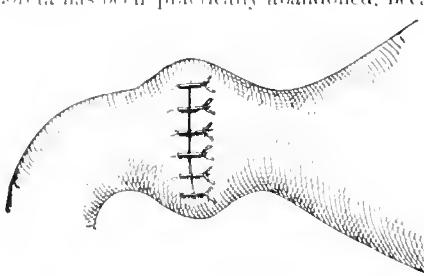


FIG. 4543. The Heineke-Mikulicz Method of Pyloroplasty. Sutures tied and lumen of pylorus inserted. (Keen.)

its performance recurrence is almost inevitable. In such a case, if gastro-enterostomy is not advisable, we perform pyloroplasty—*i.e.*, the surgeon makes a longitudinal incision through the constriction, holds the edges apart to make the line of incision appear vertical, and so applies his stitches as to maintain the vertical direction of the suture line. Thus the constriction is either mitigated or abolished. Mayo points out that pyloroplasty may fail because the degenerated gastric muscle cannot lift the food from the gastric pouches to the high pylorus. If it does fail, do gastro-enterostomy.

10. *Pylorectomy.*—This is the operation of excising the pylorus with a portion of the pyloric end of the stomach. Its performance is practically restricted to malignant disease. The operation was first performed by Péan in 1879.

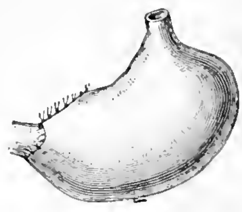


FIG. 4544.—Billroth's Method of Pylorectomy.

The mortality of the operation is extremely great, but has been considerably reduced in recent years. One reason of the high mortality is that many cases have been operated upon too late, when advanced cachexia or wide diffusion of the growth was present. The later we operate and the more marked the adhesions, the heavier the mortality. Wölfler says that the mortality in cases with extensive adhesions is over seventy two per cent., and that in cases without extensive adhesions it is under twenty-eight per cent. Mayo's mortality is only fourteen per cent.

It is rarely that genuine cures are effected by the operation in proved cases of cancer, and it is only when the procedure is undertaken early that there is any real chance of cure. Nevertheless there are more than forty cases in literature which survived three years or more. To give a real chance of cure, the operator must cut wide of the growth on the stomach side. As a matter of fact, the growth usually returns.

As a rule, the abdomen is not opened until a tumor can be palpated, and then it is generally too late for pylorectomy. This fact emphasizes the enormous importance of an exploratory incision in doubtful stomach cases. As making such exploratory incisions becomes more and more the practice, pylorectomy will become more and more successful; because it will be performed earlier. Pylorectomy is a proper operation if the pylorus is not firmly anchored by adhesions, if there is no dissemination into adjacent organs and structures, if

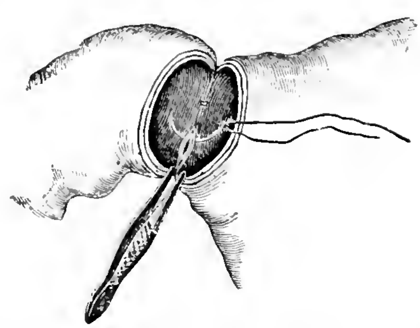


FIG. 4545. Suture of Mucous Membrane from within after Pylorectomy. (Tillmanns.)

there are no distant metastases, and if the affected lymph glands are removable; otherwise, gastro-enterostomy should be done.

The older method of Billroth gave a mortality of from thirty eight to forty per cent., as a rule. In this method, after the resection of the tumor has been accomplished, it is found that the wound in the stomach is larger than that in the duodenum; the stomach wound must therefore be lessened by suturing, until it is practically of the same size as the duodenal wound, when an end-to-end anastomosis is performed.

Kocher's method has been much more successful, and is said by Mayo to give a mortality of only sixteen per cent. In this method, after the tumor has been removed, the stomach end of the cut is completely closed, and the duodenum is implanted in the posterior portion of the stomach wall. Mayo follows Kocher's method with a slight modification. He tells us that Kocher has performed pylorectomy fifty-seven times, that eleven of the patients were living a considerable time after operation, and that five of them were living a sufficient length of time afterward to be regarded as cured.

11. *Gastrectomy.*—*a.* Partial Gastrectomy.—By partial gastrectomy we mean excision of a portion of the stomach. The operation of pylorectomy really includes a partial gastrectomy. We may remove a small portion of the stomach, a considerable portion, or almost the entire organ. In any of these cases the operation is a partial gastrectomy. The operation may be performed for malignant disease or for ulcer. After the extirpation of a malignant growth or of an ulcer, sutures are inserted in the manner recommended by Halsted.

b. Total Gastrectomy.—This operation was first performed by Connor, of Cincinnati. The first successful operation was performed by Schlatter, of Zurich. The operation has now been performed a number of times. Whenever possible, the duodenum is attached to the œsophagus, and it is a matter of surprise how easily this has often been effected. If it is found to be difficult or impossible to do this, an opening is made in the jejunum, and this portion of the bowel is attached to the œsophagus. This operation should, of course, be attempted only in cases in which practically the whole of the stomach is involved, in which the organ is still movable, in which there is no involvement of adjacent structures or viscera, in which there is no metastasis, in which the lymphatic glands are removable, and in which it is possible to attach the œsophagus either to the duodenum or to the jejunum.

It is remarkable how well digestion is performed in cases in which the whole stomach has been removed; but, of course, during the progress of chronic disease, portions of the intestinal canal gradually take upon themselves the functions of the stomach and really effect digestion for quite a while before the removal of the stomach. It is in very rare cases that this operation is necessary, but it is undoubted that it is occasionally justifiable.

12. *Jejunostomy.*—This procedure is occasionally recommended for malignant disease, when gastro-enterostomy is rendered impossible because of the situation of the growth. The permanent opening in the jejunum is used for the purpose of administering food. Either the jejunum itself, cut across, may be brought into the wound, or a tube may be inserted into the wall of the jejunum, exactly as is done in gastrostomy. The operation is very rarely necessary, but in some cases is to be employed.

Exploratory Laparotomy.—In view of the imperative necessity for early diagnosis, if we would successfully cope with many gastric diseases, and especially if we would hope to cure malignant disease, exploratory laparotomy is frequently indicated. The exploration is made to clear up doubt; and after the condition is ascertained, the incision may be enlarged and a radical or a palliative operation may be performed. The surgeon who never operates until the diagnosis is certain must often delay so long in reaching a conclusion that when he is sure what the matter is, he is equally sure that any operation is entirely useless. Dr. J. B. Murphy strongly endorses the following statement made by MacDonald (*Chicago Medical Recorder*, June 15th, 1902): "In a chronic, progressive gastric trouble that is unamended by careful diet and drug treatment; that is accompanied by loss of gastric motility and diminution in gastric peristalsis; and that is attended with emaciation, in spite of forced feeding—especially if associated with progressive reduction in the hæmoglobin, diminution in the hydrochloric acid of the gastric juice, and moderate leucocytosis—an exploratory operation should certainly be performed." With the foregoing statement I am in hearty accord; and when an exploratory operation is performed in such cases, a cancer will usually be found.

Operation for a suspected malignant growth may disclose an innocent growth, and a condition that would have been destructive to life without operation may be permanently cured. I have recently performed an exploratory operation in a case in which the symptoms indicated cancer, and yet in which it was ascertained during the operation that the whole condition was due to cicatricial obstruction of the pylorus. A complete cure followed the performance of pyloroplasty. In conducting an exploration for disease of the stomach, it is necessary, in some instances, not only to open the abdomen, but also to perform exploratory gastrotomy.

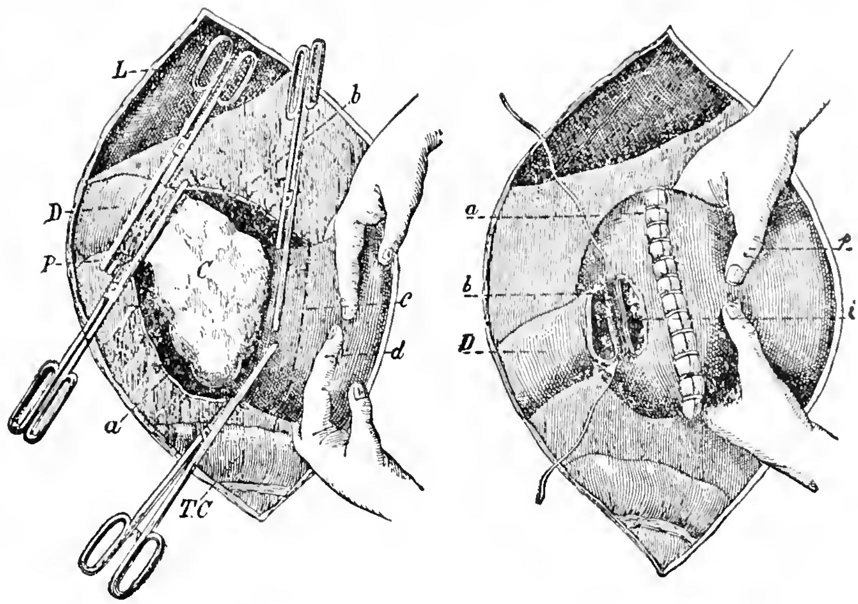


FIG. 4546.—Kocher's Method of Pylorectomy (*A*) and Posterior Gastro-enterostomy (*B*). (Kocher.)

Operations for Ulcer.—It is imperative to remember that the symptoms of perforation are not always certain; hence, when the symptoms that are supposed to indicate perforation are present, an exploratory operation must be immediately performed. When we believe that an ulcer has perforated, the proper means for bringing ing about reaction should be adopted and the abdomen should be opened. There will usually be an escape of odorless gas and fluid, and food will often be found in the peritoneal cavity. The site of the ulcer may sometimes be located by the presence of adhesions, but at other times no adhesions are present, and a very careful search is then necessary.

When the ulcer has been found, it is enough, in most instances, simply to close the perforation with inversion sutures, as described under the head of gastrorrhaphy.

Some surgeons advocate excision of the ulcer as well. When the ulcer's margins are not markedly indurated, and when inversion can be readily effected, it is not worth while to excise. In perforation excision is rarely necessary. In some ulcers which have not perforated and in a few which have, excision is advisable. In a recent case in the Philadelphia Hospital, I was obliged to excise an ulcer which had not perforated. Excision was required because the surrounding induration made marginal inversion impossible. The abdominal cavity is then carefully cleansed, the stomach is washed out, a piece of gauze for drainage is carried down to the stitch line, and the abdominal wound is closed.

In ordinary, non-perforating ulcers, medical and dietetic treatment is indicated in the majority of cases; but if, in spite of such treatment, a patient grows progressively worse, if the pain is violent, or if tenderness is marked, the abdomen should be opened and the stomach should be inspected. A single acute hemorrhage, even if large, does not call for operation; but if the hemorrhage is repeated, operation should be performed. A number of small hemorrhages call for operation. Cabot lays down the sound rule that if an ulcer tends to recur or if it lessens the ability of the patient to work—especially if he must work to live and cannot regulate his diet—an operation should be undertaken.

In operating for chronic ulcer, it is wiser, in most instances, to excise the diseased area, suturing the gap (see Partial Gastrectomy and Gastrorrhaphy). If we are operating for hemorrhage from an ulcer in the anterior wall, the hemorrhage is best controlled by excising the ulcer. In hemorrhage from an ulcer in the posterior wall, the site of trouble is determined by performing exploratory gastrotomy. When the ulcer is located, tear through the gastrocolic omentum, insert a finger back of the stomach, invert the posterior wall, look for the ulcer through a gastrotomy wound in the anterior wall, and arrest the bleeding with a ligature or a suture. After arresting the hemorrhage some advocate the performance of gastro-enterostomy to put the stomach at rest and prevent the retention of acid gastric juice. It has been shown that in cases of ulcer in which it is difficult or impossible to reach the seat of bleeding, gastro-enterostomy alone puts the stomach at rest, permits drainage, and strongly favors cure.

Operations for Cancer.—Exploratory incision should be performed in the cases indicated by Murphy and MacDonald. In limited cancer of the body of the stomach, perform partial gastrectomy and remove adjacent involved glands. In cancer involving the entire stomach, the viscus being movable, adjacent organs being free from disease, no demonstrable metastases existing, and the involved glands being obviously removable, complete gastrectomy is a justifiable operation. Pylorectomy is performed in cancer of the pylorus; but only in cases in which there are no extensive adhesions, no metastases, and no involvement of adjacent viscera, and in which the involved lymph glands are removable. In cancer of the cardiac end of the stomach in which the œsophagus is involved, removal by excision is scarcely justifiable and gastrostomy is practically useless. In some cases jejunostomy should be considered. If a radical operation is impossible in cancer of the body of the stomach, no palliative operation is indicated, except possibly jejunostomy. If a radical operation is impossible in cancer of the pylorus, gastro-enterostomy is performed, or, in rare cases, jejunostomy. *John Chalmers Da Costa.*

STOMACH, DISEASES OF.—Within recent years the literature in gastric diseases has grown so extensively that numerous text-books, good, bad, and indifferent, are now issued. Among the best for the practitioner may be mentioned: Riegel, "Die Erkrankung des Magens," Wien, 1896 (an American edition has just been issued, 1903); Boas, "Diagnostik und Therapie der Magenkrankheiten," Leipzig, 1897; Einhorn, "Diseases of the Stomach," New York, 1900; Hemmeter, J. C., "Diseases of the Stomach," Philadelphia, 1903; Van Valzah and Nisbet, "The Diseases of the Stomach," Philadelphia, 1898; Lindner and Kuttner, "Die Chirurgie des Magens," Berlin, 1898; Martin, S., "Functional and Organic Diseases of the Stomach," London, 1895; Gillespie, "A Manual of Modern Gastric Methods," Edinburgh, 1899; Osler and McCrae, "On Carcinoma of the Stomach," Phila., 1900; L. Brunton et al., in Allbutt's System of Medicine, London, 1897.

In preparing the various sections the writers have drawn freely from some of these authors, where special arrangements and topics have appealed to their requirements.*

I. METHODS OF EXAMINATION IN GASTRIC DISEASE.

Inspection.—This includes both a general examination of the patient and a special investigation of the abdomen in general, and the stomach in particular.

The *general examination* concerns the *nutrition* of the patient, the conditions of the *skin* as to dryness and moisture, the evidences of cachexia, etc. The state of the *teeth*, as one of the common causes of gastric disorder, should be examined and due note made of any condition there which may cause infection—*e.g.*, unnecessary bacterial contamination of food, faulty mastication, etc. Often a false set may fit so badly as to be the sole cause of dyspepsia, induced through insufficient mastication alone. The condition of the *gums* is likewise important. So, too, the state of the *pharynx*, more especially in chronic gastritis, in which the morning vomiting is often due solely to pharyngeal mucus swallowed during the night. Salivation, too, is often associated with disease of the pharynx and of the palate and tonsils.

The state of the *tongue* is very much over-estimated as to its diagnostic significance in gastric disorders. It is the mirror of the mouth much more than of the stomach. There may be a clean tongue in cancer of the stomach, while with merely carious teeth there may be persistent coating. As a rule, however, there is apt to be a clean, reddened tongue with hyperchlorhydria, while with subacidity the tongue is usually coated. A dry tongue is usually associated with mouth-breathing.

Examination of the Abdomen.—*Special inspection* of the stomach and abdomen is useful in not a few diseases, for in them it is possible to tell the size, situation, and even the shape of the stomach. This method is best carried out with the patient lying down, as the erect posture renders the recti abdominis rigid. Normally, nothing of the stomach is to be seen.

Among the abnormal conditions which can often be detected by inspection alone are abnormal distention with gas, gastrectasis (idiopathic or obstructive), stenosis of the pylorus (when the tumor is visible and peristaltic waves are evident), hour-glass constriction, peristaltic unrest (a neurosis), and gastroptosis.

Inspection is aided by *inflation* or *insufflation*. This is carried out by one of two methods:

1. Administration of sodium bicarbonate and tartaric acid in separate solutions, the gas forming in the stomach when the two solutions come into contact.

The details of this method are as follows: According to the age and size of the patient, from half a drachm to one drachm of each is placed in separate tumblers which are then filled to one-third with water. The tartaric acid is first administered, and, before the second tumbler is offered, the patient is directed to retain whatever gas may have formed; then the sodium bicarbonate is administered and the patient is told to lie down. With the body in the horizontal position the inflated stomach rises out of the general level of the abdomen, and a satisfactory inspection of the organ can then be made.

Remarks.—An unsatisfactory result may be due to insufficient dosage, the stomach being more capacious than

* Sections I., II., III., IV., V., VII., VIII., IX., and X. are from the pen of Dr. Charles F. Martin, while the remaining ones (on "Neuroses," "Simple Tumors," "Displacement of the Stomach," and "Foreign Bodies") have been written by Dr. F. Morley Fry.—*Editor.*

anticipated, or to adhesions, or to its situation chiefly in the left hypochondrium or under the ribs, or to incontinence of the pylorus, or, finally, to excessive gastric peristalsis. Or, again, too much gas may be formed and intense pain and unavoidable emesis follow. The physician should have a stomach tube, a basin, and a towel at hand in case the retention of gas give rise to great pain or to sudden uncontrollable emesis.

2. The second method is the introduction of air by means of the stomach tube, the air being propelled by the double-bulbed Higginson's syringe. This has the advantage of controlling the amount of air introduced and the disadvantage incident to passing the stomach tube. This method should never be tried till the patient has used the tube at least once previously, and air should never be introduced in such amount as to cause severe gastric pain. The contraindications to either of these methods are ulcer, recent hæmatemesis, atrophy of the mucous membrane, peritonitis, and advanced cardiac and arterial disease.

Palpation.—Palpation should be performed gently, systematically, with warm hands, the fingers being held flat on the abdomen at first, and the patient recumbent, breathing gently and with knees flexed. Palpation is easier when the stomach is empty, though tumors and the stomach outlines are often felt best after inflation. Narcotization is sometimes necessary to allow of satisfactory palpation, and is indeed to be strongly recommended in doubtful cases. Any tenderness found should be localized definitely and its degree ascertained. Boas' algesimeter has not been found of any great value in diagnosis.

Tumors of the stomach do not move with respiration, as a rule, the stomach being rather broadened out by descent of the diaphragm. Only when they, or the stomach, are adherent to the solid parts which move with respiration can they be made to descend on inspiration, and with expiration they may often be fixed by intervention of the fingers above the tumor.

Succussion.—Succussion implies detection of fluid with air, in a body cavity, by shaking the patient or the portion examined. The patient lies upon his back and relaxes the abdominal muscles. The physician, then grasping the iliac bones and lumbar muscles on both sides, quickly shakes the patient and a splashing sound is heard. Occurring under certain conditions this is distinctive, but may be simulated by fluid in the colon as well. Presence of this sign in the stomach is only pathological when found to extend over an abnormally large area or at times when the stomach is normally empty (*e.g.*, in gastrectasis, five or six hours after a meal), and should not be otherwise regarded as evidence of disease.

It is doubtful if much reliance for the diagnosis of atony can be placed on the following method: Give the patient half a glass of water and try succussion. If this be obtained it arouses suspicion of atony. Therefore try again in half an hour, and, if a positive result is still obtained, then atony is present. If no succussion be present the motor power of the stomach is normal.

In testing for succussion the triangular area of the stomach in contact with the abdominal wall—*i.e.*, the triangle formed by the midline of the abdomen, the left costal border, and a line joining the cartilages of the ninth ribs—should be especially examined.

Percussion.—This evidence varies according to the amount of contents—food or air. The organ is to a large extent inaccessible normally to percussion—only the above-mentioned triangular area and Traube's semilunar space being easily outlined. Percussion may reveal the size, situation, and shape of the organ and the presence of tumors. Increased area may be due to megalogastria, retracted lung or liver, ptosis, weighty tumors, and dilatation. Diminution in the size of the area may result from left pleural or pericardial effusion, pneumothorax, hypertrophied heart, enlarged spleen or left lobe of liver, etc.

Percussion is much assisted by inflation, less so by administration of fluid.

Auscultation and auscultatory percussion have not as yet proved of any great practical value in diagnosis.

Illumination of the stomach by the gastrodiaphane is sometimes valuable in locating its site, but has little other practical use. As a means of demonstrating the abnormal positions of the organ, it is an excellent method if the patient has a thin panniculus.

Examination of the Digestive and Motor Functions of the Stomach.—For this purpose the best means known is by the examination of the gastric contents after administering a test meal of given quantity and quality. This is more satisfactory and reliable than the older method of examining the gastric juice alone after physical, chemical, or electrical stimulation. It is by no means essential in all cases of gastric disorder to employ test meals or the tube; indeed, the tube is used far more frequently than is necessary or even wise. The cases should be selected according to their needs. After a given test meal has been removed we are enabled to decide from the examination to what extent the motor functions are active, and after analyzing the chemical nature of the contents we can tell to what degree the various constituents of the gastric juice are being secreted as aids to digestion.

Three types of test meals are to be recommended:

1. *Test Breakfast:* One piece of dry bread or toast (60 gm.) and a breakfast cup of weak tea (without sugar or milk). This is to be taken slowly, the bread being well masticated and the tea drunk gradually. One hour later this may be removed and examined.

Such a breakfast should have a residue of not more than 75 c.c.; should be of gruel-like consistence; should contain about fifty per cent. total acidity, free hydrochloric acid ten per cent., combined acid forty-five per cent. Such a meal contains albuminoids, sugars, salts, starches, and extractives, and makes no great demand upon the stomach—a point of importance where there is difficulty of digestion. The disadvantage of such a meal is in the fact that it scarcely demands sufficient effort on the part of the secreting glands of this organ.

2. *The Test Lunch of Germain Sée:* A large piece of bread (120 gm.), a cup of water, and 60 gm. of minced meat. This should be removed for examination two hours later. Little more than 200 c.c. will remain from such a meal, and the total acidity will be about sixty per cent. This meal, containing a more varied diet, still further tests the powers of gastric digestion.

3. *Test Dinner of Leube and Riegel:* This consists of a plate of soup (350 c.c.), 60 gm. of scraped beef, and 60 gm. of wheaten bread. In some meals potatoes in purée form and a tumbler of water are added. This meal should be removed four or five hours later, and will contain a still larger amount of hydrochloric acid (total acidity from sixty-five to seventy per cent.), and it will also give the secretory glands a fair test of their functional powers. Another advantage of this meal is that the macroscopical appearances of the contents give at a glance a fair estimate of the way digestion is proceeding, especially as regards the motor power and the digestive power for proteids. Its disadvantages are the risk of clogging of the tube, the long delay after the meal, and the fact that it is often not readily digested.

Method of Removing a Test Meal.—For this purpose an ordinary stomach tube, thirty-six inches (about 90 cm.) long and of different diameters, should be at hand. One should be careful merely to select one of sufficiently large calibre to allow the pharyngeal muscles to grasp it properly, and not so pliable as to bend in the mouth too easily when introduced. The end should be rounded and provided with two velvet eye orifices, and it really matters but little whether these be both lateral or one terminal and the other lateral. With ordinary care there is but little danger of injuring the mucosa of the stomach with the tube end. A bulb attached to the upper end of the tube may be of use in removing the contents by suction; but it is not an essential, as the tube itself may be so pressed and pulled as to create suction and thus withdraw the contents. When it is desired to wash out the stomach a funnel may be substituted for the bulb.

For the operation one requires, in addition, a rubber apron for the patient, two dishes, and a jug of hot water. The patient, seated in an ordinary chair, is then given the tube, which has been previously warmed in water (no other lubricant is necessary), and is directed to swallow it, using his lips to assist in introducing and swallowing the tube. When a gagging sensation supervenes he is instructed to breathe quietly, when he will at once observe the absence of any supposed danger from choking. The head should be held erect, not far backward, and the tongue should not be pressed down. In the case of patients who have a very irritable pharynx, they may be directed, ten minutes beforehand, to suck a pledget of cotton soaked in a five-per cent. solution of cocaine. The introduction of the tube—when such a step becomes necessary—is to be done as follows: With the left index finger as a guide to the back of the pharynx, the tube held in the right hand is quickly passed down over the epiglottis into the gullet and pushed below the level of the cricoid cartilage. The finger is then removed, the patient told to breathe quietly, and then to continue swallowing the tube. The cardia being eighteen inches (45 cm.) from the incisor teeth, twenty-two inches of tube should be inserted before removal of the contents is attempted.

Three methods of removal are employed:

1. *Expression.* This is best achieved by the patient pressing on his stomach, straining as if at stool, and bending forward—the distal end of the tube being meanwhile lowered over a dish to a point below the level of the stomach. Often the act of retching—voluntary or otherwise—aids the process. Any blocking which may seem to occur may be overcome by pressure on the bulb in such a way as to direct the force of air against the stomach end of the tube (*i.e.*, by compressing the tube on the distal end of the bulb). This is better than to remove the tube and to cleanse it, and illustrates one advantage of the bulb.

2. Failure to remove contents in this way must be overcome by *suction*, either by frequent use of the bulb so as to create a vacuum in the tube by directing the current of air outward, or by filling the funnel with water and allowing it to siphon off in the hope that the stomach contents may follow.

3. Should this method also be without result, *complete siphonage* must be tried. This is done by pouring warm water of a known quantity (say one-half pint) into the stomach, as well as retaining water in the whole length of the tube, and thus removing both the water and the contents of the stomach when the siphonage operates. To do this properly one must lower the funnel quickly before all its watery contents reach the stomach, which would otherwise prevent the action of the siphon. Having thus obtained some contents, we can estimate how much of the meal has remained, after deducting the quantity of water poured into the stomach.

Failure to obtain any contents whatsoever may be due to various factors: The motor power may have been abnormally strong and all food may have passed into the duodenum, as occurs in some neuroses. The time may have been too long after the meal. The tube may not have been pushed far enough into the stomach, and thus not have reached the fluid, or it may have been inserted too far, thus allowing the end with its orifices to curl up again above the level of the fluid. The tube may become blocked with food or mucus.

The contents having been successfully obtained, the tube is removed slowly, and, after being half withdrawn, the distal end should be tightly pinched to prevent the dripping of remaining contents; then the stomach end of the tube should be allowed to slip through the other hand and should be grasped firmly just before its complete removal. This insures less mess in removing the tube and allows greater comfort to the patient. The tube is then placed in warm, mildly antiseptic water and cleansed outside and within. It should never be boiled nor curled up after being cleansed.

There is no occasion to resort to other methods recommended (such as the use of the stomach bucket) for the removal of the stomach contents.

The *contraindications* to the use of the tube for diagnosis are as follows: (1) Recent hæmatemesis; (2) peritonitis; (3) pregnancy; (4) disease of heart and arteries, especially aneurism; (5) febrile conditions; (6) great weakness.

Examination of Stomach Contents.—(1) Macroscopical; (2) microscopical; (3) chemical.

Macroscopical.—The *quantity* depends on the kind of meal and the motor power of the stomach. From this alone we can estimate the presence of motor insufficiency of all degrees—the presence of hypermotility and of supersecretion, remembering always that each test meal has its definitely recognized amount of residue; according to the amount left behind so is the degree of motor (not of digestive) power.

Consistence. One should note, further, the relation of solids and liquids. The food may be only partly digested. A good, evenly mixed, soup-like material implies good secretory power or perhaps hyperacidity. The presence of relatively much liquid, as against a small amount of solids, implies one of two conditions: either retention of fluids from motor insufficiency or hypersecretion of gastric juice. Many coarse food particles imply subacidity, while much starchy remains with well-digested meats show hyperacidity. Sometimes the contents on removal separate into *three distinct layers*, the lowest consisting of starches and chyme, the middle one of cloudy fluid, and the uppermost one of foam, on account of gas formation which usually implies stagnation and fermentation of food. With the foam there may also be remnants of undigested food and mucus. The presence of food taken on a previous day implies, of course, retention of food, *i.e.*, an advanced degree of motor insufficiency.

Odor. Normally the contents have what may be termed a gastric odor. One should note the possible evidence of butyric or of acetic acid, both of which acids are best detected in this simple manner. Abnormal fermentation is implied by their presence. According to underlying causes the contents may have a fetid (ulcerating cancers), fecal (obstruction to intestines, etc.), putrid (phlegmonous gastritis, etc.), or urinous (uræmia) odor. Poisons such as hydrocyanic acid, carbolic acid, etc., may each lend their special odors as signs of their having been ingested.

The *specific gravity* of pure gastric juice is 1.002 to 1.005. In hyperacidity the filtered contents have a specific gravity of 1.010 to 1.020. In subacidity this is often still higher, depending partly on the amount of sugar present.

Mucus is readily seen, and normally there is about one-half drachm in a stringy, gelatinous state. It is gray or colorless, and if pigmented we may conclude that it has come from swallowed sputum or from an associated catarrhal condition. Mucus is increased in hyperchlorhydria, in ulcer, in gastritis, and in certain neuroses of the stomach. In hyperchlorhydria the mucus is often in lumps and threads.

Blood from the stomach is bright or dark, according as a large or small vessel is opened, and according to the length of time it has remained in the stomach. It indicates erosion of a vessel, as caused by ulcer, carcinoma, various forms of gastritis and hepatic cirrhosis, strain or trauma, hysteria, etc.

The vomitus, resembling *coffee grounds*, consists of blood and food-remains, the former being dark from its longer sojourn in the stomach and from the action of the gastric juice. Usually it follows an erosion of the smaller and more superficial vessels.

Pus when present is usually associated with phlegmonous gastritis or an ulcerating cancer.

Bile is commonly present, being regurgitated from the duodenum.

Microscopical.—One sees in the contents the food-remains, consisting of striated muscle fibres, starch grains, vegetable cells, fat globules, etc. Abnormally there may be sarcinæ ventriculi, characterized by their brown color and their arrangement in multiples of two (bale shaped); they are usually found with dilatation of the stomach, where hydrochloric acid is present. Yeast cells may be present, as also hosts of bacteria, such as (1) acid forms which do not liquefy gelatin—Bacillus coli, Bacillus lactis aerogenes, etc., and Bacillus butyricus (this does liquefy gelatin); and (2) Bacillus subtilis, Proteus vulgaris, B. fluorescens liquefaciens, Leptothrix, and various micrococci.

The Boas-Oppler bacillus—a thick, long bacillus—is frequently present in advanced motor insufficiency and is commonly found with carcinoma ventriculi, though not an essential feature.

Chemical.—Qualitative Tests. For this purpose the stomach contents should be filtered into a glass beaker, a process which will take time unless the French method of folding the filter paper be adopted. The filtrate is usually clear, slightly yellow, or somewhat opalescent. (Only the most suitable and commendable methods are here given, the various methods being too numerous for the compass of this article.)

The contents are either acid, neutral, or alkaline. If they are neutral or alkaline, one need not go further in testing for acidity; if otherwise, we *first* of all use litmus paper (which is suitable to all free acids, acid salts, and organic acid combinations). If they are acid to litmus, we use, *secondly*, Congo-red paper (a saturated aqueous solution into which white filter paper is steeped), to test for free acids, which if present give to the paper a deep blue. (This is much more sensitive to hydrochloric acid than to the organic acids, while combined acids do not alter the Congo paper.) *Thirdly*, we test for free hydrochloric acid by dimethylamidoazobenzol (one-half-per-cent. alcoholic solution). This yellowish solution is very sensitive to any free mineral acids, and on the addition of a mere trace of free hydrochloric acid a red color appears. Fill one-fourth test tube with the solution, and on addition of a few drops of filtered contents containing free hydrochloric acid the red will appear; 0.002 per cent. of hydrochloric acid will give this reaction. It is the most sensitive reagent as yet known, and though it reacts also to lactic acid and phosphates, it does so only when they are present in concentrated form, which rarely occurs in gastric disease.

Another satisfactory test for free hydrochloric acid must be mentioned, viz., Gunzburg's, whose reagent consists of phloroglucin 2 parts, vanillin 1 part, and absolute alcohol 30 parts. Place on a porcelain dish one drop of this solution, and with it a drop or two of filtered stomach contents. Heat gently over a Bunsen burner, and if free hydrochloric acid be present a rose-red color will appear; a brownish-yellow color is meaningless.

Test for Combined Hydrochloric Acid.—Where free hydrochloric acid is found the combined hydrochloric acid is implied; but should the former be absent, there may still be sufficient acid secreted to fulfil some of the requirements of proteid digestion. This is ascertained by a color test with alizarin (one-per-cent. aqueous solution). Filter the stomach contents, place a few cubic centimetres in two separate test tubes. To one tube add a few drops of alizarin and a decinormal solution of sodium hydrate till a pure violet color appears. Note the amount of NaOH used. To the second tube add the same quantity of one-tenth NaOH, and, if it is found still acid to litmus, combined HCl is present.

The biuret reaction, however, is simpler and shows equally well the presence of combined acids by proving the presence of peptone or propeptone in the filtered contents. Take, therefore, a few cubic centimetres of the stomach contents in a tube, add to this a few drops of caustic potash, and then, by means of a pipette, drop by drop, a ten-per-cent. solution of copper sulphate. The green color produced becomes a violet on addition of the last reagent. This is known as the biuret reaction. Propeptone would not form without hydrochloric acid being present. Failure to obtain a positive test for free hydrochloric acid, followed by a positive biuret reaction, indicates the presence of combined hydrochloric acid.

Quantitative Tests.—The total acidity is made up by the acidity from mineral and organic acids in a free or a combined state. Normally, this forms rarely more than 0.25 per cent., though, according to the time after meals, this varies, the most being found three hours or so after a mixed meal.

A decinormal solution of NaOH is used in a burette. Ten cubic centimetres of filtered contents of the stomach are placed in a beaker and one or two drops of phenolphthalein are added as an indicator. Excess of alkali renders the color red. The NaOH solution is added till the red color appears in the gastric contents, and the amount necessary to produce this result is read off on the burette. Normally from 4 to 6 c.c. are required for 10 c.c. of gastric contents; *i.e.*, 40 to 60 c.c. would be necessary for 100 c.c. Hence one speaks of forty to sixty per cent. total acidity. The exact amount of acid is calculated as follows:

1 c.c. of normal NaOH = 1 c.c. normal HCl.
1,000 c.c. of normal NaOH = 1,000 c.c. normal HCl, *i.e.*, 36.5 (molecular weight of HCl in grams to 1 litre of water).
∴ 1 c.c. of normal NaOH = 0.0365 HCl.
∴ 1 c.c. of decinormal NaOH = 0.00365 HCl.
∴ 40 to 60 c.c. of decinormal NaOH = 0.146 per cent. to 0.219 per cent. (= normal percentage of total acidity).

For all practical clinical purposes this test suffices and gives a fair idea of the proportion of hydrochloric acid present, inasmuch as most of the acidity present is due to this acid.

Test for Free Organic Acids.—Lactic acid: Uffelmann's test is the simplest, and, though not infallible, is, on the whole, the most practical. A solution is made consisting of one or two drops of Tinctura ferri perchloridi and 10 c.c. of a 1-to-40 solution of carbolic acid. This forms an amethyst blue color (if darker it should be further diluted with water); a few drops (ten or fifteen) of the filtered stomach contents are added to this solution, and if lactic acid be present the solution will show a greenish-yellow or canary-yellow color. (Anything less than a definite yellow tinge is without meaning.)

Inasmuch as combined hydrochloric acid is apt to give a yellowish-brown color with this solution, it may at times serve better to omit the carbolic acid and use merely a couple of drops of dilute iron perchloride. Lactic acid added to this more or less colorless solution gives a light yellow tint. (Phosphates, sugar, and alcohol must be excluded, as they give a similar reaction.—Gillespie.)

The Volatile Organic Acids.—After distilling off three-quarters of the stomach contents, the rancid butter smell of butyric acid and the characteristic acetic odor of acetic acid are readily detected. The more elaborate means of detecting them are of little value.

Examination for the Enzymes.—The ferments are much more constant than is the hydrochloric acid, as they are uninfluenced by circulatory or nervous disturbances, and any persistent alteration in their quantity or action implies a greatly altered function of the glands of the stomach. They assume importance only when hydrochloric acid is deficient. By knowing of the presence of enzymes, we can tell if the glands are temporarily or permanently damaged. Absence of hydrochloric acid is common in many gastric conditions, but is unaccompanied by any appreciable change in the secretion of pepsinogen. When the latter is absent it implies an advanced gastritis or atrophy of the mucous membrane. A knowledge of the enzymes thus affords us aid in prognosis and treatment, though the value thereof is certainly limited.

Test for Pepsinogen.—It is converted into active pepsin in presence of HCl, and thus can convert albumins and albuminoids into soluble substances.

Qualitative Test.—If the filtered contents of the stomach contain HCl and digest albumen, pepsin is present; or if, having no HCl, they digest albumen after HCl is added, pepsin is present. If the filtered contents have no HCl and do not digest albumen after HCl is added, then pepsin is absent.

Quantitative Test.—Add to 10 c.c. of stomach contents a small egg disc or dried fibrin, and place in a thermostat at 37° C. The egg or fibrin will become dissolved. According to Jaworski, 5 to 6 c.c. of egg disc added to 25 c.c. normal stomach contents (filtered) will digest in three hours. This is a fair quantitative test. Hammerschlag's is more accurate: Make up 20 c.c. of one-per-cent. albumen solution, containing three per cent. HCl, and divide into two test tubes. To the one (the control) add 5 c.c. H_2O, to the other add 5 c.c. filtered stomach contents. Let stand one hour in an incubator at 37° C., and test the amount of albumen by Esbach's method. The control contains the original amount of albumen, the other less, and the difference between them represents the amount of albumen digested; *e.g.*, if the control has six per cent. albumen and the other three per cent. albumen, then we have fifty per cent. of albumen digested.

The Rennet Ferment (Labzymogen).—This ferment clots milk even in faintly acid or neutral media. The simplest test is Leo's: Add three to five drops of filtered contents to 5 to 10 c.c. of milk; place in the thermostat, and clotting will occur in fifteen minutes.

The Motor Power.—The fasting stomach contains but little fluid. The highest estimate places the amount at 100 c.c. Most authorities regard 20 to 30 c.c. as the normal. This fluid is pure gastric juice and should have normally no food residuum. The tests suggested for this have been very numerous. The best and one of the simplest is to ascertain from a test meal the amount of residue in a given time. Thus, one hour after the test breakfast there should not be more than 100 c.c. of contents; two hours after the meal of Germain Sée there should not be more than 175 c.c., while five hours after Riegel's meal 200 c.c. would be regarded as the limit for a normal stomach. Anything exceeding this implies deficient motor power. There are three degrees of motor insufficiency:

1st. The stomach contents are delayed, but evacuated some time before the next meal.

2d. The stomach is empty only just before the next meal or in the early morning. This is stagnation.

3d. The stomach is never completely empty even in the early morning. This is called retention.

The smaller test meals will suffice for diagnosing the first two conditions. To test for the third degree it is well to wash out the stomach at first before giving the Riegel dinner (which should be administered in the evening), and then again to test in the early morning for what residue may be present. If food has remained, the third degree of motor insufficiency is present.

II. MINOR AILMENTS.

General Symptomatology in Diseases of the Stomach.

Indigestion or Dyspepsia.—These terms may reasonably be applied to a series of cases which every physician meets, and that very frequently—cases which, though probably associated with a slight temporary anatomical, secretory or other functional abnormality, nevertheless show little or nothing upon careful physical examination of the stomach, nor any serious alteration in the chemical constituents of its contents after a test meal. Nor, again, is it other than an admission of ignorance to assign these cases in all instances to a pure neurosis.

In health we are unconscious of the presence of digestion and do not realize the fact that we possess a stomach. When dyspepsia occurs, however, much of what we eat occasions such inconvenience as to make us only too cognizant of the fact that digestion is in progress, and that we possess a digestive organ which is functioning badly. The disturbances are usually present after eating, and are most frequently associated with some temporary derangement of the motor or secretory powers. They may appear before meals and be relieved by eating; and, when such is the case, the causative factor is usually an increase in the amount of acid secreted. Sometimes, again, the nerves alone seem accountable for the disturbance, while at other times a defective circulation from organic or functional cardiac disease, or vasomotor trouble, is the main etiological factor.

The symptoms most frequently present are as follows: A bad taste in the mouth with a disagreeable odor of the breath; a coated tongue; anorexia, or more rarely boulimia; oppression and weight in the stomach; flatulence and a sense of distention; pains of various characters; heartburn, pyrosis, water brash, acid eructations; nausea and vomiting; dyspnœa and palpitation; cough; constipation and diarrhœa; vertigo.

Any or most of these symptoms may be present with serious disease of the stomach, in which case they may be the main premonitory signs; or, on the other hand, they may be merely the symptoms of an ordinary dyspepsia of a purely temporary character.

The Causes of Simple Indigestion and Minor Ailments of the Stomach.—1. *The Food.*—The *quantity:* This should be sufficient to supply the demands of nutrition, and in order to maintain a normal digestion this should be neither too much nor too little.

Excessive Quantity.—In childhood, when too much is persistently taken, the effects are of a less serious consequence than in adult life.

Excess of food is injurious in various ways: the stomach having too much to do is easily overworked and the muscle becomes to some extent paretic. As a result it never completely empties itself, and is kept persistently busy without the necessary rest. This of course is particularly injurious at night, for which reason the custom of taking heavy suppers is baneful, all the more so as digestion is delayed during sleep and the overloaded stomach has a double reason for becoming diseased. The fact that many people can stand excesses in diet for years with impunity does not render this rule any the less true. Usually such dietetic errors are amply paid for in the latter years of life, even though individual predisposition may count for much, as also the habits of life in general, the occupation, and the daily hygiene.

Excess of food is not always the result of individual large meals, but often the consequence of a too rapid succession of individual meals, or their irregularity and multiplicity.

Insufficient Quantity.—Too little food, on the other hand, is not an infrequent cause of dyspepsia, the so-called starvation dyspepsia. It is often the outcome of some other digestive trouble, whereby the patient imagines that a strictly limited diet is necessary, not wholly as regards quality but likewise as regards quantity. Rich and poor alike suffer from this cause; the rich from errors of judgment, the poor from necessity, often laboring without a quantity of food sufficient to keep up the metabolism.

In some cases of dyspepsia it is advisable to give small and frequent meals, but such should always be given with due regard for their caloric values. In all cases, whether food is given in limited amounts or in excess to satisfy the needs of the patient, regularity in the time of meals should be carefully considered, in order to give the stomach its proper time for rest.

The Quality of the Food.—This is of equally great importance. The digestibility of foodstuffs depends upon the quality, both chemically and physically. Thus, for example, the food should never be so tough as to render complete mastication difficult; hence the need of avoiding foodstuffs which are too coarse or of too hard a fibre (as in the case of meat when old), or insufficiently cooked. Mastication is thus rendered difficult, and the saliva and secretory juices fail to come into contact with the individual particles. These undigested masses remain thus irritants to both the stomach and the intestines.

Such a condition of course is aggravated by imperfections or absence of the *teeth*, more especially the molars.

The *cooking* of the food is of the greatest importance. It is a well-recognized fact that boiling renders meats more digestible than does any other form of preparation, and for the simple reason that they thus become more disintegrated. Roasting and broiling come next in importance, while frying prepares meats and other foods in their most indigestible form. Fried foods are covered over with fat, which thereby renders them more or less impermeable to the juices of digestion.

Again, too much of *one kind of foodstuff* is likewise bad. Thus, for example, an excess of proteids over any other kind of food would exact too much of the gastric juice, and thereby both directly and indirectly injure metabolism. Upon the other hand, if carbohydrates be taken in excess, fermentation is apt to occur and organic acids are introduced in excess into the alimentary tract.

The *temperature* of foods is likewise of some importance, and excesses here, as in other particulars, are injurious. Food when taken too cold, as in the shape of ices and ice water, interferes with the proper functions of the stomach, as do also foods of various kinds when taken persistently too hot.

The ingestion of too much fluid is bad, as it renders the food pappy in the mouth, dilutes the gastric juice, and thereby increases the liability to fermentation and indigestion. Much fluid is particularly injurious in motor insufficiency, which is termed by some the dyspepsia of fluids, for in this condition fluids are with difficulty passed on into the duodenum and the water is itself not absorbed in the stomach.

On the other hand, where hydrochloric acid is secreted in excess and the motor power is good, water taken freely with meals is of benefit, diluting the excessive acid present and relieving the distressing symptoms.

A glass of hot water taken before meals, or a glass of cold water in the early morning, even for healthy people, will aid digestion.

There are many foods which custom impels us to take but which should be classed among those which are a menace to healthy digestion; such, for example, as foods which are too rich, or again too spicy, in which category we place excess of vinegar, the persistent use of pickles, and the like, which induce a chronic dyspepsia and consequent emaciation from malnutrition.

The same holds true of acid wines. Spirits, too, in excess are to be condemned, especially when taken on an empty stomach. In those in whom flatulence is common beer is injurious, especially so if recently brewed, because fermentation is thus incomplete, and is continued after the beverage has found its way into the stomach.

Tea should always be taken weak; when long infused it contains an excess of tannin, which being an astringent interferes with the secretions of the stomach, especially with the digestion of proteids.

Unripe fruit, being mainly tough cellulose, is likewise irritating.

2. *Bacteria.*—These at times contribute toward indigestion. Their invasion of the teeth and mouth, if not prevented or contended against, is liable to produce slight functional disorders, among which loss of appetite, a disagreeable taste in the mouth, fermentation in the stomach and its consequences, may here be mentioned.

3. *The secretory or motor power* of the stomach itself may be defective, temporarily and only to a slight degree, acting thus as the main factor in dyspepsia.

4. *The nervous system* may be a primary etiological factor. Excitement, emotion, grief, etc., may each contribute toward the production of a more or less ephemeral indigestion.

5. *Circulatory disturbances,* associated with organic or functional disturbances or vaso-motor conditions, may each in themselves act as causes.

6. *Malposition of the viscera, adhesions within the abdomen,* etc., may act in the same way.

7. *Inactivity* is a very important factor, resulting as it does in imperfect combustion and its results.

Symptoms in Detail.

Coated Tongue.—The tongue may be coated with a fur of varying colors, from a whitish hue to a brownish black; its thickness may vary in degree, as also its consistence and moisture. The coating is made up mainly of epithelium, bacteria, and detritus. It may be localized at one or other parts of the tongue. It is a fallacy to believe that the tongue is a mirror of the stomach, for in a large majority of cases faulty digestion in the stomach has but little to do with the coating seen upon the tongue. Much more frequently are the causes to be found on the teeth or on the pharynx or tonsils. Frequently a stomatitis is the main cause, or, again, excessive smoking.

Under other conditions a coated tongue may be due to disease of the stomach and intestines; it does not as a rule carry any diagnostic value. In many diseases of the stomach, which are of extreme gravity, the tongue is clean. This may frequently be the case with ulcer of the stomach or with a condition of hyperacidity, in which case the tongue is especially clean at the tip, and often is quite sore. In alcoholics too there is often a reddened sore tongue which is uncoated.

The Breath.—The breath may be foul or disagreeable, and this may be subjective, obvious only to the patient; or it may be objective, *i.e.*, only the patient's friends observe the affection. At times the condition is associated with defects in the mouth, pharynx or larynx, and respiratory passages. The odor may arise from the stomach. It may be of sulphureted hydrogen and due to the occurrence of putrefaction or decomposition in that organ. Sometimes this is accompanied by eructations of either gases or liquids, while at other times no obvious cause can be found to account for the peculiar disturbance.

The Appetite.—Though related to gratification of the nerves of taste in the mouth, and usually an expression of the need of the body for food, the appetite, when abnormal, may be merely an indication of the need of the gastric juice, or again an evidence of a perverted nervous system, or of an altered state of the metabolism. In health it is a definite indication of the caloric requirements. Just exactly how the sensation of appetite is induced is unknown. It is a nervous phenomenon associated with the brain, and dependent in a reflex way often on conditions of the stomach. Perhaps, as Brunton suggests, it is connected with distention of the lymphatic spaces in the mucous membrane, analogous to the itching which appears before sweating takes place. Some regard the swallowing of the saliva and its stimulation of the gastric secretions as the main factor.

The state of the circulation, however, seems to have some influence upon the appetite, and Beaumont has shown that a craving for food was present when the mucous membrane of the stomach was red. Variations again may be due to alteration of the nerves of taste and to disease in the mouth itself.

Anorexia (ἀν, ὄρεξις), diminished appetite, depends on many conditions. Many people eat too much and too often, a result being that these excesses soon lead to an impairment of the appetite.

The cause may be (*a*) in the stomach, (*b*) in the nervous system, or (*c*) in constitutional conditions.

(*a*) So far as the stomach is concerned, motor insufficiency is the most important factor, unless increased hydrochloric acid be present.

Other causes, again, are organic disease of the mucous membrane, acute and chronic gastritis, cancer, atrophy of the glands, etc.

It is important to remember that in cancer the appetite may remain good if the motor power be unaltered, especially in cancer of the body of the stomach, and the patient may even gain in weight.

Sometimes in disease of the stomach it is not so much the diseased condition as the fear of pain which induces anorexia—such, for example, is the case in gastric ulcer.

(*b*) With regard to the nervous system as a cause there may be past associations, nauseous tastes, smells, etc., or again excitement, shock, or grief, for it is well known that excessive mental exercise, worry, and the like impair the appetite.

In insanity, again, anorexia is a well-recognized symptom in many cases; in gastric neuroses diminution in appetite usually implies diminution in the function of the stomach as well. Professional fasters may come under the last category, having habituated their stomachs to less requirements, and to some extent losing the real desire for food, though the metabolism is bound to suffer in consequence.

(*e*) With reference to the constitutional conditions tuberculosis is an important one—in fact, of so great importance that any marked anorexia without any apparent cause should always suggest a careful examination of the lungs.

In fevers and the various infections, anæmias, cachexias, and wherever there is excessive tissue waste, anorexia is a frequent coincidence. An exception to this last is diabetes.

Excessive physical exertion has the same effect. Lastly, poisons formed in the intestines or in the tissues and excreted into the stomach may disturb the appetite, as frequently occurs in such conditions as uræmia.

It is well to remember two important facts: First, in endeavoring to obtain a history from the patient, his statements in regard to anorexia are apt to be unreliable; second, patients often take too little in disease of the stomach, especially in neurosis, and emaciation is the natural result. Some one has truly said that in gastric diseases more harm has resulted from treatment by starvation than from overfeeding.

Excessive Appetite.—In this there are two different conditions: (1) Boulimia (βους, λιμος, oxen hunger), by which is meant increased appetite for food, also called cynorexia. (2) Polyphagia, meaning excessive eating, whether or not the appetite is increased.

Increased appetite may depend on various factors—the condition of the stomach, for example, and especially the presence of hyperacidity. It is therefore often a noticeable symptom in gastric ulcer, in which disease there is apt to be increased acidity, provided of course the pain does not create the fear of eating. It may depend on nervous influences, being often due to an irritable condition of the centripetal gastric nerves. A mental stimulus is in itself sufficient; at other times there may be a neurosis, or hysteria, or neurasthenia, or insanity.

Polyphagia seems more or less natural with some individuals; it is common in children. It is often associated with the presence of intestinal worms, or, again, children through faulty training and bad management are forced to eat when they really do not require food. Polyphagia occurs frequently in brain affections, particularly tumors, in sexual disorders, in convalescence from various fevers, especially typhoid, and lastly in diabetes.

Parorexia, or altered appetite, is a neurosis. Apart from an excessive or diminished diet there is a desire for unusual foods and substances which do not come at all under the category of foods.

Thirst.—An increased desire for fluid depends less on the condition of the stomach than does hunger.

The quantity of fluid imbibed during the day varies according to the individual. It naturally should have some relation to the solids, but this too is uncertain.

The physiology of thirst is ill understood. It seems to be connected somehow with diminished fluid in the body; it is probably a nervous phenomenon expressing a demand for water in the tissues to distribute salts between the tissues and the blood, and thus to maintain a proper metabolism. It occurs, first, where there is increased excretion of water, *e.g.*, through the skin (sweating), in physical exertion, in tuberculosis, etc.; through the kidneys—in diabetes mellitus and insipidus, in chronic Bright's disease; through the bowels—in diarrhœa, dysentery, cholera, etc.; through hemorrhages, through vomiting, etc. Again, it occurs in gastric disorders—from faulty diet, *e.g.*, excessive salts, spices, alcohol, etc., because more fluid is excreted by the mucous membrane than is absorbed; or there may be interference with the absorption of fluids, as occurs, for example, in gastrectasis, especially from stenosis of the pylorus. In such a condition there is marked motor insufficiency, and therefore a notable alteration exists in the relation between the amount of water taken and the quantity of urine excreted. Then, too, it occurs in gastritis secondary to alcoholism or to Bright's disease, in ulcer of the stomach, gastric neuroses, supersecretion, etc.

The sensation of thirst is mainly in the back of the mouth and fauces. To allay it, absorption of fluids is necessary. Hence the great thirst in gastrectasis, where the muscle is so diseased that though much fluid is taken none is pushed into the duodenum, and therefore none is absorbed.

Stimulation of saliva by acids also helps to allay thirst. On the other hand, too much water often hurts digestion, and, vice versa, in some conditions it helps greatly, as, for example, in gout, rheumatism, and many general infectious diseases, where a flushing out of the tissues occurs in this way.

Pain.—Two features of importance should be remembered in this connection:

1. Pain in the stomach, so called, especially that which occurs after meals, is more often merely a sense of weight or discomfort.

2. Oftener than not, pain in the stomach, so called, is really in the intestines, perhaps the colon, or more rarely in the gall bladder or associated with renal calculi, neuralgic conditions, or muscular rheumatism.

Pain when really in the stomach, however, is often a valuable sign, and one should ascertain details in regard to its locality, intensity, time of onset, general characters, etc. It is well to remember that many gastric diseases are quite painless; that in other cases, on the other hand, pain is a mere incident of such a disorder, for example, as simple meteorism.

Site.—When associated with gastric digestion the pain may be in front. This occurs in dyspepsia with atony of the stomach, and with distention, ulcer, gastroptosis, etc. It occurs in the back in ulcer chiefly; between the shoulders in ordinary dyspepsias of all mild forms; in the chest in cardialgia, whether hyperacidity, hypersecretion, or gastric ulcer be present, or not. It is in the left side or in the axillæ, more commonly, when there is distention or flatulence.

The intensity may vary; it is more severe in ulcer, cancer, great distention, and acute gastritis; it is more mild in atony and chronic gastritis.

As regards the time of onset, the pain may be periodical as in gastroxynsis, or chiefly after eating as in cases of ulcer, gastric or duodenal, and of cancer; or it may appear long after eating, and particularly before a subsequent meal, as in hyperacidity. It is continuous chiefly in cancer.

The general characters refer, for example, to the burning of hyperacidity, the boring pain of ulcer, and the dragging pain of gastroptosis.

The cause may be either a direct irritation or simple nervousness, or the pain may be associated with some general disease not primarily gastric, as is the case in anæmia, chlorosis, tuberculosis, malaria, acute diseases of the central nervous system; more especially in tabes, myelitis, multiple sclerosis, and neurasthenia.

Again, pain may occur as a local neuralgia, the so-called gastralgia, in which condition the indications point less to the need of dietetic treatment than to that of rest and of other general measures.

Heart-burn, Cardialgia, Water-brash, and Pyrosis.—These terms, while differentiated by some, are very apt to be used more or less as synonyms. In the case of heart-burn and cardialgia the pain is the prominent feature, while where water-brash and pyrosis are present there is apt to be an associated regurgitation of fluid. Small quantities of fluid, sometimes acid, sometimes alkaline, are regurgitated along the œsophagus and into the pharynx, where they are tasted. The acids are usually organic acids, and the taste under such conditions is apt to be mawkish rather than burning.

The fluid may be alkaline from saliva, which is excreted at first because of gastric irritation, then swallowed, and again rejected from the stomach.

Sometimes gases alone, chiefly ammonia, cause this condition. According to Ewald, it is purely a motor neurosis, while according to Brunton the lower end of the œsophagus is protruded into the stomach like a prolapsed rectum, and being sensitive, is irritated by the greater acidity of the stomach contents.

The relief for this condition is obtained usually by a proper diet, suitable to the acidity, by the administration of bicarbonate of soda, by suitable purgation, and, if fermentation be present in any large amount, by the employment of lavage. It is only in very severe cases that opium is indicated.

Flatulence implies expulsion of gas from the stomach, and is due to the presence of too much gas in the organ. There are two or three ways in which it reaches the stomach:

1. By the swallowing of air, either associated with the saliva, in which carbonates are present, or with food containing carbonates, or with effervescent drinks.

2. The air may be generated in the stomach, either through fermentation or decomposition, or possibly through the separation of gases from the blood, or through the exchange of CO_2 and nitrogen; or, lastly, it may come from the secretions of the glands.

3. Air may be regurgitated from the intestines into the stomach, as has been demonstrated both experimentally and practically.

In atony of the stomach gas readily accumulates and fermentation is favored; often in neurotic people flatulence is persistent, with perhaps evidence of gastralgia. The gas ejected is usually odorless, and if acid eructations are present they are usually due to the organic acids present. The condition is not infrequently associated with supersecretion of hydrochloric acid. If putrid gas-like sulphureted hydrogen be ejected, one may conclude that fermentation and decomposition are taking place. This gas formation, however, is so uncommon in cancer of the stomach that some authors attach some diagnostic value to the fact. Marsh gas is not infrequently formed in the stomach and likewise expelled.

Borborygmi is a name used to imply the presence of air and peristaltic movements of the stomach and intestines, coming as it does from the Greek word βορβορύζω, "I have a grumbling in the bowels." In some cases this flatulence yields readily to treatment when the causative factors, such as dietetic errors with too much starchy foods, are removed, when the neurosis is properly treated, or when, as the case may be, decomposition or other disturbances occur in the gastric digestion. For the immediate relief peppermint, carbonate of magnesia, and bismuth preparations with bicarbonate of soda, are perhaps the most suitable. In some cases I have seen persistent relief obtained from the use of ordinary essence of pepsin. When constipation is present the bowels should be regulated.

Vomiting.—This is expulsion of the gastric contents through the mouth. This must be distinguished from retching, which is an effort at vomiting, due to the contraction of the gastric muscles together with the diaphragm and the abdominal muscles, the cardiac end of the stomach being closed or the stomach itself being empty.

It must be distinguished too from regurgitation, which implies simply the flowing back, as far as the pharynx, of food, liquid or solid, through the stomach; while rumination, corresponding to chewing of the cud, implies not only regurgitation of food, but the subsequent mastication and reswallowing.

True vomiting as it affects the stomach is due to local causes, and is to be distinguished from various other forms, of which the two chief ones are the central and the reflex vomiting.

The *central vomiting* is due to direct stimulation of the vomiting centre, which is in the medulla, and it occurs usually without the usual premonitory signs which accompany true vomiting, or with only a few of them. These premonitory signs are usually yawning, pallor, depression, sweating, salivation, nausea, etc.

Certain drugs induce vomiting, as, for example, tartar emetic, apomorphine, and ipecac. So, also, do various cerebral diseases—tumor, meningitis, and injuries to the medulla oblongata.

Sympathetic causes come under the same heading, as, for example, associations, sensory impressions, seasickness, etc., and lastly, the vomiting of hysteria and neurasthenia.

Reflex vomiting is that which is induced in a great variety of maladies, of which a few may be here cited as examples: Bronchitis, tuberculosis, and emphysema, in which either the cough or the expectoration is liable to induce the vomiting; pharyngitis, especially in alcoholics, where the mucus collected over night is swallowed into the stomach and induces the morning vomiting of drunkards; gall stones and renal calculi, particularly with great pain; strangulated hernia; diseases of the genital organs; severe pain anywhere in the body, and toxic conditions like uræmia. The onset of acute infections, especially in children; pregnancy at certain periods in its course; the chronic form of certain metallic poisons, like arsenic, lead, etc., and Addison's disease—all these are accompanied at times by a vomiting which cannot be classified as any other than *reflex*.

In *true vomiting*, on the other hand, there are premonitory signs. The patient becomes dizzy, pale, often the pulse increases, retching may follow, and then comes the onset of the vomiting. This has sometimes a definite relation to food. If it occurs after meals and is not due to a neurosis, it implies an organic disturbance of the tract; it may be due to ulcer, some inflammation, atony, cancer, stenosis of the pylorus, supersecretion, etc. Sometimes it comes on at once after meals, and sometimes again only several hours later, as occurs chiefly in atony and dilatation of the stomach.

Sometimes, as already mentioned, it occurs only in the early morning (the vomiting of drunkards which is usually associated with pharyngitis), while in supersecretion the vomiting occurs either early in the morning or during the middle of the night.

Periodicity in the vomiting is likewise a not infrequent occurrence in several diseases, such as dilatation of the stomach, where it may be present every two or three days, and then it is usually copious in amount.

The vomitus varies according to the cause, the food, the time, the nature of the gastric conditions, etc. One must note the amount of digestion undergone by the individual foodstuffs, notably the proteids and starches; also the presence of food taken more than seven hours previously, which in itself is an evidence of some dilatation.

There may be pus, blood, bile, saliva, and mucus present, and the color may be the same as that of coffee grounds. This color is frequently due to altered blood, but may have some relation to the previous nature of the food—blueberries, currants, etc.

The odor of the vomitus is comparatively unimportant except in intestinal obstruction, where it, of course, is apt to be fæcal in character.

The taste varies; it may be often acid and burning, or simply that of the food taken; but when decomposition has occurred it may be putrid in character.

It is also of some importance to ascertain if the vomiting gives relief, as various diseases are thus in part differentiated.

The quantity of the vomitus is of decided importance. It is considerable in stenosis of the pylorus with dilatation of the stomach; it is usually small, on the other hand, in chronic gastritis and ulcer, unless marked gastrectasis be concurrent.

Dyspnœa.—This is not uncommon in indigestion and is associated with distention of the stomach and pressure upon the diaphragm, as well as with interference with the ordinary movements of the heart. Usually if the dyspnœa be marked there is some graver underlying condition, such as anæmia, asthma, cardiac disease, etc. It may occur every few hours or only after several days, and is accompanied by a sense of fear and oppression, and usually by some palpitation.

Palpitation.—The anatomical relations of the heart and stomach play only a small part in the causation of palpitation. As a matter of fact, this sensation does not often possess much significance. The more serious form of palpitation is often associated with myocarditis or with angina, and under such conditions a heavy meal is not infrequently followed by a fatal syncope.

Tachycardia is comparatively rare, and when present is usually paroxysmal. It is more frequent after middle age, at the menopause, in neurotic, anæmic, or cardiac patients, and in those too who are habitués of tea and tobacco. It is more frequently present with flatulence.

Drowsiness.—This may be present either after meals or at any time, and is directly due to the relative anæmia of the brain from the extra demand, on the part of the stomach, for circulating blood.

Insomnia may be due to a coincident organic disease of the brain, etc., or to sleeping during the day, or, again, it may be due to motor insufficiency of the stomach, the remains of food being carried on into the night. The insomnia may be a temporary affair merely, or it may be chronic. A late supper may be very slowly digested during sleep, therefore not only is there insomnia but restlessness, and bad dreams are very apt to follow.

Vomiting frequently gives relief in such cases, and when this cannot be induced, lavage will have the desired effect.

Vertigo.—This symptom may be of little or of grave significance. The simple condition is not very uncommon in cases both of acute and of chronic indigestion, when the stomach is either full or empty. Milder forms occur after meals or upon exertion, or even when the patient is at rest. The vertigo is momentary in time, and there is neither fainting, falling down, nor coma. It may be accompanied by nausea and vomiting or some other digestive disturbance, and the taking of food not infrequently relieves the symptoms. Its sudden onset is rather characteristic.

One should be careful to exclude the more serious causes of vertigo, *e.g.*, Ménière's disease, an incurable condition in which there is usually deafness in one ear and a sensation of circular movements; petit mal, in which coma and perhaps alternating convulsions are present; tumor of the brain, which has its special signs, as have also tabes, ataxic paraplegia, cardio-renal disease, anæmias, errors of refraction, etc.

Cough.—In indigestion cough is usually associated with some irritation of the throat from pyrosis, and is more especially apt to occur if the tonsils be enlarged or a pharyngitis be present. A distended stomach pressing on the diaphragm may, by mechanical means, induce a cough, but perhaps the most common cause of cough is that which is associated with the ingestion of meals—in various pulmonary disorders, in chronic bronchitis and in emphysema, for example, where the diaphragm is less active and there is defective oxygenation of the blood, and when more mucus collects. For this reason, too, large meals are more apt to cause a cough than small ones. Then, again, the cough may be reflex, as is the vomiting too, as already mentioned in speaking of tuberculosis.

The General Treatment of Indigestion.—The first essential for a good digestion is a proper daily regimen. A suitable environment, physically, mentally, and climatic, is what renders the ordinary health resorts with their regular routine of life so excellent in the treatment of chronic forms of ordinary dyspepsia, and neither the specific drugs nor the specific waters can be said to confer one-half the benefit which accrues to habitués of these sanitaria.

In addition to this, the wearing of proper clothing is an essential element. Clothes worn too tight, and corsets too much laced, interfere with the action of the diaphragm, of the stomach and liver, and in this way easily induce dyspepsia.

The occupation of the patient must likewise be considered; it should, as far as possible, be in every respect free from mental strain or anxiety.

The number of meals should be regulated, as should also the intervals between them. The food should be taken slowly, for digestion in the mouth is extremely important. Mastication and insalivation are essential to proper digestion, and the teeth should therefore be duly cared for.

Rest and exercise should be carried out in accordance with the needs of the case. After each meal and also before meals, it is well for everybody to rest a short time; at other times exercise, if moderate, aids digestion; the gastric motor power becomes more quick and the intestines act more readily. While this is true of healthy people, it is all the more important in cases of disease. After heavy meals all persons should rest, and, later on, they should exercise in the open air. Rest is most essential in cases of gastroptosis, gastrectasis, hyperacidity, and cancer. Not only should the rest be physical but it should also be mental.

As regards the dieting, the prophylactic measures in this respect have already been mentioned, and each case must be treated on its own merits, in accordance with the views already expressed or to be mentioned.

Too much fluid should never be taken with meals, while before meals a glass of water, particularly hot water, is of benefit.

Frequently warmth is of benefit to some patients, and for this reason, and this only, does one obtain relief from the use of flannel belts about the abdomen.

The *medicines* which are given are perhaps the least important features in the treatment of dyspepsia. To stimulate the secretory and motor power of the stomach when necessary, and to lessen decomposition, are the main factors of use in medicines. As a rule, it is not possible by medicines to accomplish much even in this respect, though other measures, mechanical or dietetic, may be helped by the judicious administration of certain drugs.

Medicines which are intended to increase the appetite and stimulate secretion are numerous, and stomachics, as they are called, are variously lauded or frowned upon by the specialists. Reichmann holds that the use of bitters upon an empty stomach—no matter whether its secretion be normal or abnormal—exerts no immediate effect upon these secretions; it is only a little later that bitters stimulate them somewhat. When taken with the food they interfere with gastric digestion. Riegel strongly recommends the use of condurango bark, while others again successfully employ orexin to stimulate the secretion. This last drug, however, is frequently followed by disagreeable symptoms, such as nausea and vomiting.

A favorite prescription of the English authors is the following: Sodium bicarbonate, gr. x., tincture of gentian, ʒ ss., and peppermint water, ℥ i., three times a day before meals.

When too much secretion is present, on the other hand, powders of bismuth and soda, with perhaps some powdered nux vomica and compound cinnamon powder, may give relief, as recommended by Brunton, both because of their sedative action and from the fact that such powders in bulk the more readily absorb acids.

The Use of Acids, especially Hydrochloric Acid.—It is now well established that the hydrochloric-acid secretion of nature cannot be artificially replaced. If hydrochloric acid is absent from the stomach contents, one cannot administer it artificially so as to get the free acid back after a test meal. Nevertheless, its use, where hydrochloric acid is absent, aids in promoting the digestion of proteids; it should be given with a glass tube after meals, or as a stomachic one-half hour before meals. It is contraindicated when hydrochloric acid is in excess.

The Use of Alkalies.—Reichmann's experiments show that sodium bicarbonate, taken either on an empty or on a full stomach, has no influence whatever on gastric secretion, but it lessens total acidity, that is, it acts upon the juices abnormally secreted, as takes place, for example, in hyperacidity, hypersecretion, and gastric ulcer, where it is useless to stimulate the secretion. One should never give alkalies unless hydrochloric acid is the cause of the acidity; it should also never be administered where organic acids are present. An excellent way of administering alkalies is in powder form, combining sodium bicarbonate, calcined magnesia, and powdered cinnamon, they may also be given in the form of Carlsbad salts, or of Kutnow's powder, in the early morning before breakfast.

The Use of Pepsin.—Pepsin is employed in various forms: powder, pill, combined with hydrochloric acid, in fluid essence, and as various tinctures. The pure article, the so-called absolute pepsin, is by far the best; it should be given in doses of from five to fifteen grains; the official preparation is given in doses of from thirty to forty-five grains. Most preparations of pepsin, it may be said, are unreliable. Those which are combined with various alcoholic media are useless, except for the alcohol which they contain, and which is largely responsible for the aid which they give to digestion. Technically and *in vitro*, there would seem to be no benefit, or but little, from the use of pepsin. There is always enough secreted even when the hydrochloric acid is plentiful, as well as when it is deficient in quantity

The indications for the use of pepsin are found in those conditions in which it is either deficient or absent Now if it be deficient, the only requirements are medicinal amounts of hydrochloric acid to make the pepsin active. If, on the other hand, pepsin be entirely absent, so much hydrochloric acid is required to make the pepsin active that it is impossible to administer the drug in that way. However, it must be admitted that one often meets in practice instances in which the benefit derived from the use of this drug is undoubted, the fluid essence perhaps being the most suitable preparation of all.

Pancreatin.—Pancreatinized foods are used where hydrochloric acid is deficient, in order to aid intestinal digestion. The powder acts on the stomach itself, and its value is probably confined to cases such as those mentioned. Unfortunately, most of the preparations when tested are found to be negative. Some, however, made by the more reliable firms are good, and are used in pellet form with sodium bicarbonate.

Saliva is never much diminished in indigestion, but a very great excess of hydrochloric acid causes it to lose its activity, and under such conditions *ptyalin* is sometimes of benefit.

The preparation known as *takadiastase* acts in the presence of even 0.05 per cent. of hydrochloric acid, and hence is apt to be better than others, which act in only 0.01 per cent. of hydrochloric acid.

When much decomposition occurs in the stomach, lavage is probably of much more use than medicines. The medicines, however, which give considerable relief for this disorder are *thymol*, which is prescribed in minim doses with alcohol, and *creosote*, which may be given in the form of the carbonate, or pure, as a pill.

III. MOTOR INSUFFICIENCY.

1. *Relative* or symptomatic, as in stenosis of pylorus (*q.v.*), or in cancerous or benign obstruction. This may be atonic or hypertonic.

2. *Absolute*, as in idiopathic dilatation, simple atony, atonic dyspepsia, simple gastrectasis.

Definition.—Motor insufficiency is a relative or absolute lack of power on the part of the muscular wall of the stomach to propel the food through the pylorus within the normal time.

(For relative insufficiency see paragraphs on stenosis of the pylorus, carcinoma ventriculi, etc.)

Absolute motor insufficiency, or idiopathic dilatation, has two periods:

1. *Stagnation*, which has two forms: mild atony and severe atony. In stagnation there is delay in evacuation of the stomach contents. In mild cases the stomach becomes empty between any two successive meals; in severe cases it is empty only in the early morning.

2. *Retention*.

Etiology.—(*a*). Excessive work for the stomach is the essential cause. Such excessive work is inflicted by deviations from the normal diet; *e.g.*, the taking of food which is faulty as regards quantity, quality, or mode of preparation.

(*b*) The propelling power may become weak through other causes, *e.g.*, hereditary weak stomach; trauma or peritonitis may weaken the gastric muscle; wearing improper clothing; prolonged sedentary habit; disease of the stomach itself; organic changes in the muscular coat; ulcer or cancer in other parts than the pylorus, apart from stenosis; chronic gastritis; degenerations—fatty colloid, or amyloid; cirrhosis of the stomach; the use of narcotics and of alcohol; constitutional troubles, *e.g.*, chlorosis, anæmia (Collier's stomach, as described by C. Allbutt), tuberculosis, typhoid fever, and nervous troubles. Great anxiety or grief may aid an already existing cause. There are acute and chronic causes.

Acute.—It may be induced *acutely*, though this is rather rare and sometimes fatal. In advanced cardiac disease with previous atony the latter is doubtless sometimes the final direct cause of sudden death. German students have it at times after severe bouts of beer drinking. Dietetic errors from mechanical causes exert most influence. The overloaded stomach may drag upon the duodenum and cause kinking and occlusion. Hasty eating and the eating of indigestible foods favor such atony, especially in children and after prolonged illnesses, in anæmia, and in various forms of dyspepsia. This is usually temporary and fairly common, and may be mistaken for acute gastritis. It is not due to spasm of the pylorus, as some think, for this orifice is often found open in such cases, and bile has frequently been present in the organ. Neither is there evidence of gastritis, neurosis, or fermentation.

Chronic.—The main causes are frequent heavy meals, hasty eating, especially of vegetables; drinking much fluid frequently. In this way the forced milk cures are sometimes responsible for prolonged atonic conditions of the stomach. So, too, beer and gaseous fluids may induce the same condition.

Pathological Anatomy.—Simple slight atony shows no obvious pathological changes. When gastrectasis exists there may be partial dilatation, *e.g.*, a diverticulum, or general idiopathic dilatation. The lowest point is first involved—the fundus and greater curvature. The muscle is thinned and atrophied, and if the condition has lasted long enough there may be fatty degeneration. Sometimes the wall is compensatorily thickened. Displacement of abdominal viscera may be present.

Symptoms.—These depend on the degree.

Simple Atony.—In *mild atony* there may be no symptoms, or very indefinite ones, with lassitude and heaviness, or a sense of pressure and fulness after meals; perhaps flatulence, with or without a tasting of food taken previously. *This is the commonest of all forms of so-called dyspepsia*. The symptoms are at first present only after the chief meal; later, after each meal. The appetite varies; it is good before the meal, but easily appeased, and there may be cardialgia, and even cramp-like movements (peristalsis), without pyloric obstruction. In such cases there is usually increased secretion of HCl, or of the total gastric juice. There is usually increased thirst owing to the non-propulsion onward of the water, and thus less is absorbed (water is not absorbed by the stomach).

Dizziness, headache, depression of spirits, stupidity, physical languor, and deafness are not infrequent; they are doubtless due to the abnormal dryness of the tissues, to auto-intoxication, and to inanition. The patient may complain of insomnia, especially if hypersecretion is also present. Circulatory disturbances with palpitation or intermittency, also urticaria and erythema, may be superadded. Cold extremities are complained of, and if the disorder is prolonged the patient often looks sallow and his features drawn.

Vomiting.—There is nausea, and even in mild cases sometimes vomiting, though slight and intermittent and at long intervals.

Intestinal symptoms may supervene, with pain, diarrhœa, and mucous stools. Unless there are complications or faulty dieting, the general health and strength are maintained.

Objective Signs.—These depend also on the degree of the atony. The food may be merely stagnant or it may be retained.

Inspection usually shows nothing, or at most slight distention or prominence of the epigastric region.

Palpation often gives a peculiar sense of *even resistance*—flabby, however, rather than tense.

Percussion enables us sometimes to find a somewhat increased gastric area. This increase pertains chiefly to the fundus, which pushes up the diaphragm and gives great increased resonance up to the fourth rib and backward to the posterior axillary line. Or we may find succussion, seven hours after a good meal or two hours after a large tumbler of water. Succussion soon after a meal, obtained in persons who do not complain of indigestion, is suggestive of some atony. We may find dulness at the left parasternal line (on a level with the navel), obtained in the sitting posture, and altering when the recumbent position is adopted. In an atonic stomach percussion areas alter greatly within a very short time.

These methods are all, however, more or less unreliable. *Insufflation* by means of the Higginson's bulb syringe, or *inflation* with CO_2, are better means, and enable us to note the site of the lesser curvature, and to decide on the presence or absence of gastroptosis. *Auscultatory percussion* is unsatisfactory and not to be relied on. Of real importance is the breakfast test, as a preliminary examination. In great stagnation of food this should show the presence, say, of more than 100 c.c. of contents. Another valuable test for the motor power should be employed, viz., an examination of the state of the stomach in the early morning before breakfast. Should this reveal gastric contents there is retention of food—*i.e.*, marked gastrectasis.

Motor Insufficiency with Retention.—(Synonyms: Gastrectasis [Idiopathic Dilatation], Myasthenia Gastrica with Retention.) This is the severer form of motor insufficiency. To mere atony is added fermentation and retention; there is no interval of gastric repose.

Inspection.—The stomach is found to be flabby and much enlarged; the greater curvature may be as far down as the pubis. When patients have thin and relaxed abdominal walls the outline may be easily seen. (Unless ptosis is present the lesser curvature remains high in the epigastrium.) In uncomplicated cases the prominence of the stomach is above the umbilicus, in contradistinction to the prominent swelling of gastroptosis, which is situated lower down.

Inflation with tartaric acid and sodium bicarbonate, or *insufflation* with a stomach tube or Higginson's syringe, will readily reveal the size and situation. *Succussion* will be present in the early morning, and can often be produced at will if the patient suddenly depresses the diaphragm. Sometimes one can feel the gas going through the pyloric orifice, and it may also be heard on *auscultation.*

Percussion gives a deep tympany over the stomach. When fluid is present a dulness may be obtained in the lower part of the gastric area when the patient stands, and this will alter when he assumes a recumbent position. As a means of diagnosis for motor insufficiency this test has but a minor importance.

Fermentation is common, as there are many bacteria present, there are also pyrosis, distention, and vomiting. Vomiting is the rule, and affords great relief; it is characteristic in the following particulars: It is often explosive, but the stomach is by no means fully emptied by the emesis. Periodical recurrences are the rule, and days will often intervene between two attacks. The onset may occur some hours after eating, sometimes showing food that has been retained in the stomach for twenty-four hours or longer. The vomitus is copious; it may amount to one quart or more. It is bitter; usually it has a putrefactive or rancid odor, and is acid in reaction, from the presence of organic acids. Hydrochloric acid may be absent, however, or diminished, normal in quantity or increased, according to the underlying condition. Three layers are apt to form: the lowest containing more or less partially digested solids; the middle layer containing turbid fluid; and the uppermost is foamy, with perhaps some undigested foodstuffs, etc.

Microscopically, there are shreds of mucus, yeast cells, especially if HCl be present, and many putrefactive bacteria. Hydrogen sulphide occurs with benign obstruction chiefly, and marsh gas is not uncommon. The foodstuffs will show different degrees of digestion, according to the presence of HCl, etc. Starch is usually abundantly present, and the granules may still manifest their peculiar characters; the iodine test is also available. There are crystals of fatty acids, epithelial cells, and yeast cells, and sometimes blood cells or pigment. Sarcinæ as well as the various bacteria abound.

General Signs: The *nutrition* suffers proportionately to the degree of dilatation, especially when the secretions are diminished. The tissues become dry, especially the skin. Emaciation may be great on account of the intestines failing to do their part in digesting food which comes to them so badly prepared. The temperature is subnormal, though temporary fever may occur from an associated gastritis.

Constipation results from atony of the bowel, and dry, hard scybala are passed. There is rarely diarrhœa. Sometimes mucous colitis develops. The appetite is worse, and there is more mental depression and more insomnia than in a mild case. The urine is diminished according to the degree of the gastrectasis. It is more concentrated and has a higher specific gravity. The phosphates are increased, and the alkalinity will be marked if there be a hyperchlorhydria. The chlorides are diminished. Sometimes there are albuminuria, acetonuria, and diacetic acid.

The *heart* may be rapid and irregular, owing to the pressure of the distended stomach on the thoracic organs. Sometimes there is bradycardia, though the reasons for this are ill understood. *Dyspnœa* may occur; it should not be confounded with asthma. It is often due to tympanites; hence its temporary duration.

Neuroses of various kinds develop, and especially hypochondriasis. *Tetany* is not rare, and may be present when cases run a severe course. In two patients I have seen death result during a time when dilatation and tetany were combined and no other grave condition was present. Epileptic seizures sometimes occur.

Diagnosis.—The easiest method is by a test meal and an examination of the quantity which remains at a given time. Thus, one hour after a test breakfast there should be not more than 75–100 c.c. of contents left; anything more implies a motor insufficiency. To diagnose the degree of insufficiency one may take three steps:

1. Examination after a test breakfast: If less than 75 c.c. is extracted, the motor power is normal; if the quantity extracted is larger, proceed to the second step:

2. Examination seven hours after a dinner: If no food remains, the motor insufficiency is of the nature of a simple atony; if food still is found, one proceeds to a third and final examination, viz.:

3. Examination of the stomach in the early morning before breakfast: If the stomach be empty there is merely stagnation; if, on the other hand, food be present, the patient is suffering from the third and severest degree of motor insufficiency, *i.e.*, retention, which is equivalent to a gastrectasis.

In the *differential diagnosis* one must exclude:

1. Megalogastria, *i.e.*, a congenitally large stomach (whose motor power is normal).

2. Chronic hypersecretion, in which fluid (gastric

juice) may be found in the stomach in the early morning. This may be decided by careful lavage on the previous evening, when, if mere dilatation is present, little or no fluid will be found in the morning; whereas if supersecretion exists, juice may be removed at that time.

3. Gastroptosis. Sometimes dilatation exists with this condition. The differential point is the determination of the situation of the lesser curvature.

4. Neurasthenia. In this condition the symptoms are usually out of all proportion to the amount of retained food. Solids, too, cause more trouble than liquids in neurasthenia, while the reverse holds in gastrectasis.

5. Gastritis, pure and simple, has no motor insufficiency. The stomach is of normal size and there is mucus.

6. It is of the greatest importance to decide whether the insufficiency is idiopathic or due to an obstruction at the pylorus. The following table will assist the diagnosis:

	Atonic motor insufficiency.	Obstructive motor insufficiency.
History	None other than dietetic excesses.	Previous gall-stones, ulcer, carcinoma, etc.
Course	Slow	Rapid.
Emaciation	Slow	Rapid.
Pain	Insignificant	Is a marked feature.
Contents	A dyspepsia of liquids mainly.	Preëminently solid contents.
Peristalsis	Little or none	Much present and easily excited; the wall is hypertrophic and peristalsis may be visible and palpable.
Dilatation	Usually moderate	Extreme.
Vomiting	Infrequent, copious, liquid, incomplete, less painful.	Frequent, copious, thick, and with much solids, complete, painful; may show blood and pieces of mucosa.
Tumor	None	Present.
Lavage	Quick inflow, slower outflow.	Slower entrance, sometimes quick exit of fluids, expression of fluids easier.
Therapeutic tests.	Improvement decided with lavage.	Progressively worse in spite of lavage.

There should be no difficulty in differentiating gastrectasis from conditions such as ovarian cyst or other abdominal tumor, ascites, distended urinary bladder, pregnancy, though such difficulties are said to have occurred.

Prognosis depends upon the cause and the chance of its removal. The concurrent presence of gastritis or of intestinal disease is unfavorable. Moderate atony is easily curable, by a careful regulation of the diet. Acute cases usually recover; rarely they die. Chronic cases depend upon the degree of insufficiency. If no obstruction exists, the conditions are more favorable. The earlier the treatment is instituted, the better the prognosis. Surgery may often relieve what medicinal treatment has failed to accomplish, and a gastro-enterostomy may restore even the most advanced kind of benign motor insufficiency.

Treatment.—Prophylaxis consists in the taking of nutritious, non-voluminous food (*i.e.*, concentrated), and in advance of those causes mentioned above. The diagnosis of the condition in its early stage is of paramount importance.

Treatment is based on the etiology in regard to food and methods of eating and drinking; it must also have reference to the constitution of the patient and to the fact whether the weakness has followed some general disease like typhoid fever, tuberculosis, etc. In the latter condition, especially, atony is common, and the greatest care is required to prevent the condition from becoming chronic and intractable. Stagnation must be prevented and weakened motor power restored. For this reason no further strain must be placed on the muscular wall of the stomach. The rules and regulations concern mainly, (1) dietetic, and (2) mechanical measures (lavage, electricity, massage, baths, bandages)

Diet: Small amounts taken at short intervals will be better than three large meals during the day. The food should not consist too largely of fluids, as motor insufficiency is essentially a dyspepsia of fluids. For this reason food may be given chiefly in the form of soup, and made up of nutritious constituents in small bulk. The passage of fluids into the intestine is delayed if too much solid food be simultaneously taken. Water alone goes through fairly easily if not in excess. *Multum in parvo* is the guide (*i.e.*, concentrated non bulky nourishment). Milk is therefore good, and one may add some fine cereals to the milk—*e.g.*, barley, tapioca, rice, etc. Bouillon with egg is also a form of concentrated nourishment. The diet should depend, however, to no small extent on the condition of the secretions.

When hydrochloric acid is deficient: Fluid food and soup-like fluids are preferable to dry diet; they should be taken in small amount and frequently. If meats be taken, they should be white meats, or others hashed finely, or fish. Vegetables should be finely divided. Milk is often well borne with cereals, or with nutrose of plasmon. Lactoglobulin is also an excellent preparation.

When hydrochloric acid is increased: Solids are better, especially proteid foods, like meat; starches must be limited; butter is the only safe fat to employ.

In extreme gastrectasis feeding by the mouth may be so insufficient that nutrient enemata will be necessary. In any case water enemata may be used twice daily, even if the condition of dilatation be only moderate. One pint of water with half a teaspoonful of salt may be injected twice daily, or broths, when more nourishment is required, and to this an egg may be added. Alcohols and sugars should be avoided because their absorption induces an extra flow of water into the stomach.

Rest after meals is essential. Exercise at such times tends to injure the muscular coat of the stomach.

Mechanical Measures: Lavage is indispensable in the medical treatment of motor insufficiency if it be at all marked. In the mild cases this may not be required, though it often affords great relief, and is not merely a symptomatic treatment, but even curative, *i.e.*, in the early cases. As a rule, however, early mild cases merely require strict attention to diet and daily regimen to effect a cure. One must judge according to the individual case how much lavage is necessary in severer cases. Moderately severe cases require lavage, as delayed food leads to decomposition and hinders repair.

If food remains in the stomach even till early morning, lavage may be required twice daily: (1) before breakfast, and (2) before the evening meal. The essential is that the lavage be thorough, and that the return flow of water be finally quite clear. It may be necessary to wash out the stomach with the patient in various positions, standing and lying down. Much time and patience may be needed, and often an hour is required before the water returns perfectly clear. The method is similar to that described under "Methods of Examination," on p. 490.

How long should one keep up lavage? This must depend on the remains in the stomach. It should be done daily till we are sure that digestion is not delayed over night. Mere warm water suffices, unless there is great fermentation, and one may then employ salicylic acid (two per mille) or boracic acid in a two per-cent. solution.

Electricity, while often used in vain, is certainly of benefit sometimes, notwithstanding the contrary evidence of experiments upon dogs. Faradism over the stomach, with large electrodes, has a stimulating effect which benefits digestion, either because of its general effect or through the local stimulus to the abdominal wall. There is no advantage to be gained by intrafaradization.

Massage is beneficial in a general way, but it must be employed systematically, and over a sufficient period of time. It is not supposed to be of direct benefit to the muscle of the stomach.

Hydrotherapy is of the greatest benefit, in fact, apart from lavage there is no treatment which compares with it. Cold douches daily with proper friction afterward are most commendable.

Bandages of a supporting nature, or proper-fitting corsets which support from the pelvis, are useful; such corsets are constricted about the hips, but are loose about the epigastrium and lower part of the thorax, thus affording room for breathing, and not allowing the stomach to be without support from below.

Medicinal Treatment.—*Strychnine* is probably the most suitable of all drugs, and may be given in moderate doses after meals. Condurango bark has been recommended in those cases in which the appetite is deficient. It may be given in doses of fifteen to twenty drops of the fluid extract, or may be prepared as a decoction with the addition, afterward, of HCl. If there are signs of supersecretion, atropine may give relief.

For *constipation* purgatives are to be avoided where possible. Cascara and colocynth may be recommended. Massage, proper exercise, and occasional injections of water and oil may not only excite peristalsis but soften the stools. Two per week are sufficient. But few saline waters are useful here. The Carlsbad (Sprudel) are the best of all the salts.

For *vomiting*, diet and lavage should suffice; or if they do not, then nutrient enemata may be employed. Should the symptoms still persist and if they are not due to mere irritability, surgical intervention may be recommended.

For the *thirst*, a Dover's powder, gr. iv., will often be of service.

Surgical treatment in dilatation of the stomach is indicated in: 1. Acute cases in which medical treatment is contraindicated or useless, *e.g.*, twisted duodenum.

2. Idiopathic dilatation (atrophic or atonic form): (*a*) When the medical treatment (dietetic, mechanical, etc.), though beneficial, must be continuous and cannot be properly carried on; or (*b*) when these means fail to relieve sufficiently. The weight of the patient under treatment and the strength and the amount of urine serve as good criteria.

It is well not to wait too long, lest the enfeebled condition may make operation more difficult to withstand.

3. Stenosis of the pylorus (*vide infra*).

The *objects* desired are: To remove the cause of the insufficiency and gastrectasis; to remove the consequences of insufficiency and gastrectasis, *i.e.*, stagnation and retention, and thus give readier transport of food to the intestines.

Patients must realize that with gastrectasis they cannot with benefit carry on the usual routine of living, but that special care is absolutely essential.

Kind of Operation: Gastro-enterostomy, as being simplest and most rational, is by far the best, even when stasis exists. Of this, *vide infra*.

Bircher's operation, to diminish the size of the stomach, affords no benefit and has many disadvantages.

IV. HYPERCHLORHYDRIA.

Definition.—Increased secretion of the hydrochloric acid with the gastric juice during digestion. This is to be distinguished from hypersecretion in which the gastric juice is secreted in excess, not only during digestion, but also at any period of the day or night. It is a symptom rather than a disease *sui generis*, and occurs as a neurosis purely or as a reflex irritation from organic disease of the stomach itself or of other organs (pyloric stenosis from cicatrized ulcer, cholelithiasis, etc.).

Etiology.—This is a very common affection, occurring in young adults rather than in old people, and equally in both sexes.

Among the causes which have direct relation to the disease are chlorosis, neurasthenia, melancholia, psychical disturbances, generally worries and excitements; dietetic errors (eating too quickly or at irregular intervals, especially food which is irritating, *e.g.*, too cold or too hot food, spices, coffee, alcohol). The condition is common in students and overworked business men (stock-brokers). It frequently accompanies ulcer of the stomach, excessive use of tobacco, renal calculi, cholelithiasis, etc., and is often, too, associated with biliary affections and migraine.

Symptoms (in pure hyperchlorhydria with normal motor functions).—The symptoms occur always during digestion, either after each meal or mostly a few hours after the chief meal of the day. Inasmuch as the symptoms arise coincidently with the appearance of the free HCl, their time of onset will depend on the size of the meal (*i.e.*, on the amount of the stimulus). The symptoms bear no ratio to the amount of HCl secreted. There are in pure cases usually a gradually increasing uneasiness, discomfort in the epigastrium, with acid eructations, and heart-burn. About the same time pain appears, which may be slight or severe or of a burning character, and perhaps followed by water-brash or, more rarely, actual vomiting. As a rule the ingestion of food, especially albuminous food, or alkaline drinks, affords temporary relief, while vegetarians find but little comfort under similar circumstances. Headache and dizziness may be present, but all the symptoms disappear as the stomach becomes empty. The appetite is usually good, often voracious (*Heiss-hunger*), and there may be great thirst. Constipation is frequent.

These patients, as a rule, have comfortable nights, and maintain good general health and nutrition.

The *objective* signs present are chiefly a diffusely tender epigastrium, especially during digestion, slight enlargement of the stomach upon inflation, while a test meal reveals a normal motor power, well-digested albumins, and less digested starches. The total acidity is variably increased, the increase being due to HCl. The contents may be rich in ferments, and no bacteria of importance are evident.

Course.—The symptoms may come and go irregularly or periodically; sometimes after certain kinds of food, or sometimes only after psychical or other causes, and in spite of a proper diet. Sometimes there is no pain at any time, even with great hyperacidity, and Riegel is evidently justified in insisting on an examination of the contents to establish a diagnosis.

Cases last for a variable period, most often with remissions and exacerbations, and a cure in aggravated cases is effected only when the cause is removed. In other cases symptomatic treatment alone is of use, and the underlying condition (*e.g.*, tabes dorsalis) keeps up the trouble persistently.

All grades of the condition may occur, from slight temporary attacks of hyperchlorhydria to the advanced condition of chronic hypersecretion.

Prognosis.—The prognosis is good if the condition be uncomplicated. Even after relief has been afforded, however, recurrences are very frequent.

Diagnosis.—The *subjective symptoms* often suffice for a diagnosis. Thus, for example, the pains coming on at definite periods after meals, the relief afforded by certain foods, the good appetite and preserved nutrition, are all important. An accurate diagnosis, however, depends on a chemical examination of the contents and the finding of excessive secretion of free HCl. The presence of free HCl, shown by a qualitative test, and the finding of a total acidity of 70 by the burette after a test breakfast, or of 80 after a test lunch (Germain Sée), indicate a hyperchlorhydria. The excess may double that amount.

One must exclude ulcers of the stomach, gall-stones, and Reichmann's disease (chronic hypersecretion).

The *morbid anatomy* is practically *nil* in pure cases.

The complications are hypersecretion, dilatation, and ptosis.

Treatment.—The daily regimen is of paramount importance. The daily life should be regulated and cares avoided where possible. Proper exercise, especially riding and the like, and a cold bath every morning, are to be advised. Patients should rest after meals.

Medicinally, sodium bicarbonate or magnesia usta in hot water taken half an hour before the pain is expected, usually prevents attacks.

Diet List: Food should be eaten at regular intervals, and slowly, and should be well masticated, and it should not be too hot or too cold. One should avoid anything which stimulates secretion of HCl, *e.g.*, coarse, insoluble foods like cabbage, turnips, celery, carrots, nuts, fruit cores, etc.; too much fatty food and too much sweets; sharp spices, *e.g.*, pepper, mustard, vinegar and other acid foods, horseradish, rich salads, and very salty dishes. Avoid also coffee, beer, and strong alcoholics.

For beverages one may take Apollinaris, seltzer, Vichy, soda waters, etc., with a little mild wine or milk.

Of proteid food one recommends eggs, fish, meats—veal, beef, mutton—and limits starchy foods, which should be well divided up and combined with proteids; also dextrinized forms, *e.g.*, toast or, as soup, oatmeal gruel. Potatoes must be mashed, and sugar should be taken in solutions if no atony exists.

Sample Dietary: 1. Early breakfast: 7–8 A.M., weak tea, milk, or cocoa, dry toast with butter.

2. Late breakfast: 10 A.M., roast meat or chicken, or eggs, toast, and weak tea.

3. Dinner: 1 P.M., soup with egg; roast meat, chicken, or fish; asparagus tops; a little mashed potatoes; omelette soufflée; Vichy or Apollinaris with hock or claret.

4. Tea: 5 P.M., tea and biscuits.

5. Supper: 7–9 P.M., cold meat sandwich, or a hard-boiled egg at bedtime, cocoa or milk, or a little honey instead, Swiss or Dutch cheese and crackers.

If the appetite is good, meals Nos. 1 and 4 may then be omitted, and but three meals daily taken; if the appetite is poor, four or five small meals should be taken daily.

Alkalies are taken as directed, and among the most useful are the Sprudel salts for constipation, one teaspoonful being taken in hot water before breakfast.

V. HYPERSECRETION.

(Synonyms: Continuous Secretion, Reichmann's Disease, Gastro-succorrhœa Continua Chronica).

Definition.—An excessive secretion of gastric juice, usually hyperacid, occurring not only after meals, but during fasting also. This is more often a symptom than an idiopathic disease, and occurs probably oftener than is realized in benign pyloric stenosis and certain forms of chronic gastritis; also in gastric neuroses. It is at times paroxysmal and recurrent (the intermittent form), and has been called gastroxynsis (Rossbach) and intermittent hypersecretion (Riegel). Patients thus afflicted are usually quite well in the intervals. To the more continuous form the term Reichmann's disease has been applied. Normally there should not be more than 20 c.c. of gastric juice at any time when the stomach is without food, and usually there is only from 1 to 10 c.c.

Etiology.—Young nervous men are most often affected. Dietetic excesses in quality and quantity, excitement and gastric motor insufficiency, are the chief direct causes.

Symptoms.—These vary according to the degree, and come on insidiously, often after long-standing dyspeptic symptoms. Early signs are restlessness, discomfort, and finally pain two to three hours after meals; then perhaps headache, nausea, flatulence, and, after another hour or two, vomiting supervenes, giving temporary relief, or the vomiting may occur after many hours of fasting. The vomitus varies in quantity, is usually fluid, of a low specific gravity, 1.004–1.006, showing free HCl usually in excess, is clear, or turbid green with bile, and bitter to the taste. Sometimes vomiting is absent.

These distressing symptoms come on frequently at night and in the early hours of the morning, disturbing the patient's sleep, a fact which is of considerable importance in the diagnosis. Added to the headache are signs of intestinal indigestion, from an over acid chyme, and constipation. The appetite varies, as also does the sense of thirst. Emaciation and weakness follow, and the patient, if untreated, often develops signs of cachexia.

The degree of these symptoms varies greatly. In some cases they are of short duration, but recurrent at long intervals; at other times several attacks may occur in a single day, or, lastly, the condition may persist and the patient be a chronic sufferer.

Examination of the patient reveals often a sunken abdomen, and perhaps an enlarged and dilated stomach, at times too a gastroptosis. The stomach contents, after a test meal of Riegel, show marked digestion of albumens, and relatively little alteration in the starches.

Diagnosis.—If the tube is passed in the early morning before food has been taken, a varying but excessive quantity of gastric juice (usually hyperacid) may be removed—an indication that secretion persists even without the stimulus of food. This is the *crucial feature of the diagnosis*, though to avoid error it is important thoroughly to wash out the stomach on the evening previous to such an examination, inasmuch as there may be a concomitant motor insufficiency (which should of course be thus excluded).

One must exclude ulcer of the stomach and duodenum, scarred ulcer, hypertrophic stenosis, and other benign obstructions at the pylorus, and finally organic cerebral and spinal-cord lesions.

Course and Prognosis.—The course depends upon the possibility of removing the cause. Intermittent cases are usually easy to relieve. These idiopathic cases may, if mild, be readily cured by treatment. The severe ones may last for years, and then usually result in a complicating dilatation. In such cases the symptoms become aggravated and patients suffer much, especially at night. Death does not occur from the simple idiopathic condition, but in complicated cases it may follow from marasmus or fatal hemorrhage from an ulcer.

The prognosis is uncertain. Recurrences of the mild condition are common; complicated cases are especially difficult to cure. Operation (gastro-enterostomy) relieves cases with marked dilatation and motor insufficiency.

Treatment.—Treatment must be directed to prevent stimulation of HCl, and yet to afford enough nutrition without overburdening the stomach. Hence those substances should be taken and avoided as in cases of hyperacidity (*vide antea*). Special care must be taken in the diet to avoid the onset of motor insufficiency, or, if it is already present, to prevent its increase. Hence meals must be nourishing and in small volume. Fluids and starches must be limited, the latter finely divided, and given when the stomach is freest from HCl. In most cases it is well to give food five or six times daily in small quantities each time.

Lavage is useful in most cases, and is essential where atony is marked. It is best carried out, as Riegel suggests, before the evening meal. Pains are thus relieved and digestion made more easy. Alkalies, however, often suffice to relieve the pain, and are given before digestion reaches its height. If no atony exists, one may give alkaline waters with benefit; or one may use powdered calcined magnesium and sodium bicarbonate. Atropine sometimes gives remarkable relief, while others find in Dover's powders immense benefit.

Gastro-enterostomy is of value only where marked motor insufficiency is present, and in such cases it is useful, not only in aiding digestion, but also in relieving the pains and discomfort of faulty digestion. The excessive secretion need not thereby cease. It is doubtful if the direct application of galvanism to the stomach has more than a normal effect on the condition.

Hygienic conditions and daily regimen are to be provided for, as in cases of hyperacidity.

VI. NEUROSES OF THE STOMACH.

To group the neuroses of the stomach one may well follow the German method, according to which neuroses are: motor, secretory, or sensory. Even more than in other classifications these divisions overlap, neuroses of different groups frequently occurring in one patient. Leube even puts into one group those cases which show a combination of two or more of the above divisions. These he speaks of under "Nervous Dyspepsia," in which chapter he shows that the sensory disturbances predominate.

And one is reminded here that no irritation or disturbance can be felt by the stomach or transferred to the centres, or *vice versa*, except by means of the nervous system. Every gastric trouble then is, strictly speaking, largely nervous. We now know, too, that for the secretion of gastric juice the undisturbed function of the vagi is essential, the mere mechanical irritation of the gastric mucous membrane not always sufficing, while suitable stimulation of the mouth or gullet, or even some of the organs of special sense, will call forth the secretion. The circulation in the stomach, too, as well as the secretion, and the muscular tone are controlled, for the most part, directly by the nervous system.

The causes of gastric neuroses in general are those which so incoördinate the nervous system by afferent impulses, or so exhaust it by afferent energy, that it is unable to supply that work which is one of the essentials to gastric function. The exciting causes are frequently illustrated by persons eating large meals while in a condition of general exhaustion. A physician's eating heartily immediately after a worrying night's work in obstetrics, a commercial man's taking an unusually large meal after an anxious day, or an athlete's heavy meal after his first practice, are familiar examples. Such indiscretions are followed by distress and burning sensations, restlessness, at best diarrhœa and flatulence, leading to a "bilious" attack next day. Atony is a frequent accompaniment.

MOTOR NEUROSES.—*Peristaltic Unrest* (Kussmaul).—Strong, sometimes visible and palpable movements, not due to stenosis or ptosis, are rare. They do, however, occasionally occur as a result of increased excitability of the peripheral nerve apparatus—that is, as a motor neurosis. This may be observed even in the early morning when the stomach is empty, but it is usually worse after a meal, and sometimes produces movements even in the small intestine. This neurosis may be temporary or permanent, and it is frequently observed with ptosis. There are, of course, all grades between peristaltic unrest and that condition in which digestive movements are abnormally hastened (hyperkinesis). The patient complains of a sense of unrest, movements in the stomach, and a drawing-together of the abdominal organs which leave him no peace, although there is no pain. There are usually no secretory or other changes.

Anorexia, nausea and vomiting, and insomnia may accompany the other complaints. On inspection of the abdomen one sees the peristaltic movements. Palpation and chemical examination should exclude the presence of any organic disease.

Diagnosis. Diagnosis is easy if there is ptosis, which enables one to watch the stomach, including the pylorus, satisfactorily. If there are only subjective symptoms, one must exclude mainly stenosis and dilatation. It is well to remember that the fact of a patient being neurotic is not *per se* sufficient to insure the exclusion of organic disease!

Course and Prognosis.—This depends on finding and removing the cause.

Treatment. Remove the nervous cause if possible. General hydrotherapy may be ordered. The diet is to be non-irritating, and the evening meal light. Compresses or galvanism may be tried, and small doses of bromide of potassium.

Hyperkinesis.—This is an increased motor activity, the stomach emptying itself more quickly than normal, and is a pure neurosis. In its pure form it is a neurosis without secretory changes; but nearly always there is, preceding the condition, an increased production of hydrochloric acid. For the diagnosis one must carefully examine the stomach contents and the motor power.

Spasm of the pylorus is usually secondary to ulcer, more rarely to cancer (even if lactic acid is present in increased quantity), to gastritis, and to secretory disturbances. It is also due to dietetic errors, especially extremes of temperature of the food, or mechanical excess. According to Osler, its existence as a true neurosis is doubtful. Clinically, one hears of sharp pain and observes a prompt peristalsis, perhaps vomiting, or flatulence and distention, and a sudden relief, which is suggestive. One can sometimes feel the hard pylorus. Inflation is easy, but evacuation is prolonged. Intermittent stagnation and retention turn one's mind to this condition. Pyloric spasm, when secondary to a continuous hyperacidity, may lead to dilatation and its sequelæ.

Etiology. In searching for the cause one looks for a neurotic constitution, with worry and anxiety. The disease has been caused by biliary colic and acute enteritis.

Treatment. This is general and dietetic, according to needs. Galvanism and bromides may be of slight service.

Spasm of the Cardia.—This is a spasm of the circular fibres of the cardia with or without pain, and of variable duration. Food and secretions are retained in the œsophagus, above the spasm; gases remain below the spasm, in the stomach.

Etiology. Spasm of the cardia results from: 1. Irritants entering the œsophagus, *e.g.*: (*a*) the stomach tube, (*b*) irritant poisons, (*c*) food which has been too quickly swallowed, and (*d*) too hot or too cold food. 2. Inflammations. 3. Ulcer. 4. Cancer. 5. Hyperchlorhydria. 6. Tympanitic stomach. 7. Simple spasm. This last is rare, though it may occur at any age as a result of hysteria in neurotic individuals, and has been met in air swallowers. It is caused by tobacco, by arteriosclerosis, by tetanus, and by diverticula.

Spasm of the cardia may last for a long time, or may be of short duration and recurrent. Each attack is sudden, with painful contraction perhaps, and a sense of pressure and pain. One feels as if the food were held back about the stricture or regurgitated. In a few there is distress, with retching and vain attempts to bring up food, or actual vomiting may occur. The patient makes voluntary efforts to compress the thorax, or holds his breath, or drinks fluids in order to force the food through into the stomach. There is dysphagia or delay in swallowing, and sounds of deglutition are less distinctly heard or long delayed. In passing the tube one meets with a resistance which can be overcome.

Einhorn believes that the recurrent filling of the lower area of the œsophagus with food and taking water to force down every few mouthfuls lead to dilatation of the œsophagus. Riegel doubts this, rather regarding the dilatation, more especially the diverticula, as the result of concurrent inflammation. The dilatation may be symmetrical, pouched, or diverticular. As soon as dilatation exists dysphagia becomes constant, and there is more dyspnœa, with palpitation, contributed to by fermentation and putrefaction. A dilated œsophagus may hold more than one pint.

Differential Diagnosis. One must exclude the various non-spasmodic obstructions, such as tumors causing external pressure, or, again, organic stricture from any cause.

Treatment. Mostly prophylactic. In general the food should be of a proper temperature, slowly eaten and well chewed. If a sensitive œsophagus seems to be the cause, pass thick sounds, which gradually relieve, unless erosions are present, in which case only very soft food is allowed. As a rule in such conditions local treatment is over-treatment. It has been recommended for chronic cases to give food of the consistence of soup, to direct the patient to press the food past the stricture, to stretch with sounds, and to perform lavage daily!

Nervous Eructations.—These occur independently of meals and from nervous causes; flatulence being generally present. They may be audible, and may last for hours or days. They depend on hysteria or neurasthenia, while children produce them in mimicry. The air which escapes is not always gas generated in the stomach; it may be air which has been aspirated or swallowed chiefly the latter. The discharge is partly reflex, but mainly voluntary, the swallowing of air being followed by induced spasm of the pharynx. The paroxysm has no constant relation to food in any way or at any time. Emotions, however, are closely related to the eructations. Belching may or may not relieve. Sometimes the eructations are periodical, while at other times they are sudden and unexpected, being noisy and most embarrassing. They cease at night generally.

Diagnosis. The problem is to distinguish between the nervous and the fermentative origins. One may examine the stomach contents, though the general aspect of the case is of more significance.

Course and Duration. These depend largely on the success or failure of suggestive therapy and general treatment of the nervous system.

The *treatment* is mostly psychic, though bromides will relieve, temporarily at least. Tonics, change of climate, and hydrotherapy have done good. One can stimulate self-control by advising great care in combating the trouble.

Nervous Vomiting.—The following varieties are not included:

Cerebral Vomiting.—(*a*). Organic disease of brain, circulatory changes, concussion, tumor.

(*b*) Intoxication, *e.g.*, opium, chloroform, ether, tobacco, uræmia, cholæmia.

(*c*) Psychical, through the special senses—*e.g.*, sight of disgusting objects, or waves on the ocean.

(*d*) Reflex, due to anatomical changes, *e.g.*, neuritis, vagus affections (in mouth or in stomach); peritonitis, ileus, appendicitis, ovarian disease, pregnancy, etc.; liver disease, kidney disease (stone), worms, constipation, etc.

Spinal Vomiting.—Tabetic crises, characterized by sudden pain in the abdomen, with agonizing vomiting of food, then of mucus, often with hyperchlorhydria. The crisis may last two or three days, and in the interval the stomach is normal. Such a crisis comes either early or late in the disease and may persist. It is sometimes seen, too, in general paresis, multiple sclerosis, and myelitis.

True nervous vomiting is hysterical and therefore far more frequent in the female sex than in the male. It may come with or without other symptoms, coming easily with no preceding vomiting, and not always after a meal. In some cases it is produced only when solids have been eaten; in others, when fluids have been taken. In some patients it occurs only in the recumbent position; in others only in the erect posture. The quality of the food seems to make no difference, and there are no other dyspeptic troubles in the interval. It is striking, too, that the nutrition, as a rule, is well maintained, though exceptionally there is emaciation. Psychic influences are strong in its causation. Hæmatemesis rarely accompanies it. As a rule, the general health is unaffected. In its diagnosis one must exclude all anatomical changes and then find a cause. One must exclude, too, hyperchlorhydria, hyperchylia, and tabes.

The *treatment* is suggestive. In severe cases rest in bed with careful experiments in dieting is necessary. Lavage is useless, and one may have to resort to rectal feeding.

Periodical vomiting resembles tabetic crises. It occurs in healthy people independently of any spinal disease, suddenly and without apparent cause, often in the early morning before any food has been taken. Nausea precedes the vomiting, which is violent, and then perhaps malaise, headache, etc., follow. Vomiting begins as soon as food is taken; the vomit is copious, and when all the food has been returned the vomit becomes bilious. Then it ceases, either suddenly as it began or gradually. More food can now be taken and retained, sleep intervenes with recovery until the next attack, which is a close copy of the first. Often there is no pain, but sometimes the patient complains of cramps and of considerable prostration afterward.

Regurgitation.—There is a nervous regurgitation of liquid or solid food, apart from organic disease of the stomach. The ejected material shows no abnormality of smell or of taste and is spit out, or in some patients swallowed again. Relaxation of the cardia is suspected in these cases. In severe cases, with loss of large quantities of chyme, serious inanition has been observed (Einhorn). Intragastric faradization is of doubtful use, and strychnine may be ordered. The patient should be informed of the evils of such a habit, and her self control otherwise stimulated. When a subject of this neurosis faithfully reswallows according to order, it may give place to genuine

Rumination or Merycism.—This implies the regurgitation of food, its remastication and subsequent reswallowing. It is generally acquired through mimicry and may lead to a habit. Einhorn could collect only one hundred and six cases in the literature, and most of them were males. It is repeatedly seen in the insane, while in Montreal hospitals and elsewhere we have found it not uncommon in persons healthy in both mind and body. Like other hysterical manifestations it is influenced by critical events—it having appeared the day after marriage in one case; in another it was cured by marriage. Suggestive treatment has proved the most successful. The patient should be soundly lectured on the vice, for it is among the most disgusting of habits.

Gastroplegia.—Atony of the stomach is familiar as the result of many organic changes in that organ and of general wasting processes. A paresis of functional origin does rarely occur, in the diagnosis of which a very thorough exclusion of other causes must be carried out. The main symptom is marked motor insufficiency. Its main treatment must accordingly be directed along these lines.

Pyloric Incontinence.—This can be recognized by the presence of bile and intestinal juice in the stomach during the fasting hours, though this is not constant. Generally speaking, one is not able to force air through the pylorus during excessive inflation. An incontinent pylorus, however, is apt to prevent prolonged distention of the stomach after inflation, and a test meal is said to leave the stomach sooner than normal.

SECRETORY NEUROSES. — 1. *Hyperchlorhydria and Hypersecretion.* (Vide sections IV. and V.)

Hyposecretion and "Achylia Gastrica."—Under this heading one includes deficient hydrochloric acid, deficient total secretion, and absent secretion. The existence of the latter as a neurosis is doubted by many. Such are secondary to many organic diseases, *e.g.*, cancer, gastritis, amyloid degeneration, profound blood changes, and atrophy. They occur, too, as a neurosis. Complete achylia, it is said, sometimes occurs in tabes. In true achylia due to organic disease one can generally find without much delay definite signs of organic change, whereas in neurotic achylia the mucous membrane is in normal condition. In a case recorded by Einhorn the secretions returned after five years of total achylia gastrica! Subjectively the patient may be in good health and free of symptoms, but if motor insufficiency or intestinal trouble is present there are always symptoms. There are generally various gastric symptoms and mild enteric manifestations, though no characteristic symptom complex whatever. Objectively, one finds, on withdrawing the contents after a test breakfast, that their total bulk is small, and there is very little fluid. The food is unchanged, hydrochloric acid is absent, and the contents are neutral or faintly acid, a total acidity of four and even two having been observed. Lactic acid is absent, or very nearly so; there is no peptone, propeptone, pepsin, or rennet ferment, and no mucus.

The *course* is very protracted, and the *treatment* consists of stimulation by lavage or faradism, preparation of the food to suit the intestines, a large proportion of vegetable food, and medicinally nux vomica with hydrochloric acid.

SENSORY NEUROSES.—*Hyperæsthesia* occurs also with ulcer, hyperchylia, gastritis, chlorosis, arthritis, uræmia, irritating foods, habitual ingestion of narcotic drugs, fasting, and various excesses.

Subjectively there is discomfort immediately after a meal, whether fluid or solid, then a tingling pain throughout digestion (due to contact of food with the mucous membrane). Sometimes there are excessive nausea and vomiting. During gastric repose there is no pain, but generally a sense of emptiness, and perhaps faintness. Pain is induced sometimes by too warm food, or by pressure over the stomach, and often by the tube. The skin of the epigastrium may be tender. Fear of pain leads the patient to take an insufficient quantity of food, and this, with vomiting in severe cases, brings about emaciation. The secretions remain normal.

One must differentiate this neurosis from:

(*a*) Atypical ulcer, in which there is a distinct relation of the pain to the quality of food, to the evolution of the secretion, and to the movements of the body. The differential diagnosis is often difficult, and can often be only surmised from facts in general.

(*b*) Hypersecretion, in which the pain occurs later on, toward the height of digestion—*i.e.*, in which the pain is not related to contact, but to function and to the quality of the food. The effect of albuminous foods in hyperchylia may be to relieve; in hyperæsthesia such foods aggravate the pain.

(*c*) Hypersthenic gastritis; the differential diagnosis is the same as in hyperchylia.

Gastralgia.—Gastralgia is *symptomatic* in ulcer, cancer, gastritis, retention, gastroptosis, and hyperchylia; it is *reflex* in genito-urinary diseases, etc.; it is *central* in tabes, multiple sclerosis, myelitis, and tumors; it is *neuralgic* in neuroses, chlorosis, syphilis, auto-intoxications, and possibly in malaria.

Gastralgia is a pneumogastric neuralgia. It may be mild or severe. The pain is intermittent, *i.e.*, there are intervals of normal painless digestion; it comes suddenly, working up to a paroxysm, being felt first in the epigastrium and then shooting through to the back, with an increase in its severity. It has no relation to functional activity in the stomach, and is not associated with any dyspeptic signs except distention. This pain may last several hours or may persist during two days.

The urine is usually neutral, and on the cessation of the pain large quantities are passed. Sometimes vomiting ends an attack. The stomach contents are normal.

Gastralgia nervosa is to be differentiated from all diseases in which pain occurs at or near the epigastrium, *e.g.*, from intercostal neuralgia and myalgia; from gallstone colic; from intestinal colic; etc. In gall-stone colic the pain may also be felt to the *right* of the twelfth dorsal vertebra. The liver is enlarged and the gall bladder palpable, while there may be jaundice and fever. The colic may be related to the taking of excessive food, as in two cases which I have seen; the differential diagnosis is then often difficult. The stools should be carefully examined.

When, in a case of intestinal colic, the seat of the trouble is in the transverse colon, the diagnosis may be difficult. There may be mere peristaltic pain, or plumbism, simple distention or mucous colitis.

Gastric hyperæsthesia, hypersecretion, and hyperchlorhydria must also be considered in the differential diagnosis, nor should one omit to think of ulcer (gastric or duodenal), pancreatitis, peritonitis, etc.

Treatment. In severe cases a hypodermic of morphine should be promptly administered by the physician. In less severe cases one may try the various gastric sedatives (bismuth, cocaine, chloroform, and silver nitrate). Washing out the stomach freely with hot water, combined with hot fomentations externally, has acted well, though, as a rule, it is an unnecessary procedure. The chief indication is to treat the underlying cause (general condition).

Anorexia Nervosa.—*Definition.* Anorexia nervosa is a term applied to a sudden loss of appetite, developing along nervous channels, and in the absence of organic disease in the stomach. It is thus a pure neurosis, and occurs most commonly as a very prominent symptom in hysteria or neurasthenia, of which it forms the most striking complaint on the part of the digestive system.

Etiology. Various gastric symptoms are very common in neuropathic persons, whether the latter suffer from a slight passing irritability, a profound neurasthenia, or insanity; and this neuropathy should be looked upon as the background and the foundation of the gastric trouble. Anorexia nervosa occurs, too, in perfectly healthy people, after psychical excitement, a fright, or a sudden depression of spirits, as also after a disgusting sight or odor. In such cases the symptom is of short duration, whereas when it is a part of general hysteria it is very obstinate, becoming serious and even dangerous in many individuals. It is particularly common in young females, owing to the great prevalence of hysteria and chlorosis in such persons. Typical examples have been seen in those who abuse morphine, tobacco, or alcohol. In fact, any influence which exhausts the central nervous system may lead to anorexia nervosa, whose etiology is that of the parent disease, hysteria.

Symptoms. The loss of appetite, which is sudden and generally complete, comes on commonly immediately after the ingestion of food; more rarely it occurs several minutes after the first mouthful. The patient comes to table with a good appetite, but on beginning to eat experiences from the first mouthful a sense of satiety and even of fulness and weight in the stomach; her appetite, and, indeed, her ability to swallow, instantly leaving her. For it is more than a mere loss of appetite, and the approach of food brings about contraction of the œsophagus or an obstinate gagging, while food forcibly inserted is returned before it reaches the stomach. In less severe cases the appetite is absurdly capricious, varying quickly from one extreme to the other. When the ability to eat has gone, no suitably chosen food as to quality or quantity can well be taken, for one spoonful of fluid is intolerable. This may be lasting, and, when such is the case, it leads to loss of weight and muscular restlessness, producing muscular atrophy and contractures, so that the patient lies in flexion, and feeding her becomes a very difficult problem. Such are the extreme cases to which Weir Mitchell applied his treatment. Emaciation may be extreme, the very skin becoming dry and wasted. Patients have died from starvation. Osler records the case of a girl who died at forty-nine pounds' weight without any lesions being found after death. A woman under Riegel's care kept on reducing the size of her meals until only from two to four drachms of fluid could be taken; she became bedridden from weakness, and her weight fell to sixty-four pounds. After ten months' careful treatment she was discharged weighing one hundred and thirty-four pounds.

Diagnosis. The diagnosis depends on the history, family tendencies, and the nervous disposition of the patient, and, above all, on the exclusion of all organic disease in the stomach or elsewhere. Therefore a very searching investigation of the stomach and of the entire organism must be carried out. In the absence of any recognizable disease the symptom may depend on a hidden lesion, notably tuberculosis.

Treatment. In treating these cases, any contributory causes (abuse of drugs, excesses, anæmia) must be combated, and a cure depends largely on the personality of the physician and his ability to win and hold the complete confidence of his patient. In all severe cases the only hopeful treatment is the removal of the patient to an institution where her nurses are strangers and where a strict regimen, dietetic and otherwise, can be carried out. In such surroundings sensational cures are sometimes obtained. Rectal feeding and gavage have at times to be tried, and their psychic effect is in some cases successful

"Neurasthenia Gastrica" and "Nervous Dyspepsia."—*Definition.* We have seen above that gastric neuroses are secretory, sensory, or motor. These are, unfortunately, often combined and form what some authors call "nervous dyspepsia," or neurasthenia gastrica. The term "nervous dyspepsia" was first given by Leube to a condition characterized by gastric symptoms referable to the nervous system in the presence of normal digestion —*i.e.*, normal as to its chemistry and duration. Such a condition is generally a sensory neurosis, which, however, is sometimes combined with other neuroses. We, therefore, look upon nervous dyspepsia as a composite neurosis, in which sensory disturbance is always prominent.

Symptoms. The symptoms are a sense of fulness and weight, eructations of gas, nausea, and even vomiting; there may be pain and tenderness (not limited to a small area), also burning, and disturbed appetite. Secondary symptoms are headache, palpitation, insomnia, and moodiness. The symptoms always appear shortly or immediately after taking food, but they do not vary with variations in the quality or quantity of the food, but persist in spite of judicious reductions in the diet. Such symptoms are at times a part of general hysteria or neurasthenia. They occur, too, reflexly from disturbance of other organs, *e.g.*, the female sexual organs, during a heightened general nervous irritability. They probably occur as a result of sexual excess, though in this and other distant disturbances an increased irritability of sensory nerves in the stomach is essential. If this irritability is present, physiological events in the stomach call forth unpleasant symptoms or become painful, leading to abnormal secretion and abnormal motility. The patient may or may not be hysterical, for these neuroses can occur apart from definite hysteria, though a neuropathic constitution is essential. This constitution may be congenital or acquired by such means as excesses, abuse of drugs, chronic malaria, anæmia, etc.

On physical examination of the abdomen one finds no abnormality, not even localized tenderness. The gastric juice, too, is almost always perfectly normal, though rarely it is slightly changed. Motility is generally normal, rarely there is hypermotility, and more rarely atony. Generally there are also perverted sensations in the intestines.

Course. The course is always long, but the condition varies sensationally, especially with the mental state and surroundings of the patient.

Diagnosis. The diagnosis is made only by the general clinical picture, never by any single sign, nor by the examination of the gastric contents. In this condition the pain is not so severe as in hyperacidity. Changes in the secretion or motility at frequent intervals are suggestive, especially when vomiting is absent or infrequent and the tongue clean. Striking variations in the symptoms, synchronously with changes in the humor of the patient, together with excellent nutrition, in spite of severe symptoms, are the most suggestive points. One must not lay too great stress on other functional disturbances, for organic disease in the stomach may coexist with hysteria, and the more conscientiously one examines his patient, the more frequently will he find an organic basis for the symptoms.

The diseases differentiated with greatest difficulty are atypical ulcer, carcinoma, and chronic gastritis. In ulcer, when there is no localized tenderness and no hæmatemesis, one may have some doubt. In ulcer the pain is much more regular in its relation to a meal, and it varies markedly with the quantity and the quality of the food; vomiting is far commoner and the appetite is good, fear alone preventing eating. In ulcer, too, hyperchlorhydria is almost constant, and the symptoms respond more to treatment than is the case in neurasthenia gastrica. In cases of carcinoma, with absent hydrochloric acid as the only sign, one may long be in doubt; one must consider the age, sex, and the course of the disease, and look for constantly absent hydrochloric acid. In chronic gastritis the course is always steadier; there is much mucus, and the symptoms increase or diminish with the diet.

Prognosis. The prognosis is good as to life, but the symptoms are of long duration or frequently recur.

Treatment. One should try to remove all exhausting influences and give his chief attention to the general condition of the patient. The diet is not of prime importance, but should be nourishing and unirritating. A change of scene, as by a trip to the country or by a sea voyage, acts well. Tonics, hydrotherapeutics, massage, and static electricity may be given, mostly for their psychic effect. Obstinate cases can be cured only by the Weir-Mitchell treatment, in which suggestion and the encouraging personality of the physician are important.

VII. GASTRITIS.

ACUTE GASTRITIS.

DEFINITION.—An acute inflammation of the superficial membrane of the stomach with excessive secretion of mucus, desquamation of epithelium, and a resulting disturbance of digestion. The term is often misapplied, and is confused more especially with gastric neurosis, in which there is no evidence whatever of inflammation of the lining membrane of the stomach. The term should be restricted to those cases in which definite evidence exists of a catarrhal or other inflammation of the gastric mucosa, and should not include even those cases of neurosis in which much mucus is secreted in the stomach, and in which there is no cause or symptom otherwise of inflammation. One should exclude, too, the many cases of acute indigestion from temporary indiscretions of diet, etc., and the cases of slight atony, in which there is no reason to suspect an active inflammatory process.

It is true, on the other hand, that in many cases it is impossible to say whether one is dealing with an acute inflammation or with merely an acute non-inflammatory dyspepsia.

ETIOLOGY.—The condition is either primary or secondary.

Primary Acute Gastritis.—The causes of the primary simple gastritis are mainly the following: Food or drink when taken in an irritating form, *e.g.*, too hot or too cold, or if decomposed, or if too spicy, or too bulky and coarse—all these act more especially on an empty stomach.

Alcohol, which is one of the most common causes, induces a very typical form of the disease.

Individual predisposition and sensibility have much to do with the case, and perhaps, too, heredity plays its part. Again, people with impaired vitality—such, for example, as anæmic individuals and those who are convalescing from the specific fevers—are more susceptible. For the same reason tuberculous patients are often susceptible to the disease. Bacteriological invasion is not infrequently a factor in its causation, and more especially is this claimed for the Bacillus coli communis, while in many cases the disease is associated with the parasites of pyæmia, diphtheria, anthrax, thrush, lymphangitis, etc. Animal parasites, again, may be introduced, such, for example, as the Ascarides and the various Tæniæ.

Toxic causes are amongst the most common factors in the production of acute gastritis, though in most instances they produce a more severe form than is here described. Such, for example, are the mineral acids, the alkalies, various salts, alcohol, phosphorus, arsenic, mercuric chloride, calcium chloride, etc.

Externally, heat and cold, when excessive, may induce gastritis, though just why extensive burns on the external surface of the body should produce so frequently catarrhal inflammations of the mucosa is not understood. Foreign bodies when swallowed form another cause (fruit stones, hair, etc.).

Lastly, there seems to be an epidemic form of the disease, the cause being doubtless some micro-organism, though the mode of infection is as yet ill understood.

Secondary acute gastritis frequently develops with the general infectious diseases, such as measles, scarlatina, erysipelas, pneumonia, etc., and may indeed be the primary condition which manifests the early symptoms, and this is especially so with children. In acute nephritis, again, gastritis is a common secondary condition. With diseases of the throat and with putrid bronchitis, gangrene, or other disease of the lung, or in other conditions in which the degenerated tissues are in part introduced into the stomach, a secondary gastritis may readily occur. The disorder, too, is not uncommon with, and as a result of, intestinal disease.

MORBID ANATOMY.—Macroscopically there are a diffuse circumscribed swelling of the mucosa, redness, due either to congestion or to hemorrhage, and an excessive quantity of mucus. Sections under the microscope show partial desquamation of the superficial epithelium, the remaining cells being swollen and cloudy and filled with much mucus. In the glandular epithelium it may be impossible to distinguish between the chief and the parietal cells. All the cells may be more or less cloudy, fatty, or granular and shrunken, the chief cells being those usually most affected. The capillaries are dilated, and in the interstitial tissue one sees collections of small round cells, due to inflammatory infiltration.

SYMPTOMS.—The symptoms may occur with or without fever.

Subjective Symptoms.—There is usually general malaise, perhaps headache and dizziness; the patient complains of anorexia, increased thirst, a sense of pressure and fulness in the epigastrium, eructations of a gas which is either tasteless or bitter; there is a pappy taste in the mouth, and nausea is usually present. In most cases there is some vomiting of a foul, very acid, bitter material, consisting of more or less undigested food remnants and much mucus. There may be bile. Such a vomitus has a very marked acid reaction, though the HCl acidity is usually diminished, and there may even be no free hydrochloric acid; very often the three organic acids—lactic, butyric, and acetic—are found.

If a test breakfast is given after the first violent attack is over, one will find the bread after one hour almost unchanged, very much mucus present, and a greatly diminished secretion of hydrochloric acid.

Objective Symptoms.—These are not specially characteristic; the tongue is usually coated, and it may be indented by the teeth; if fever is present, there may be herpes labialis. There will be some tenderness in the gastric area, and perhaps fulness from distention. The intestines are sometimes involved in a severe case, and there may be constipation or diarrhœa. A more or less subicteroid condition may be added. The pulse is increased in rapidity and is small in volume. The urine is diminished and the specific gravity increased

COURSE.—Sometimes vomiting affords immediate relief; at other times the vomiting and the symptoms are concurrent. Not infrequently involvement of the intestines follows that of the stomach, and then after a preliminary constipation there is more or less persistent diarrhœa for one or more days.

The intensity varies, and in the milder cases there is even no vomiting. On the other hand, in those cases which are somewhat more severe, rigor may be present, with fever and herpes.

DIAGNOSIS.—An obvious cause is usually the important factor, and in addition the vomiting of coarse undigested food after some hours, with much mucus and organic acids, suffices to render the diagnosis easy.

The differential diagnosis concerns gastric ulcer, biliary colic, gastralgia, with increased hydrochloric acid, the onset of some acute infectious disease—more especially typhoid fever and pneumonia—and lastly, the gastric crises of tabes dorsalis. The individual symptoms and the course of the disease usually suffice for a diagnosis.

PROGNOSIS.—The prognosis is good. There may, however, be recurrences in susceptible individuals, which, when they occur frequently, increase the liability to a chronic gastritis with secondary dilatation.

TREATMENT.—*Prophylactic.*—This is of especial importance in children, inasmuch as an improper diet is the frequent cause of gastritis at that age. It is important, therefore, to avoid overloading the stomach, especially with sweets, fruits, cakes, and other foods which cause fermentation and more or less acute dilatation of the stomach. Some authors have laid stress on the importance of avoiding uncooked fruit, which is especially irritating to the stomachs of the young.

Direct Treatment.—The condition often subsides of its own accord without any further interference, and nature, by inducing vomiting and a subsequent anorexia, carries out the two main therapeutic essentials. When vomiting has not been induced, emetics often give relief, though lavage is, perhaps, the more thorough method of treatment. It is specially useful in children, in whom lavage, by means of a catheter or properly devised tube and funnel, gives more rapid relief than any other treatment. It may be necessary to employ lavage with the patient in various postures in order to insure a thorough cleansing of the stomach, and this process should be repeated several times if symptoms of discomfort and distress indicate its use.

If an emetic is desired or necessary, apomorphine is doubtless the best one for the purpose. Drugs are otherwise rarely necessary, while dieting, on the other hand, is of the utmost importance. The diet should be such as to protect the injured mucosa and give rest to the functional action of the stomach. For this reason it is well to give the stomach complete rest at first for some hours, after which time the thirst may be relieved by chopped ice, or by swabbing out the mouth with water or a suitable mouth wash. Small quantities of effervescent waters or cold, weak, unsweetened tea may be sipped. It is especially important that any fluids given at this time should be administered in small amounts.

When food is finally given, it should be given in fluid form. Milk diluted with lime water or soda water, and broths, with perhaps the yolk of an egg, may then be tried, and, after this, more solid diet may be gradually administered.

If purgation is desired, calomel may be used in small doses and combined with bicarbonate of soda. This is particularly useful if an enteritis is also present.

For the anorexia which accompanies and follows this disease a few drops of hydrochloric acid, as recommended by Riegel and Ewald, may be administered—eight to ten drops of the dilute HCl are placed in a wine-glass of water and taken in sips before each meal. Narcotics are rarely necessary, but if required they may be given in the form of suppositories.

SEVERE TOXIC GASTRITIS.

This is merely a more aggravated form of the simple gastritis. It must be remembered that all toxic gastritides, however, are not necessarily severe, though, as many hold, nearly all gastritides are usually toxic. The severe and toxic gastritis, however, is usually caused by the voluntary or involuntary ingestion of concentrated mineral acids—carbolic acid, caustic alkalies, the poisonous metals, such as arsenic, phosphorus, mercuric chloride, calcium chloride, potassium cyanide, etc., and also the essential oils.

SYMPTOMS.—The symptoms vary according to the quantity of poison taken and according to the position of the patient at the time—that is, whether standing up or lying down; in other words, these symptoms vary according to the portion of the alimentary tract against which the irritant comes in contact

The most striking symptoms are pain and vomiting. The pain is usually complained of all the way down from the pharynx to the stomach, and especially along the line of the sternum; it is severe and burning in character.

Vomiting usually occurs soon, especially if something has been present in the stomach at the time It is often repeated, and, as characteristic of the disease, it brings no abatement of the symptoms. Mixed up with more or less foodstuff, there are usually blood, mucus, and perhaps portions of mucous membrane.

The facies is usually anxious and pale, and there is profuse sweating; the pulse is small, rapid, and compressible; the extremities are cold, perhaps cyanosed, and the respirations are shallow, rapid and thoracic (because pain impairs the movements of the diaphragm).

Examination of the abdomen shows nothing characteristic apart from great tenderness, and, if the condition has been extreme, there may be signs of perforation and peritonitis; but this latter occurs only in the severer forms of the disease.

There are all degrees of this form of gastritis; it may be mild with only a few hours of pain, or there may be signs of general intoxication with hæmaturia, icterus, etc. The results are, mainly; stenosis of the œsophagus from subsequent cicatrization; atrophy of the mucous membrane, chronic gastritis, etc.

MORBID ANATOMY.—This varies according to the nature of the case and the extent of the damage; there are always hyperæmia, hemorrhages, and swelling of the mucous membrane, with fatty degeneration of the glandular epithelium, more especially in phosphorus poisoning. Where the erosion has been great there is sloughing, and there may be perforation, or, later, severe hemorrhages, with scars and contractions (stenosis, hour-glass contraction, etc.). The secretory changes are usually great; there is marked diminution of the hydrochloric acid, and there may be gastrectasis.

DIAGNOSIS.—This is based on the sudden severe gastric signs in an otherwise healthy individual, while the poison, or its effects, are usually found on the lips or in the mouth.

TREATMENT.—This consists of lavage, when it is not otherwise contraindicated, and the use of an antidote. If a somewhat longer protection of the gastric mucosa is indicated, rectal feeding may be employed. Special treatment may be required to deal with the sequelæ of the disease.

PHLEGMONOUS GASTRITIS.

Interstitial Purulent Inflammation.—This is a very rare disease, and commences primarily in the submucosa, going through the thickness of the various parts of the stomach. It seems to be sometimes primary, the exact cause, however, being hard to find. More often it is secondary, *i.e.*, metastatic from some other primary focus. It may be diffuse until the whole wall of the stomach is involved to a greater or less degree; or it may be circumscribed, an abscess being thus formed.

MORBID ANATOMY.—The submucosa, especially at the pylorus, is thickened and infiltrated with pus or seropus, and this usually extends more or less to the muscle. The mucous membrane is almost always involved, though often very slightly, and one sees signs of infiltration between the glandular loops. The mucosa is thickened, hyperæmic, ecchymotic; the epithelium is granular or shows fatty degeneration, and there is a small-celled infiltration between the glands. In some cases there are perforations going through the whole stomach (the appearance of a sieve), or ulcers of varying extent may be found.

There are often adhesions with the neighboring organs, and, according to the extent of the pathological changes, the results vary widely. Purulent peritonitis is a not infrequent termination, though infiltration may extend into the duodenal wall or up into the œsophagus, and thrombi may form in the surrounding veins where one or other of the different varieties of pus organisms may be found.

ETIOLOGY.—As a primary affection, we are totally ignorant of the direct cause beyond the fact that it must be a micro-organism. On the other hand, phlegmonous gastritis is secondary to cancer and ulcer of the stomach, to the various general infections, such as pyæmia, variola, scarlatina, etc.

SYMPTOMS.—The symptoms are nearly always acute. The onset is sudden, and there may be a chill, but in no sense are the early symptoms characteristic. It is true that there are severe gastric symptoms, the fever is high, perhaps 105° F., and there are general malaise and severe prostration. Vomiting is nearly always present and persistent, and the vomitus contains mainly mucus or bile.

One never, or hardly ever, gets pus in the vomitus until the abscess has opened into the stomach shortly before death. The case thus often resembles acute poisoning. The pains are very severe, extending over the whole gastric area; there are meteorism and signs of a general or local peritonitis. The fever is usually persistent, septic in type, and there are sometimes repeated rigors.

The pulse, as one might expect, is increased in rapidity, small, and may be irregular. The course of the disease throughout indicates severe general disturbance; the vomiting gradually diminishes toward death. With the development of the disorder there may be coma or delirium, and, following upon this, collapse and death with or without signs of general peritonitis.

The duration is rarely ever longer than two weeks, being usually fatal within the first week. Where the disease is localized an abscess forms and the condition may last somewhat longer, but in other respects there is no difference between the symptoms of the diffuse and those of the circumscribed variety.

DIAGNOSIS.—The diagnosis is never certain, and one usually labors over the differentiation between a general peritonitis and a toxic gastritis.

PROGNOSIS.—Ninety-five per cent. of those cases which are recorded have been fatal. That cases have recovered has only been proven by anatomical preparations, indicating the previous existence of a phlegmonous gastritis.

CHRONIC GASTRITIS.

This consists of a prolonged alteration of the mucous membrane of the stomach resulting in changes in the gastric digestion. The alteration is mainly in the secretions, there being an abundance of mucus and sometimes a stagnation of food.

ETIOLOGY.—The condition may be primary or secondary.

Primary chronic gastritis sometimes follows the acute, though this is uncommon. On the other hand, all the cases of acute gastritis, if persisting for a long period, may assume a chronic form. Thus, for example, dietetic errors, with reference to the manner of eating and chewing of food; the irregularity of meals; overloading of the stomach, especially with indigestible food; the presence of faulty teeth, acting as an impediment to proper digestion—all these separately or combined may induce in time chronic gastritis. Alcohol, especially if undiluted, particularly brandy, is another important cause. Other toxic causes are tobacco, especially if chewed to excess, tea and coffee, spices, certain drugs, drastic purgatives taken too frequently and in too large doses—all of these act as etiological factors, and they are all more potent when combined with a sedentary life.

Secondary chronic gastritis is associated with various diseases of the stomach and the general system; thus, with carcinoma ventriculi, with gastrectasis and adenoma of the stomach, more rarely with ulcer. Diseases of the heart and of the liver, in which passive congestion of the vessels in the stomach are a frequent accompaniment, act as important factors in inducing a chronic catarrhal inflammation of the mucosa.

To a less extent are renal and pulmonary diseases (especially tuberculosis) responsible; still, in certain constitutional diseases, more especially in anæmia, chlorosis, leukæmia, diabetes, and gout, the malady is not uncommon.

MORBID ANATOMY.—The mucous membrane is swollen, thickened, and covered with a layer of tenacious mucus; its color is either dark red or grayish-red, especially around the pylorus.

Microscopical examination of the mucus overlying the mucosa shows that it contains epithelium, which is mostly broken down, and perhaps blood corpuscles; the mucous membrane itself may present isolated hemorrhages, loss of epithelium and erosion; according to the degree of inflammation, one sees degeneration or fibrosis.

The superficial epithelium undergoes more or less mucoid degeneration; the glands are enlarged, partly cystic from retention, and degenerated, while the interglandular tissue shows small-celled infiltration. The capillaries and lymphatics are dilated; the submucosa shows thickening here and there, and sometimes the productive fibrosis results in the formation of warty and polypoid excrescences—what is known to the French as *état mamelonné*.

Pyloric stenosis sometimes occurs as a result, and especially if there is much hypertrophy of the muscular coat.

Cirrhosis of the stomach is a special form of this chronic gastritis, and if advanced it may lead to degeneration and atrophy of the muscular coat.

The final stage in chronic gastritis is an atrophy of the mucous membrane, and this may result in the practical failure of all gastric secretion.

The size of the stomach varies. When there has been serious disease, the organ as a whole may appear shrunken. On the other hand, when the muscular coat has been the one chiefly involved, dilatation of the stomach may be observed.

SYMPTOMS.—The disease may remain for some time latent, or the symptoms may at first be insignificant and then gradually become more pronounced. This stage may continue indefinitely, or, again, the mild symptoms may alternate with periods of complete health. It is well recognized, at all events, that changes in the symptoms from time to time are quite frequent.

Early Signs.—As a rule, chronic gastritis develops slowly; slight dietetic errors cause some discomfort in the epigastrium, with the signs of fulness, pressure, and, perhaps, even pain, either when food is present or when the stomach is empty. There is usually anorexia, together with a bad or a sour taste in the mouth. Flatulence is common and often very troublesome, though the explosion of wind (which is odorless, as a rule) tends to relieve the oppression in the epigastrium and lower part of the thorax. There are nausea, and later on, as a rule, vomiting, which occurs either at the height of digestion or sometimes early in the morning (the result of a pharyngitis, mucus from the throat being swallowed during sleep). Thirst is usually added, and there is a general indisposition for any exertion. The nervous system suffers, too, and neurasthenia is apt to develop; dizziness is not uncommon, more particularly during the digestive period.

Well-Developed Cases.—In these the appetite varies; there is usually, however, anorexia, with satiety after only a little has been eaten. Voraciousness is uncommon, though a special desire for acid, sharp and spicy foods is well known, and often increases with the development of the malady. A disgust for meats is frequent in the well-developed cases. Thirst likewise varies; sometimes it is increased, though not nearly so much as in the case of acute gastritis. There is sometimes a bad taste in the mouth, though this varies; it is usually due to stomatitis or to a chronic pharyngitis. The breath may be foul from the same cause. Salivation or dryness in the mouth may be present. The tongue is furred or red and often sore at the edges.

The dyspeptic signs vary largely according to the secretory or motor disturbance which is present. The quantity and quality of food are of great importance to the patient. Fluids are well borne, as a rule, but solids seem to increase the symptoms. The usual dyspeptic signs—*e.g.*, fulness, oppression, flatulence, eructations, etc.—are common. Water brash is not uncommon; so, too, is cardialgia. Not infrequently there is true pain in the stomach, which, however, disappears rapidly under suitable treatment. Nausea occurs either early in the morning or at the height of digestion, though this symptom is not by any means so common as in carcinoma.

Vomiting is frequently present, though much less common than in acute gastritis. It may be slight or severe, and often occurs in the early morning (vomitus matutinis potatorum), at which time it consists of saliva that has been swallowed and of mucus coming from an old pharyngitis. Such vomitus is apt to be alkaline in reaction. If the vomiting occurs after meals, it takes place usually about an hour and a half after food has been ingested. It is made up of undigested food remnants and thick, ropy mucus, bile, and the various products of fermentation, yeasts, etc. Sometimes the mucus is extremely elastic and tenacious, due, it is thought, to the mucous fermentation of carbohydrates.

General Symptoms.—Constipation is the rule; it sometimes alternates with diarrhea. The nervous symptoms consist of dizziness, anxiety, hypochondriasis, lack of energy. There is inanition, especially among those who are poor and uncleanly, and whose mouths are never properly cared for. Where the intestines are unable to take on the functions of the stomach, malnutrition is very common. The urine varies; urates are often present in large amount.

Although palpitation is not uncommon, the heart, as a rule, presents nothing abnormal.

Physical Examination.—Inspection reveals nothing unless there be stenosis of the pylorus or idiopathic dilatation of the stomach, when inflation or insufflation will demonstrate the increased size and altered position of the organ. The lower border may reach much below the umbilicus.

Palpation shows some tenderness, as a rule, and there may be a succussion splash if atony be present.

The test meal reveals the presence of undigested coarse food with much mucus.

The motor power is either normal or diminished, according as to whether the muscle is in a healthy condition or atonic. When atony exists, the quantity of the test breakfast will be abnormally great and usually contains much mucus.

The results of a chemical examination vary according to the state of the secretory functions. As a rule free hydrochloric acid is diminished or absent. In some cases, on the other hand, there is hyperacidity, pepsin is less in quantity, and the labzymogen is either diminished or absent. Unless atony be present there are usually no organic acids to be found, though sometimes one may find butyric, acetic, and the volatile fatty acids; likewise, though uncommonly, lactic acid.

COURSE.—It is usually of long duration. There are remissions and exacerbations, especially with errors in diet. If taken within a reasonable time and properly cared for, chronic gastritis may be quite readily cured. Recurrences are frequent, however, and alcoholics (in whom the disease is especially common) are very liable to have relapses through repeated indiscretions.

The secretory power is injured, but this may be repaired much more readily indeed than can the motor power when once severely affected. Weakening of the muscular coat results in gastrectasis, which, if of long duration, causes general malnutrition and aggravates the gastritis.

Atrophy of the mucous membrane is extremely uncommon, and the condition known as achylia gastrica cannot be said to be of frequent occurrence.

DIAGNOSIS.—This cannot be made from the symptoms alone, though the long course of the malady, with the above-described signs and symptoms, may aid greatly in the diagnosis. It is essential to examine the stomach contents chemically after a test meal if one would desire any accuracy in his methods of diagnosis.

The *differential diagnosis* concerns, first of all, the distinction between the primary and the secondary forms of gastritis, which latter accompanies hepatic, cardiac, and other diseases. There may be some difficulty in excluding a pure neurosis, in which, however, the effect on nutrition is not so serious, and in which there is usually less mucus in the stomach contents. The symptoms, too, are more variable; there is more neurasthenia; and the symptoms are not always digestive in point of time, nor is it always solid foods alone which cause distress. There may be, on the other hand, a nervous subacidity, and the motor power of the stomach may be somewhat impaired by a long standing neurosis.

The age of the patient is of some importance, inasmuch as a gastritis is not common before thirty, and a neurosis may occur at any age.

In making the distinction from carcinoma it is often quite difficult to determine in the early stages the true nature of the disease. Frequent examination of the stomach contents is necessary; hydrochloric acid is usually absent, and the peptic power is usually diminished early in carcinoma and late in chronic gastritis. Carcinoma is a disease of comparatively short duration, and one must further take into consideration all the various signs and symptoms.

Atrophy of the gastric follicles is determined only by the complete absence of gastric secretions, and is an occasional sequel to chronic gastritis.

Amyloid disease of the gastric mucosa may simulate chronic gastritis, but the differentiation is easily made if amyloid disease be found in other organs and if a suitable cause therefor be present.

There should be no difficulty in distinguishing gastric ulcer from chronic gastritis, inasmuch as the clinical pictures are entirely different.

Prognosis.—The mild cases of chronic gastritis are easily cured. In the more serious cases, on the other hand, especially where the secretion is much diminished and there is atony, the condition is less favorable. When pyloric stenosis is present or atrophy of the mucous membrane or great dilatation of the stomach, the condition may be looked upon as very serious as regards the cure, though the menace to life is not necessarily great. The prognosis should be based less upon the general condition than upon the outlook for securing a sufficient supply of nourishing food, upon the condition of the secretions and the enzymes, and upon the motor power, and, lastly, upon the condition of the intestines, which, if in a healthy state, may largely replace the functions of the stomach. It is well to warn one's patients that relapses are quite frequent, and that exacerbations and remissions are the rule rather than the exception.

Treatment.—A detailed diagnosis is essential to the proper carrying out of the treatment of a case of chronic gastritis. Secondary gastritis must be treated according to the cause, which will involve the therapeutics of the lungs, heart, liver, or general constitution. In the primary cases, on the other hand, the treatment concerns prophylaxis, palliative and curative measures. The curative measures are mechanical, dietetic, and medicinal, and for this reason it is necessary to have a detailed diagnosis of the condition.

One must consider the cause of the disease as well as the condition of the secretory and motor functions and the quantity of mucus present. Prophylaxis is of some importance, and one should, therefore, remove any external conditions which tend to bring on or aggravate the malady. Excesses of all kinds must be guarded against; bad habits cured; the patient should be taught to eat slowly, to chew his food well, and carefully to select his diet both as regards quantity and quality.

The actual treatment is chiefly mechanical and dietetic, and drugs play a comparatively unimportant part. The mechanical treatment consists mainly in the use of lavage. It is necessary that the stomach should be clean before any food enters, and for this reason one must remove any mucus which covers up the superficial epithelium and prevents proper action of the digestive juices. Lavage may be carried out in the early morning or, in bad cases, six hours after dinner (which is usually taken at midday), and the evening meal should be as light as possible. Under ordinary conditions one may wash the stomach out with simple lukewarm water. If, on the other hand, much mucus is present, sodium chloride may be added, or, if there be much fermentation, boracic acid. According to the severity of the case, lavage should be done daily, or every second day, for a few weeks, and on each occasion it should be continued till the water returns from the stomach quite clear.

When atony or much fermentation is present this may require some patience.

When, for one reason or another, lavage is impossible one may employ "natural lavage" by means of frequent administration of mineral waters of various kinds, especially the saline waters, with carbonic acid; those, for example, from Saratoga, containing sodium chloride (Hathorne, Congress Springs), are often beneficial in relieving the stomach of its mucus and inducing a combination of the organic acids. And, again, the alkaline sulphates, such as are combined in Carlsbad waters, are useful for this purpose as well as for relieving the constipation. According to the condition of the secretions and the motor power, the use of these waters should vary. They should be taken cold, where motor insufficiency exists with diminished secretion and constipation. Where, on the other hand, there is irritation in the stomach with diarrhœa, they are best taken hot. Whenever atony exists it is well to remember that only small quantities should be taken at a time. In addition, daily cold baths or shower baths with subsequent friction of the skin are of great benefit. Where pain or great discomfort is present, a wet compress may be placed upon the epigastric area and covered with oil silk.

Electricity is of very doubtful value, though the proper regulation of rest and exercise, which latter should always be moderate, is of the greatest importance.

Dietetic treatment is of prime importance, though often hard to regulate because of individual preferences. The diet must be administered with some regard to the severity of the case; but in all instances the food must be easily digested, and for this reason must require but little on the part of the gastric juice or muscular action of the organ. It must be, further, non-irritating.

When only the scantiest diet is tolerated, milk, preferably diluted with lime-water, may be given at regular intervals, and this, while the patient is at rest, may suffice, provided he can be induced to take from one to two quarts *per diem*. We may say, however, that in the large majority of instances a mixed diet, selected with reference to the needs of each case, is advisable.

When the motor power of the stomach is demonstrated to be normal, one may administer albumens, starches, and fats. If, on the other hand, it is deficient, it is wiser to exclude the fats. When, again, the secretory power of the stomach is defective, a mixed diet is very easily given so long as the motor power remains unimpaired, for the intestines will perform the secretory functions of the stomach. In all cases, however, albuminous food should be finely divided. Starches should form the bulk of the food in those cases in which the hydrochloric acid is deficient, and those starches should be selected in which there is less residue after digestion is complete.

Fats are imperative when malnutrition exists, and for these cases butter and cream form the most easily digested varieties. It is thus essential where possible to give a mixed diet, non-irritating, finely divided and containing as much nutriment as possible within the smallest compass.

In severe cases one may give, in addition to the milk, gruel, milk soups, light puddings, rice, arrowroot, toast, and then eggs. In some cases light meats, if tender, may be added; but it is not wise to add spices nor any rich sauce. The craving which many patients with a chronic gastritis have for spicy things, under the impression that they will stimulate the functions of secretion, are usually not good indications of the best method of treatment.

Of the lighter meats, etc., calves' brains, sweetbreads, chicken, fish, minced beef, are those most preferable.

Alcohol is best avoided unless in the form of very light wine. The quantity of water taken with the meals should be restricted, unless there be hyperacidity, in which case it is well to dilute one's food moderately. Instead of ordinary water, Radnor, Apollinaris, or other effervescing alkaline waters, may be tried with benefit.

The determination of the proper number of meals per day is based upon the condition of the motor power. If this be good, three meals a day may suffice. Where, on the other hand, there is atony, four or five meals, each small in quantity, are more advisable. Coffee, tea, and cocoa may be given except in those cases in which hyperacidity exists. As the patient improves, such vegetables as spinach, carrots, maize, potatoes (mashed), and macaroni, may be added in small quantities and gradually. In severe cases maizena, semolina, and the like may be added. Bread should be stale and not hot. When constipation is marked, it may be well to give stewed fruits, such as apples, prunes, etc. When, on the other hand, diarrhœa is present, stewed blueberries are often very efficacious.

Medicinal Treatment.—Inasmuch as hydrochloric acid is deficient in the course of most cases of chronic gastritis, one may add with some benefit a few drops after each meal. One-half drachm of dilute hydrochloric acid in a tumblerful of water, to be sipped at intervals for an hour after each meal, may be prescribed. On a scientific basis there is little to be gained from the use of pepsin, though practically one frequently does find that its employment seems to afford considerable aid to digestion. Pancreatin in doses of fifteen grains is perhaps better, and should be administered with soda, though rationally this should not be prescribed unless there is some evidence of atrophy of the gastric follicles. After all, these artificially prepared ferments are of little use when one realizes that the intestines carry on the defective actions of the stomach.

It seems of prime importance, however, to give some stomachic before each meal, and for this purpose one may try either dilute nitromuriatic acid, in doses of ♏ x. to xv., or nux vomica, quassia, gentian, or condurango.

In many cases the greatest relief from the more acute suffering incident to chronic gastritis is a pill consisting of silver nitrate gr. ⅙, Pulv. opii gr. ¼, and extract of hyoscyamus gr. ss.

Where fermentation is an annoyance the diet should be carefully looked into; one may sometimes add thymol, or carbolic acid, to the other modes of treatment. For a distinct pyrosis, bismuth subnitrate and sodium bicarbonate, of each ten grains, combined with three to five grains of calcined magnesia, will usually afford relief.

For persistent vomiting lavage is the most rapid means of giving relief. When this is impracticable, a careful adjustment of the diet, with perhaps the administration of one or other of the usual drugs for that purpose, may give benefit.

Constipation is one of the greatest annoyances in these cases. It is well that the patient should develop great regularity in his habits, going daily to stool at regular hours, whether or not there be need therefor. As soon as possible there should be added to his food vegetables containing much cellulose, also stewed fruits, especially a combination of figs and prunes; or in the early morning he should drink cold water or eat a fresh orange; and only in aggravated cases should we resort to either purgation or enemata.

Where purgation is necessary, it is a difficult matter to determine what drugs should be employed; only the mildest forms of purgatives should be given, and of these rhubarb, aloes, and cascara are probably the most beneficial. The use of Carlsbad salts in the morning, as already indicated, is another efficacious means of treatment in aggravated constipation.

VIII. GASTRIC ULCER.

(Synonyms: Round Ulcer of the Stomach, Peptic Ulcer, Simple Ulcer, Perforating Ulcer, etc.)

Definition.—It is a destruction of the mucosa and sometimes of the deeper layers of the stomach wall, of the nature of a degeneration or necrosis; it leaves an open loss of substance, usually round or oval in shape, with clear-cut edges. Such ulcers may be acute or chronic, with or without tendency to cicatrization and healing. In both forms there may be hemorrhage and perforation.

Statistical.—In Berthold's Berlin series ulcer was present in twenty-seven per cent. of all autopsies; in other series the percentage is much less. Thus, in Thüringen it is reported as being ten per cent., and in F. P. Cantlie's statistics from the Royal Victoria Hospital, of Montreal, gastric ulcers formed 0.001 per cent. of all cases admitted.

Etiology.—*Age.*—It is most common between twenty and thirty years of age, though it may occur in childhood, even in infancy, and is seen not infrequently in old age. Kundrat found small superficial ulcers, of recent formation, quite frequently in children, but these are doubtless of a different nature from the true round ulcer. The average age at the Royal Victoria Hospital was twenty-seven and one-half years.

Sex. It is commoner in females.

Occupation has a doubtful relation to ulcer. According to some authorities cooks are predisposed, as are also those who work in glass and porcelain factories, metal turners, tailors, and shoemakers. In Payne's statistics only three out of fifty females are cooks.

It is doubtful whether *trauma* bears any relation to gastric ulcer. *Chlorosis* and *anæmia* are predisposing factors, and *vice versa*, chronic ulcer often leads to anæmia. Again, gastric ulcer is often falsely diagnosed as mere chlorosis, especially as hyperacidity is common in chlorotic girls.

Dietetic Errors.—Alcohol is not a cause of true gastric ulcer. Vegetables and indigestible foods are considered by some as frequent antecedents.

Poisons are not a cause.

Infections.—Tuberculosis, syphilis, trichinosis, and infections generally are a frequent cause of gastric ulcer, but not of those having the characters of the ordinary round ulcer. That an ulcer occurs in other affections does not imply that the gastric round ulcer has the same etiology, nor can we infer, from the mere facts that ulcers are found lying opposite to one another, and that they manifest an œdematous condition of their immediate surroundings at the time when perforation occurs, that they owe their origin to an infection. These ulcers are purely necrotic in all their typical pathological characters.

Pathogenesis.—It would seem that the two main factors are: (*a*) Some interruption to the circulation going to the stomach, or anæmia. (*b*) Hyperacidity. It is probably the increased hydrochloric acid which keeps the ulcer chronic. In anæmic conditions the vessel walls are liable to changes, especially fatty and atheromatous. Normally, the gastric juice does not digest the mucous membrane, because the blood furnishes the neutralizing element. When ulcer occurs, we conclude that:

1. There is increased hydrochloric acid, and it is not sufficiently neutralized by the blood.

2. The circulation is in one way or another restricted, so that neutralization is impossible.

3. The blood shows diminished alkalinity.

The second of these is doubtless of greatest significance, though proof of the real pathogenesis is absolutely lacking.

Morbid Anatomy.—*Situation.*—These ulcers exist wherever gastric juice flows. The posterior surface is the commonest site, ulcers being found there in 42 per cent. of all cases, especially near the pylorus. In 15.6 per cent. the pylorus is the site, while in 26 per cent. of all cases the ulcer exists either in the lesser curvature or in the pylorus. They are on the anterior wall in 4.9 per cent., on the greater curvature in 2.4 per cent., and at the cardiac end in 0.2 per cent.

Number.—These ulcers are usually single, but sometimes they are multiple. In one of Berthold's cases there were thirty-four. When multiple, they may all seem to be of the same duration, or some may be in a state of healing, while others seem to be quite recent.

Shape.—The more acute ulcers are punched-out in appearance, round or oval, and sharp in outline, while the chronic ones are shelved or terraced, the widest diameter and greatest loss of substance being at the mucosa, the ulcers becoming gradually narrower as one approaches the serosa (funnel-like). This would seem to correspond to the distribution of the blood-vessels. Orth has drawn attention to the fact that these ulcers are often oblique, *i.e.*, their long axis corresponds to the direction taken by the blood vessels. Often these older ulcers are irregular in outline, spread out, and, with the mucosa, rolled inward and thickened at the edges. Cicatrization may often be seen progressing at various portions of the walls. The muscles beneath are shrunken. The floor is smooth and grayish-brown or red, rarely ragged.

Size.—The usual size varies from 2 cm. in diameter to 3–4 cm. In some instances, however, they may be as small as 1 cm., or as large as 10 cm., in diameter, and sometimes the ulcers form a ring more or less completely surrounding the organ.

Healing and cicatrization are common. Scars vary in size, and—according to their size and situation, and to the amount of contraction which followed the healing process—they may or may not cause perceptible deformities in the organ and corresponding functional disturbances. The deformities thus caused comprise hourglass contraction, pyloric stenosis and gastrectasis, and cardiac stenosis. The process of healing begins with proliferation of the adjoining fibrous and glandular tissues, and finally, when healing is complete, the central portion is occupied by fibrous or adenoid new growth consisting of cylindrical cells arranged about a lumen, no opening existing toward the stomach cavity and no secretion flowing from the cells. Fibrous tissue replaces lost muscle cells. Sometimes healing leaves, in the vicinity of the ulcer, chronic inflammatory areas which tend to erosions and recurrent bleeding. This may be serious, and even fatal, if large vessels are involved.

SYMPTOMS.—There may be no characteristic symptoms, the first discovery of a gastric ulcer being made unexpectedly at the autopsy. Then, again, the first evidence may be a sudden or perhaps fatal hemorrhage; or the peritonitis following a perforation may give the first indication to patient or physician that an ulcer has been present. The symptoms may simulate spinal disease, hysteria, hyperacidity, and only upon the appearance of more serious signs does the diagnosis become clear.

Dyspeptic Signs.—When the symptoms are marked there is a sense of weight and pressure coming on in one-half to two hours after meals—after a time becoming more aggravated. These may be the only signs throughout the whole disease, or others may and usually do follow. Pain develops, and then follows vomiting during the digestive period; the pains are in the area of the stomach, often of a piercing nature and felt in the back, and a small localized area of tenderness can be detected. There are often signs of hyperacidity, such as acid eructations and heartburn. The tongue, though often coated, is usually clean, red, and moist. The appetite varies, and, though it is usually good, patients fear to eat because of the chance of inducing pain. Thirst may be present. One or more hemorrhages may occur, and pallor usually becomes marked, with perhaps weakness or collapse. The stools may contain blood, and there is usually constipation, due to the anaemia, the nature of the food, the lack of exercise, and the vomiting. Remissions and exacerbations occur, and the disease may run on for a very long period.

The general condition remains good, as a rule, though the anaemia and emaciation are sometimes marked. Nervousness, melancholia, headache, and dizziness are common; so, too, is amenorrhœa or dysmenorrhœa. Fever is usually absent unless complications arise—especially peritonitis, and sometimes hemorrhage. The urine is lessened in quantity when vomiting occurs or when less nourishment is taken. It is usually less acid, especially when there is gastric hyperacidity.

Special Symptoms.—*Pain* is described as boring, burning, gnawing, rarely lancinating or cramp-like, and radiates often to the back. It is paroxysmal, and may be at times excruciating. It occurs during digestion, either at once after taking food or at the height of digestion. The hyperacidity increases it. When the ulcer is at the pylorus, the pain may not appear for from three to four hours after meals, and will thus lead one to suspect a duodenal ulcer. It is distinctly aggravated by a large amount of food or by food that is solid. On the other hand, the pain is relieved by rectal alimentation. It is frequently localized, and nearly always referred to the same spot, while pressure of the hand or clothing usually aggravates it. It may or may not be altered by a change of posture. The most tender spot is usually in the epigastrium below the xiphoid cartilage, or it may be located to the left of the spine between the seventh and twelfth dorsal vertebræ. It is an important diagnostic feature that the tenderness of the stomach corresponds to the seat of pain after eating, and that the situation of this tenderness rarely varies during the whole course of the malady. The cause of the pain varies, it being due sometimes to the food, sometimes to the gastric movements or to involvement of the peritoneum. Scars do not usually cause pain unless there are adhesions.

Vomiting is less constant than the pain. Cantlie found it in seventy-nine out of eighty-five of his cases in Montreal. There may be merely nausea and flatulence, and never any vomiting, or the vomiting may appear only at intervals of a week or more. The vomiting occurs sometimes immediately after taking food, but usually one, two, or three hours later—during digestion, and generally at its height. The pain is relieved by it. To a great extent the onset of vomiting depends on the quality of the food; it occurs less often after taking fluids than after taking solids, and especially coarse heavy foods.

The *vomitus* varies according to the food and its sojourn in the stomach. Digestion is usually quick, and albumens are well divided on account of increased hydrochloric acid. At other times the food is quite undigested, and the vomitus is acid and "puts the teeth on edge."

Hæmatemesis occurs in more than twenty-five per cent. of all cases of gastric ulcer. In the statistics of University College Hospital the percentage was eighty-four; at the Royal Victoria Hospital sixty per cent. had hæmatemesis. It is well to remember the other causes, especially erosion of the mucosa elsewhere than in the stomach, with oozing of blood which may be fatal and which may show no signs at autopsy of its origin. There is also the possibility that the hemorrhage may be dependent upon some circulatory disturbance, especially mitral stenosis, or upon cirrhosis of the liver, splenic anæmia, leukæmia, uræmia, tabes dorsalis, fraud, etc.; and one must include in the diagnosis of hæmatemesis the previous taking of wine, iron, coffee, fruit juices, etc., which may simulate altered blood. The history, too, must be carefully taken to insure the gastric origin, and the mouth, throat, and lungs must be thoroughly examined, as well as the liver, spleen, and blood.

In hemorrhage from the stomach the source is usually arterial, the vessel becoming eroded during the development of the ulcer. Hæmatemesis occurs in about one-third of all ulcer cases. The blood is usually dark in color, the hæmoglobin being changed to hæmatin by the hydrochloric acid. Few corpuscles are then left unaltered, and the vomitus may resemble coffee-grounds, though it may have a brighter color if a large vessel be eroded and if the blood be vomited quickly after it escapes from the vessel. The matter vomited, which may be copious in quantity, contains coagula and bits of food, and is acid in reaction but not foamy.

The hemorrhage may be fatal at once, without any blood being ejected from the stomach—as, for example, when a comparatively large artery is eroded. This, however, rarely happens; usually, when there is a serious hemorrhage, the patient vomits a large amount of bloody fluid, becomes pale, cold, semi-conscious, and complains of dizziness and headache. The pulse is rapid and small, and there is a warm feeling in the epigastrium. Sometimes the hemorrhages are oft-repeated in spite of care, and sometimes again one or more insignificant ones take place, and then they cease altogether. Some of the blood gets into the intestine, and during the next day or two the fæces are black, or brownish-black, with a shining surface. This color is due to the intimate mixing of blood and chyme in the small intestines.

Sometimes all the blood escapes per rectum, and there is no hæmatemesis. This occurs where bleeding is more gradual, and there is thus less tendency to vomiting.

Tests for the presence of blood, especially in the fæces: Teichmann's test with hæmin crystal formation is sometimes unsatisfactory, and one may not obtain the crystals. The spectroscope is better. Weber's test is the most reliable. It is made as follows: Rub up a little of the fæces with water, to which has been added one-third volume of glacial acetic acid; shake out with ether, and, on its clearing up, take a few centimetres of the ethereal extract and treat it with ten drops of tincture of guaiacum and from twenty to thirty drops of turpentine; a blue-violet color results if blood is present.

Objective Signs.—But little is gained from an examination of the stomach. A localized tender spot, often no larger than 2 to 3 cm. in diameter, may be present, and is felt often "through to the back" on deeper pressure. It is found most often just below the xiphoid cartilage. Very frequently, however, the tenderness is not so localized, and a more diffuse soreness is felt in the epigastrium on palpation. No tumor is palpable in fresh ulcers. In *older ulcers*, where scarring has occurred at the pylorus, the signs of stenosis may be present; peristaltic movements, and even a tumor, may be seen on inspection, while palpation may reveal the latter as a more or less movable mass situated at some part of the upper right quadrant of the abdomen.

Diagnosis.—In making a diagnosis of ulcer of the stomach one should first exclude the possibility or likelihood of gall-stones, simple gastralgia, simple hyperacidity, cancer, renal calculus, aneurism of the aorta, and spinal disease. The points which favor this diagnosis are: sex (female), pain after taking food, tenderness over the region of the stomach, hyperacidity, vomiting, usually preceded by pain, and hæmatemesis.

A diagnosis of the seat of the ulcer is usually impossible. The ordinary evidences mentioned by many writers are now known to be quite unreliable. Then again, there may be several ulcers present at the same time, and we may overlook this in laying stress on the site of one which gives evidences of being located at a certain spot.

The Use of the Stomach Tube for Diagnosis of Ulcer.—The contraindications are: Recent hemorrhage, or where an ulcer at the cardiac orifice is suspected, or where there is but little doubt in regard to the existence of a gastric ulcer.

Riegel asserts that when the introduction of the tube is "carefully done" there is but little danger. At all events severe efforts at vomiting are dangerous, and expression is an unwise method; but if the tube is readily taken it may be safe to resort to this procedure.

Prognosis.—Recovery takes place in most cases in which perforation has not occurred. Fatal hemorrhage occurs in less than five per cent. of all cases. One sees post mortem twice as many scars as fresh ulcers. In men the mortality is twenty-two per cent., in women six per cent.; in both together eight and one-half per cent. for all cases. Older ulcers are more favorable. Relapses are frequent, and may occur after several years. Sometimes a new ulcer forms alongside of an old and chronic one. Cancer may form on top of an ulcer.

Complications.—Perforative peritonitis; perigastritis, suppurative and adhesive; subphrenic abscess; fistula between stomach and adjacent organs; abscess of liver and chronic hepatitis; acute and chronic pancreatitis; pressure on or constriction of main bile ducts, with jaundice; contraction of scar followed by the development of a cancer; hour-glass stomach; pyloric stenosis; dilatation of stomach; cardiac stenosis.

Perforation is one of the most serious complications in gastric ulcers, and occurs in about fifteen per cent. of all cases. It takes place from the deeper extension of the ulcer, and is most common on the anterior wall, where there is greater mobility of the part and less tendency to the formation of adhesions. It may, however, and often does, occur in the posterior wall.

Partial or general peritonitis may follow. Partial peritonitis is usually confined to the epigastrium and left hypochondrium and is usually purulent, or pus may collect in the lesser omentum if the perforation is located posteriorly. General peritonitis occurs chiefly when the perforation takes place rapidly and before any previous adhesions have formed.

The perforation may extend directly or indirectly (*i.e.*, after adhesions have formed) into adjoining organs or tissues; no serious results may follow, or the affected organ may show more or less serious symptoms and signs. Perforation into the pancreas or liver may cause abscesses or chronic inflammation in either organ. Subdiaphragmatic abscess sometimes develops. If the perforation extend into the gall bladder, gall-stones may fall into the stomach through the fistulous opening. The intestines may be penetrated and severe diarrhœa occur, with bloody or purulent fæces, or fæcal vomiting may take place instead. Rarely, the ulcer perforates the abdominal wall itself, penetrating muscles and skin and leaving an external fistula. The pleural cavity is sometimes invaded, with the formation of a pyopneumothorax; more rarely, the lung is penetrated and the sputum may then contain stomach contents. Rarely, too, the pericardium is penetrated.

The Symptoms and Signs of Perforation.—The onset is usually sudden; indeed, it may be the first and only sign of the ulcer. The patient need not be overcome and incapacitated at once; oftentimes he is able to walk into hospital with such a perforation. It commonly follows some strain (vomiting, exertion, etc.) or trauma, or a hearty meal. Pain is the earliest sign; it is usually referred to the epigastrium, spreading soon to the right and left, but not leaving its original site. There is no pain or difficulty during micturition. Dyspnœa soon follows and deep breathing causes pain about the diaphragm, so that these cases are sometimes mistaken for acute pleurisy.

Collapse and prostration supervene, although in some cases remarkably little prostration is observed—a fact which is apt to mislead, all the more so as the general signs may greatly improve after a few hours, before graver symptoms develop. The face then is anxious, often pinched, and there is apt to be great restlessness. The pulse is usually accelerated, though sometimes it is normal, and the temperature may be but little altered immediately after perforation has occurred; usually there is slight fever. The abdomen may be flat and tense; sometimes it is distended; the muscles are rigid. Tenderness is chiefly in the upper abdominal zone, mostly about the epigastrium. Percussion may or may not give dulness here, and the liver dulness need not be obliterated. On auscultation a friction rub can often be heard over the diaphragm, and sometimes the gurgling of fluid through the perforation.

Though it is commonly taught that vomiting never occurs after a perforation, this cannot be relied upon, as experience teaches the fallacy of too strict an adherence to this rule. Attention should be paid to the base of the thorax on the left side, where one often obtains restricted movement, localized pain and tenderness with dulness in the lower axillary region, and other signs of fluid. Fluid may collect beneath the diaphragm, about the anterior and external surfaces of the spleen, or in the lesser peritoneum. Later on, one may obtain the usual signs of general peritonitis.

Treatment.—Rest in bed is essential for at least four weeks after the diagnosis has been established and the treatment commenced. After this, the transition from bed to walking about must be very gradual, and the patients should be made to rest after every meal. This precaution should be observed for some months. It is true that even this does not always suffice, and a much longer period may be necessary; but apart from active operative interference, rest to the body and to the stomach are the main essentials in the present state of our knowledge.

Dietetic.—In all cases it is well, during the first few (three to eight) days, to depend exclusively upon rectal alimentation. In this way the stomach is given a complete rest. Every six hours the patient should receive (by way of the rectum) six ounces of broth with egg, and if necessary a little whiskey. Each enema should contain a little salt; the bowel should each time be first washed out. Any other diet is apt to cause distention, to increase the hyperacidity, to induce vomiting, and thus directly or indirectly to prevent healing of the ulcer. At most, a little water or chopped ice may be taken.

When food is admitted by the mouth it is best to commence with milk and lime-water, strained oatmeal gruel, or albumin-water—at first in small quantities (a few ounces)—every two hours, and to combine this as required with the nutrient enemata. Then, while gradually increasing the amount of food furnished to the stomach, one may reduce the rectal feeding. At the end of four weeks one may add finely divided albuminous food, minced white flesh, chicken, partridge, pounded fish and tender beef, and light puddings. *The greatest care should be taken in changing to a more solid diet, and it is always safer to go very slowly at this stage.* After six weeks, red meats may be given. One must, however, take special care with the diet for several months after there is an apparent cure, and all coarse, irritating, spicy, and rich foods must be avoided.

Medicinally, Carlsbad salts in small doses (one drachm), given in hot water in the early morning, will often be found beneficial, and bismuth, especially the subgallate, in doses of twenty to thirty grains, three times daily, affords great relief. Again, with other patients, the combination of sodium bicarbonate and calcined magnesia assuages the pain and the burning.

The constipation may not be relieved by the Carlsbad salts; in which case enemata of soapsuds should be administered. Lavage may be used where there is a very intractable stomach, and sodium bicarbonate may be added to the water used.

Pain, if severe, may need morphia; a wet compress over the epigastrium is often soothing.

For *vomiting*, ice, bismuth, and nitrate of silver (gr. $\frac{1}{4}$).

For the *hæmatemesis*, absolute rest and quiet, ice to suck, and small doses of adrenalin chloride in solution of 1 to 1,000, may be effective. For the restlessness one may use morphine hypodermically. For severe recurrent hemorrhage surgical intervention may be necessary and is often most successful.

Surgical Treatment.—If the bleeding be of a very serious character, recourse should be had to operation. The indications for surgical interference in gastric ulcer are briefly:

Repeated, profuse and dangerous hemorrhage.

Scars which have resulted in tumor formations, which greatly interfere with the motor function. In these cases gastro-enterostomy is recommended. The operation is also indicated where active ulceration exists, inasmuch as draining the stomach suffices to heal the ulcer. It can be performed, too, very quickly. In some of the cases, however, pylorectomy is required or advisable, and in others pyloroplasty.

Purulent perigastritis, especially if subphrenic or thoracic.

Perforation into the abdominal cavity. In this condition operation must be done early, otherwise the case is almost certain to end fatally. Early operations are followed by more than fifty per cent. of recoveries, in some institutions the proportion being even greater. Dr. James Bell's cases at the Royal Victoria Hospital, Montreal, numbered ten, with nine recoveries.

In hour-glass contraction one of three operations is employed, viz.:

Gastroplasty, gastro-enterostomy, or gastro-gastrostomy.

[For further details concerning these operations consult the article on *Stomach and Œsophagus (Surgical)*.]

IX. CANCER OF THE STOMACH.

Carcinoma Ventriculi.

This is a malignant epithelial neoplasm of the stomach. About one-half of all cancers arise in the stomach.

Etiology.—It occurs chiefly between the ages of forty and seventy, and most of all between the ages of fifty and sixty. Lebert's statistics show that only 1 per cent. occur under 30 years, 17.6 per cent. between 30 and 40 years, 60.7 per cent. between 40 and 60 years, 16.3 per cent. between 60 and 70, and 4.4 per cent. over 70 years of age.

It is a little more common in males than in females. There are no climatic conditions of importance, except perhaps the fact that it is more rare in tropical countries. Such, at all events, is the evidence given by physicians residing in those lands.

Heredity seems to acquire a more and more doubtful value in the etiology of cancer.

Parasites have not yet been proven as a direct cause, nor has irritation as such been definitely associated with the disease as its chief etiological factor. Chronic ulcer of the stomach, however, is a frequent antecedent.

Morbid Anatomy.—Cancer of the stomach is a typical epithelial overgrowth extending to the other coats of the organ, and thence to neighboring glands and to other organs by continuity and by way of lymph and blood channels. It is nearly always primary in this part of the body, rarely secondary.

The Situation of the Growth.—The pylorus is the most common place of origin, the growth often starting at the tubercle, while next in frequency come the lesser curvature and the cardia; the fundus is nearly always free. The statistics of Hahn on this point show that out of 170 cases 60 were at the pylorus, 27 at the lesser curvature, 40 at the cardia, 7 in the anterior wall, and 7 in the posterior wall; in 8 cases the disease began in the greater curvature, and in 21 the whole organ was diffusely involved.

Orth's statistics differ somewhat from Hahn's. He found that in 60 per cent. of all cases the pylorus was involved chiefly, while in 20 per cent. the lesser curvature was the seat of origin; the cardiac orifice was involved in only 10 per cent. of all his cases, while the remaining 10 per cent. were distributed more or less unevenly over the other portions of the organ.

The Neoplasm.—This is either circumscribed or diffuse in character. When circumscribed it projects as a villous or fungoid growth, with or without central degeneration and ulceration; when diffuse it extends along the submucosa, causing thickening and rigidity of the wall and a roughening of the mucosa, which may be ulcerated in various portions, while the rest of the mucosa shows either a chronic inflammation or hemorrhage.

Orth distinguishes four forms:

1. The cylindrical celled, *i.e.*, the soft fungous-like growth, which often forms papillary projections on the surface. These projections show microscopically an adeno-carcinomatous arrangement. Such growths are oftenest at the pylorus, where they are sharply delimited toward the duodenal end. Necrosis, ulceration, and hemorrhage are apt to occur, and perforation may result.

2. The medullary or soft form, which is mainly ulcerative, and shows a projecting wall. Degenerative processes are common, and the growths may extend to the serosa or through it. Extension to the glands is especially common in this variety, and it is very rapid in growth.

3. The scirrhus form, with carcinoma simplex as its subvariety. This is the hard form of carcinoma ventriculi. Instead of being circumscribed, it shows a more diffuse thickening of the whole wall. The mucous membrane may be superficially ulcerated, but there is a tendency to scar formation on the surface which may be either rough or smooth. Here the cancer extends gradually into the surrounding parts, more especially into the muscles, and the microscopic appearances are such as to render the differential diagnosis from chronic simple ulcer, or from simple cirrhosis of the stomach, either difficult or impossible without a microscopical investigation. These cancers tend to shrink, and, inasmuch as they are most common at the pylorus, stenosis of that orifice is apt to follow; moreover, adhesions are very commonly found between the pylorus and the surrounding parts, which tends further to increase the liability to stenosis.

4. The colloid variety. In this form there is a diffuse thickening of the wall due to the presence of a jelly like, translucent material, brownish-gray in color, the result of colloid degeneration of the cancer cells. Shallow ulceration accompanies this extension and secondary nodules are frequent. Here, too, the pylorus is the commonest seat of origin, and from this point the cancer may spread far and wide. In some cases, however, the stomach is really smaller than normal.

These different forms of cancer of the stomach are apt to be combined in one and the same case, and the name carcinoma simplex is given to that form in which the medullary and the scirrhous varieties are more or less evenly mingled.

The Shape of the Stomach.—This depends upon the situation and upon the variety of the tumor. Where the pylorus is involved there is apt to be dilatation; where the cardia is the original site, the stomach may be smaller than normal; and where the body is involved, there may be either a diminution in size or, if much scarring has taken place, there may be an hour-glass contraction or some other perversion of the original form.

The Position.—There may be ptosis of the stomach, or, if the growth at the pylorus be heavy and free, the stomach may assume a more vertical position, while in other cases there is no alteration whatever from the normal.

Extension.—The advance of the disease may be confined to the stomach, in which organ it causes degeneration and hemorrhages, great or small, and such hemorrhages may be fatal. There may be perforation with general peritonitis, or merely a local peritonitis with adhesions. This, however, is evidently a rare event, for out of forty cases at the Johns Hopkins Hospital only six were found to have such a condition. The perforation may result, however, in establishing an abnormal communication with other organs or cavities of the body, or with the spaces in between the various organs and tissues of the abdominal cavity.

The cancer again may extend to the œsophagus, or by contiguity to any other part in the vicinity. It may extend by way of the lymph channels, getting into the glands, chiefly those about the portal vein and cœliac axis, and eventually it may reach the thoracic duct, whereby it will involve (by retrograde progression) the left supraclavicular gland as well.

The liver is involved in more than twenty-five per cent. of all cases, chiefly by way of the blood or lymph channels; and inasmuch as growth in the liver is easy, from the nature of its tissue and constituent parts, the secondary nodules there may be much more extensive than was the original disease in the stomach.

The peritoneum and omentum may likewise be involved through extension by the lymph channels; so, too, may the pancreas, in which case sugar is usually present in the urine.

Secondary Cancer of the Stomach.—This is a rare condition, and is due to direct contact, the disease extending from the pancreas, liver, œsophagus, etc., or, as in one case recorded, by implantation from a primary cancer of the tongue. Another method by which it may arise is through metastases from the blood. Welch has collected 37 cases in all; of these, 17 were secondary to cancer of the breast, 8 to cancer of the œsophagus, 3 to cancer of the mouth.

In the recent series of the Johns Hopkins Hospital, reported by Osler and McCrae, three cases were found—two associated with primary cancer of the pancreas and one with primary cancer of the uterus.

The morbid anatomy is in all respects similar to that of other cancers. So far as the other organs are concerned, it may be stated that brown atrophy and fatty degeneration are often observed.

SYMPTOMS AND COURSE.—*The Onset.*—This is usually insidious, and shows mainly a persistent dyspepsia, more or less progressive, with pain in the abdomen and loss of flesh. As time goes on, vomiting occurs and cachexia gradually develops, until after some months, or perhaps at the end of two or even three years, the patient succumbs to the disease.

Examination of such patients in the fairly advanced stage shows profound weakness, an earthy hue to the skin, emaciation, and vomiting of more or less undigested food and coffee grounds, which show on chemical examination the presence of abundant organic acids, and especially lactic acid.

Examination of the abdomen shows, in the majority of cases (because the majority are pyloric in origin), a marked dilatation of the stomach with succussion splash, tenderness in the epigastrium, and perhaps a tumor.

The symptoms, of course, vary according to the stage of the disease, the extent and the pathological nature of the growth, its site, and its direction of progression.

The Individual Symptoms.—The onset may be latent entirely, and development may occur under the picture of senile marasmus, or a chronic gastritis, or a primary cancer of the liver; or the condition may be found accidentally at autopsy in death from other causes.

In nearly all cases the onset is insidious. In the majority of cases there has been previously no dyspepsia, and the patient may seem to be suffering from a mild gastritis, though without apparent cause. There are loss of appetite, a sensation of fulness after taking very little food, and flatulence. Sometimes indeed the onset is sudden, after an acute indigestion or influenza. This is less marked in young persons, as has been shown in the cases of Osler and McCrae.

There is, however, one set of cases in which the onset is exceptional—viz., those in which the cancer is engrafted upon a previous ulcer with all its classical signs. Even when there is cancer of the cardiac end the onset is gradual, except perhaps that the pain comes earlier, and is present not only after meals but at any time during the day.

The Appetite. The appetite becomes gradually worse; very little satisfies the patient, and there is rarely a good appetite for any length of time. As a rule there is anorexia; meat is especially abhorred. That anorexia is more marked in young persons cannot be considered as an infallible statement.

Pain. Pain is rarely absent. In Dr. Osler's series thirteen per cent. ran a painless course, but even when present the pain as a rule is not intense; not so severe, at all events, as in ulcer. There are a painful distress and a dull ache in the stomach region rather than true pain, and the symptoms are rarely localized. It cannot be said that any relation exists between the absence of pain and the site or nature of the tumor, nor can it be said that there is any relation between the presence of the tumor and the site of the pain.

Food often increases the pain, especially late in the digestive period, unless the cancer be at the cardiac end. Sometimes the pain has no relation to the ingestion of food, but is continuous. It may radiate, more especially to the back, or, if the cancer be at the cardiac end, it will be referred to the vicinity of the sternum. There is nothing characteristic about it. It is less acute, as has been said, than it is in ulcer of the stomach, and if there be great tenderness a complication may be suspected. With pyloric stenosis especially, there is a sense of gastric unrest; cramp-like pains due to the peristalsis may be present.

Vomiting. This is a very frequent symptom, occurring in from eighty to ninety per cent. of all cases. It usually appears late in the disease, and is especially common in cancer of the pylorus. In such cases there are dilatation of the stomach and stagnation of food. As a result the vomiting is often severe and consists of coarse, undigested acid food with a foul odor or one of fæces (in the latter case even when there is no communication with the bowel).

Much mucus is present when the cancer is at the cardia, and in such cases the vomiting is more of the nature of a regurgitation of œsophageal origin than a true vomiting.

In some cases there is no vomiting at all, more especially when dilatation is absent, or when the cancer is on the greater curvature or on the posterior wall of the stomach. Absence of vomiting does not depend upon the presence or absence of ulceration. Sometimes, again, vomiting, which has been very severe, may cease more or less suddenly, as, for example, when the pyloric stenosis breaks down and gives a new exit for the food into the duodenum.

As to the time of its appearance, the vomiting usually occurs late in the afternoon or evening; it is sometimes more or less periodical, every two or three days only, in which cases the matter vomited is often copious (several litres), and its appearance depends chiefly upon the nature of the food ingested.

Hæmatemesis. Hæmatemesis occurs in less than half of all cases of gastric cancer. It is associated with small parenchymatous hemorrhages from degeneration of an ulcerated tumor, or, more rarely, with the erosion of a larger vessel, in which case a fatal result may ensue, though this is rare. The amount of blood is usually small; it oozes slowly and remains a long time in the stomach. For this reason it becomes rapidly changed in color and nature, and assumes the appearance of chocolate or of coffee grounds, and the blood cells in it are more or less altered and much pigment is formed.

Bowels. These are at first costive; constipation indeed is much more common than is diarrhœa, though sometimes diarrhœa and constipation alternate. There is no relation between the growth itself and the regularity of the bowels.

Objective Signs.—Nutrition. At first the nutrition is good, and it should be remembered that a good nutrition is not necessarily incompatible with the presence of a cancer of the stomach, unless the disease has been of a year's duration. Again, the patient may, after being emaciated for a certain length of time, regain his weight for a brief period under the employment of lavage, a proper diet, etc. As a rule, emaciation follows soon upon the onset. The skin becomes lax and assumes an earthy color, the muscles waste, and the patient becomes dried up and cachectic. Loss of strength goes hand-in-hand with loss of weight.

Fever. Fever occurs probably in about one-half of the cases; it is usually very slight and manifests itself at varying intervals. The type varies; it may be slight and intermittent, or very irregular, or sometimes—and more especially when ulceration and metastases are present—there may be periods of high fever following sudden rigors. Such a condition is usually associated with absorption of toxins, where fever is persistently high, and one is justified in suspecting an inflammatory complication, such, for example, as peritonitis or pleurisy.

The Tongue.—The tongue is apt to be thickly coated, though this varies very much with the condition of the mouth and teeth, and one may find for months a tongue that is perfectly clean while the cancer is progressing.

Taste is apt to be much altered in various ways, and the patient, if an habitué of tobacco, loses a desire for smoking.

The neck may show evidences of swollen glands, as may also the left axilla. Swollen glands, however, are not common; they are associated with involvement of the thoracic duct, and when present form a valuable sign of gastric carcinoma. And yet their absence is in no wise of value as a proof against cancer.

The Abdomen.—Inspection. This is of great importance in the examination for gastric carcinoma, and Osler has drawn especial attention to this fact. One should examine the abdomen for unevenness in the furrows below the ribs, for fulness in the epigastrium, for nodules in the skin or about the umbilicus, for peristalsis and antiperistalsis; this last especially is of great importance in the diagnosis of pyloric stenosis. One may even see a tumor when present, as well as gastrectasis and gastroptosis. Such an evidence of tumor implies either its large size (because if at the pylorus or cardia it would be covered over by liver or ribs), or else a gastroptosis which exposes the otherwise covered portion of the stomach.

The mobility of the tumor may also at times be ascertained by inspection, both when adhesions are present and when there are no adhesions. Various positions of the body too may alter its situation, while artificial inflation may cause it to become more prominent or to disappear. It is to be remembered that a full stomach sometimes pushes tumors up underneath the liver and makes them thus temporarily disappear. Pyloric tumors are the most movable of all, and they are especially so when they are circumscribed and solid.

Percussion is of but little importance in the examination for gastric cancer. When the tumor is present there may be a dull tympany; when gastrectasis exists percussion reveals the enlarged size of the organ and aids in its proper delineation.

Auscultation and auscultatory percussion have practically no value in the physical examination for gastric cancer. Occasionally, when the cancer is obscure and involves the cardiac end of the stomach, one finds the deglutition sounds delayed or lost.

In the absence of a tumor the diagnosis often remains doubtful, though other signs are valuable positive aids.

The Functional Signs.—It must be remembered that there is no pathognomonic sign of cancer. Each item of evidence must be considered in connection with others, and only from the combination of signs and symptoms is one able to make a positive diagnosis.

The Motor Power.—This is usually greatly diminished; it depends to a large extent on the site of the neoplasm. When the tumor is at the cardiac end of the stomach, the motor power is but little impaired until extension has occurred to other parts of the stomach wall, or until a concurrent catarrh of the mucous membrane is present. When the cancer arises at the pyloric end, however, the motor power is rapidly impaired, and often to an extreme degree. This is more especially the case when there is complete obstruction without a sufficient compensatory hypertrophy of the gastric muscular coats. Hence we have pyloric stenosis with gastrectasis and atony of the wall.

When the cancer involves the body of the stomach, the motor power is impaired in more than one-half of all the cases. It is altered mainly in two ways: firstly, by infiltration of the walls with cancer; and secondly, by simple weakness of the muscular tissue due to a toxæmia and to cachexia.

Motor insufficiency appears early, especially in the case of pyloric cancer, and increases progressively till marked retention of food occurs. Indeed, the retention is often extreme, and foreign bodies remain for weeks and even months in the stomach without finding an outlet.

The Secretory Power.—The secretory power of the stomach is likewise disturbed, and there is diminution of the hydrochloric acid and subsequently of the peptone and rennet ferments.

With regard to the presence or absence of hydrochloric acid in cancer of the stomach, the following facts are important:

1. Hydrochloric-acid secretion usually diminishes with the development of the cancer until free hydrochloric acid is ultimately permanently absent. This occurs in from eighty to ninety per cent. of all cases, very often early in the disease. It should be remembered that one examination alone does not suffice, inasmuch as hydrochloric acid may be only temporarily absent in this as in other diseased conditions of the stomach.

2. Combined hydrochloric acid is also quite often absent.

3. Hydrochloric acid is not always absent; indeed, it may be present up to the end. This is usually coincident with either a very localized tumor, where the rest of the mucous membrane remains more or less intact, or it may occur when the cancer develops upon a previously formed chronic ulcer. In this latter case the hydrochloric acid may be increased. The presence of hydrochloric acid in a test meal is no proof against the presence of cancer in the stomach.

4. The absence of hydrochloric acid in the stomach contents is no proof in itself of the presence of cancer. Such a condition arises in many ways; for example, in neuroses of the stomach, cardiac disease, gastritis, febrile conditions, amyloid disease, atrophy of the gastric glands, etc.

The presence of organic acids is a frequent sign in cancer of the stomach. The chief organic acids found are lactic, butyric, and acetic acids, which arise as a result of fermentation, which occurs so frequently in cancer in association with the presence of hydrochloric acid, of subacidity, and of motor insufficiency. Butyric and lactic acids are the most common, both being present with about equal frequency, though the latter is more constant and thus more characteristic of cancer, though by no means pathognomonic. The following facts are of importance in regard to lactic acid in cancer of the stomach:

1. Its presence is not pathognomonic of cancer. The requirements necessary for the production of lactic-acid fermentation are merely these: subacidity, stagnation of food in the stomach, and a lessened digestion of albuminous foods. It may be present in the stomach in a case of intestinal obstruction, sometimes even in pyloric obstruction from benign growths, where the hydrochloric acid is diminished; also in severe gastritis, in atrophy of the mucous membrane, in fat-necrosis of the pancreas, in cardiac and renal disease, in gall-bladder carcimona, in pernicious anæmia, etc.

2. Lactic acid is introduced preformed into the stomach, under normal conditions, with the food. For this reason Boas recommends a test breakfast consisting of oatmeal and water, such a meal being free from lactic acid. It is prepared by adding a tablespoonful of Knorr's oatmeal, with a little salt, to one quart of water. This may be introduced at night into a previously washed out stomach, and the remains removed in the early morning. When cancer of the stomach exists, the bacilli present can form lactic acid, even after such a meal, more promptly than when lack of hydrochloric acid and a motor insufficiency are present.

3. Lactic acid is formed only in the absence of free hydrochloric acid. Even a little combined hydrochloric acid sometimes suffices to prevent lactic-acid fermentation, unless there also be a very marked atony.

4. In cancer of the stomach lactic acid usually appears early, often long before gastrectasis appears, though, according to Kuttner and Lindner, not before the tumor is palpable.

5. The presence of lactic acid merely implies three circumstances: (*a*) subacidity, (*b*) motor insufficiency, (*c*) lessened digestion of ferments, all three of which happen to occur most commonly in cancer of the stomach, though they may be present in other conditions.

Lactic acid, then, is not pathognomonic and may be entirely absent. Statistics show it to be present, however, according to Strauss, in ninety-one per cent. of all cases, according to Rosenheim in seventy-eight per cent., and in Kuttner's cases in sixty per cent.

The Microscopical Examination of the Contents of the Stomach.—This reveals at times the presence of blood cells and pigment, though these have no special significance *per se*. Particles of cancer formation are very rare in cancer. At the Royal Victoria Hospital this occurred but once in eighty-five cases in which the stomach contents were examined, but the event proved here of great value inasmuch as the diagnosis was otherwise in doubt.

The Boas-Oppler bacilli, which are long, thread like, non motile bacteria, occur chiefly where lactic acid is present, but are of no other diagnostic value so far as carcinoma of the stomach is concerned. Sarcinæ are uncommon unless free hydrochloric acid is present—therefore, as a rule, they are found only in those cases of cancer in which the neoplasm has been engrafted on a previous ulcer. It should be remembered, however, that the presence of sarcinæ is no proof against the presence of cancer. Yeast cells sometimes occur. Inasmuch as the digestion of proteid is delayed, meat fibres in abnormal quantities are usually found, while the starchy foods show more evidence of digestion.

Cancer of the Cardiac End of the Stomach.—In this condition dysphagia is a prominent symptom. At first there is a sense of the food stopping in the œsophagus, especially after solids have been taken, and liquids are ingested to assist in the deglutition of the solids. The symptoms are progressive, and water is now essential to carry down the solids, and discomfort and oppression follow. The food is then ejected by retching. Liquid diet alone is then possible. Later on, even very little of this, and still later none, can be taken without its being rejected.

There is regurgitation of much mucus, with or without food particles, and more especially at night. As already said, the deglutition sounds may be delayed or absent, though this is an unreliable sign. The passing of the tube meets with resistance and tubes of various sizes must be tried. It should be remembered that this resistance is not always a sure sign. However, the repeated finding of blood, commonly in a fresh state, on the tube after it has been withdrawn is a matter of grave significance, even if there are no signs whatever of stricture.

Cancer of the body of the stomach is associated with atrophy of the organ. This usually reveals a smaller stomach than normal, and its capacity becomes progressively less. The tumor is usually felt on the left side beneath the ribs. The passing of the stomach tube in such a case aids the diagnosis, and inflation either causes vomiting at once, or, at all events, no marked increase in the gastric tympany.

The *metastases* which occur in cancer of the stomach vary in size; they involve, of course, most commonly the glands and the liver. The thorax may be invaded, and the pleuræ, more especially the left; the lungs and the mediastinal glands may all be involved, as also, though more rarely, the peritoneum and the heart itself. There is practically no organ in the body which may not be secondarily involved by metastases, and under certain conditions these develop so much more rapidly than the original growth as to mask the primary seat of the disease. This is a most common occurrence where the liver is involved, or the peritoneum.

The metastases which occur upon the abdominal wall are of special interest, and attention has been chiefly called to them in recent publications by Dr. Osler. These occur subcutaneously as small nodules of various sizes, in and about the umbilicus, which itself may become very hard. The nodules may extend up over the chest, also over the area of the liver, and often their removal and examination constitute the necessary final step in establishing the diagnosis of carcinoma ventriculi.

Complications. Perforation of the stomach is not very common: most statistics agree in placing it at four per cent. There is usually a walled-off abscess cavity, which often progressively increases. Tracks may be made into the other viscera or the neighboring tissues.

Jaundice often occurs and may be due either to an obstruction of the main bile ducts, a secondary involvement of the liver, or, more rarely, to a simple catarrh of the common duct. As a rule, the jaundice persists when once present, though this is not always the case.

General anasarca, more or less slight in degree, may appear in the late stages of the disease. It is due to the cachexia and anæmia, or more rarely to a peripheral thrombosis.

Ascites may be present, and is associated usually with a cancer of the peritoneum, or an occlusion of the portal vein from the pressure of glands or the extension of the cancer into the part. The ascites may be a prominent feature, masking the original cause of the disease. When the ascites is associated with a cancer of the peritoneum, the fluid is usually hemorrhagic in character.

Multiple thrombi may occur, usually associated with marasmus, more rarely with occlusion caused by the neoplasm.

Diagnosis.—The earliest possible diagnosis is essential to a rational treatment of the condition, and a diagnosis should be established before a tumor is evident, either to palpation or to inspection. To establish such a diagnosis one must depend largely upon early evidences of functional disorder. It must be remembered that there is no single pathognomonic sign of cancer of the stomach. The disease of course may be latent, but the absence of gastric symptoms is an important negative sign. When the gastric signs are present and no tumor is evident, one must rely upon the age, the history, hæmatemesis, emaciation, gastrectasis, the chemical signs in the stomach contents, etc. When the tumor is palpable its location must be determined to be gastric, and this fact must be weighed in connection with the history and the general features, above described.

In the *differential diagnosis* one must consider mainly: (1) Those diseases in which hydrochloric acid is diminished or absent, and in which a tumor is not evident upon physical examination; (2) those general diseases in which the gastric evidences of disease are unsatisfactory, but in which the general signs warrant the suspicion that there is a latent gastric carcinoma; (3) the necessity, in the cases in which a tumor is present, of differentiating between (*a*) one which is located in the stomach and (*b*) one which is located outside that organ, in the immediate neighborhood.

1. Diseases with diminished or absent hydrochloric acid. These are mainly (*a*) chronic gastritis, (*b*) atrophy of the mucous membrane, and (*c*) gastric neuroses.

(*a*) Chronic Gastritis. Here the course and duration of the disease are important. The insidious onset with remissions and exacerbations, the local rather than the general features, the fact that hydrochloric acid is not always completely and permanently absent, and the probable cause (alcohol, etc.), all may be placed against a history in which there has been a previously healthy digestion with an unexpected and unexplained dyspepsia, not relieved by diet or drugs; with a probable hæmatemesis, severe general signs, and stomach contents which show persistent and progressive diminution of the hydrochloric acid and the presence of more or less lactic acid. Difficulties indeed arise where the gastritis is accompanied by atrophy of the mucous membrane and where the course is rapid and characterized by emaciation. Vice versa, it must be remembered that cancer sometimes develops slowly, and only with a mild dyspepsia.

(*b*) Atrophy of the Mucous Membrane. This may be associated with pernicious anæmia, with the terminal stage of a chronic gastritis, with achylia gastrica, with benign pyloric stenosis, or with cancer elsewhere.

In pernicious anæmia the nutrition is usually maintained, and there is an absence of hæmatemesis, gastrectasis, lactic acid, etc. The blood-changes, too, in pernicious anæmia are, as a rule, more marked than are those which occur in cancer of the stomach, though at times, it is true, the conditions of the blood may be incidental in each case. As a rule, however, there are more nucleated red cells of the blood, the poikilocytosis is greater, the color index may be higher, and there is more likelihood of the presence of megaloblasts when pernicious anæmia is present. Exacerbations and remissions too are more apt to occur in pernicious anæmia than in carcinoma.

Chronic gastritis has already been considered.

Achylia gastrica, considered by Einhorn and some others as an independent disease, implies a total absence of gastric juice. It is not associated in any way with cachexia or with progressive emaciation. The general condition of the patient is usually good, the digestive power excellent, even when there is no motor insufficiency, and examination of the stomach contents does not necessarily show the presence of lactic acid. More probably, as many suggest, achylia gastrica is merely a symptom associated with some other primary disease, such, for example, as cirrhosis of the liver. (Such a case has come under my personal observation.)

Benign pyloric stenosis, *vide antea*.

Cancer elsewhere, *vide infra*.

(*c*) Gastric Neuroses. In gastric neuroses in elderly people there is at times considerable difficulty in arriving at a proper diagnosis, though as a rule the general condition of the patient, frequent examination of the stomach contents, and the course of the disease soon lead one to a conclusion in the right direction. In such cases, as already mentioned, one must consider the age of the patient, the history, the presence of hæmatemesis, gastrectasis, lactic acid, etc., as well as the effect of treatment, both general and dietetic.

2. Those general diseases in which the gastric evidences are indefinite, but in which the general signs lead one to suspect a latent gastric carcinoma.

I have seen, for example, such difficulties arise in cases of suspected Addison's disease in which the general malaise, progressive weakness, dyspeptic signs, and general condition aroused a suspicion of the possibility of latent gastric cancer. As a matter of course, valuable aid may be derived from the examination of the stomach contents, where possible, and from a proper examination of the mucous membrane for the presence or absence of the usual pigmentary changes which accompany Addison's disease. To this may be added the injection of tuberculin, a reaction to which would render the presence of Addison's disease somewhat more likely.

3. The differentiation between (*a*) gastric and (*b*) non-gastric tumors calls for a careful weighing of the symptoms and signs presented and for a determination of the exact situation of the tumor.

The gastric tumors must be mainly differentiated as to their nature and situation. The signs and symptoms accompanying cancer of the cardiac end of the stomach and of the body of the stomach have already been mentioned (*vide antea*). As regards the nature of a tumor of the pylorus, there are four possibilities to be considered: It may be (1) a malignant growth; or (2) a scarred ulcer of the pylorus with stenosis; or (3) a simple hypertrophic stenosis of the pylorus; or, finally, (4) some other form of benign tumor, such as lipoma, fibroma, etc.

The symptoms connected with a cancerous growth of the pyloric end of the stomach have already been sufficiently considered. A scarred ulcer of the pylorus can be diagnosed as such only by the previous history of ulcer and especially of hemorrhages from the stomach, and by the finding—as happens in nearly all the cases—of free hydrochloric acid in the contents of the stomach. In other respects there are the usual signs of motor insufficiency associated with any pyloric obstruction, but there is not, as a rule, the same degree of wasting of the gastric muscle wall. Unless the general condition of the patient has suffered very greatly from malnutrition, the muscle wall remains hypertrophied for a great length of time, and peristalsis and anti-peristalsis may very frequently be seen even in spite of extreme dilatation.

The vomiting occurs, as in other cases of motor insufficiency with obstruction, at long intervals, is very copious and explosive in character, but as a rule, in contradistinction to what is observed in pyloric cancers, the proteids are well digested and the starches more or less unaffected.

Hypertrophic stenosis of the pylorus is usually slow in growth. It is very often congenital, and there is a history of many years of gastric symptoms without evidence of metastases; there are intervals, too, of good digestion, and the tumor which is found is usually smooth, not large, without adhesions, and therefore very movable.

Examination of the stomach contents will show the presence of hydrochloric acid and the absence of lactic acid.

The presence of some other form of benign tumor is rather to be inferred than accurately diagnosed. When it causes obstruction, the symptoms and signs resemble very much those of hypertrophic stenosis.

Growths Located Outside the Stomach.—The tumors simulating gastric growths, but existing in reality outside the stomach, are mainly:

1. The pancreas, either normal or pathological. When normal it is usually found deeply situated in the median line, fixed and immovable with respiration, and absent upon inflation of the stomach. When it is diseased, and especially when it is the seat of a cancerous growth, one may find clayey, fatty stools, even when there is at the same time no jaundice. Jaundice may, however, be present from pressure of the growth upon the common duct. The portal vein may be pressed upon and the resulting obstruction may give rise to ascites. There may also be glycosuria, and as a rule the course is a rapid one.

2. Tumors of the transverse colon. These usually give evidence of some degree of intestinal obstruction; the stools may be bloody. Examination of the stomach itself by test meals and inflation shows the absence of gastric disorder.

3. Tumors of the gall bladder are situated in their appropriate place, are somewhat movable, and may by pressure upon the surrounding ducts cause early jaundice. At times, however, the differential diagnosis is extremely difficult. While there need be no motor insufficiency, yet adhesions in the neighborhood of the gall bladder tumor may cause pyloric stenosis and certain signs of gastric cancer. The absence of respiratory mobility may suggest a gastric cancer rather than one of the gall bladder; but a test meal, when possible, will usually reveal the absence of the functional and chemical signs of gastric cancer.

4. Cancer of the duodenum. Here the difficulties are great indeed; it may be impossible to diagnose the true condition. One may have diminution or absence of hydrochloric acid. Lactic acid, on the other hand, may be present, as indeed may most of the other signs of gastric cancer.

5. Omental and peritoneal tumors, whether of a cancerous or of a tuberculous nature, are apt to be confused with cancer of the body of the stomach. In such cases one usually observes that these tumors are not mobile with respiration. The other important evidence of the nature of the disease is furnished by the examination of a test meal. It is especially necessary in such cases, however, not to omit an examination of the rectum. When the peritoneum is tuberculous, the subjects are usually young; there are fever, a longer course of the malady with exacerbations and remissions, and a reaction to tuberculin.

6. Cancer of the liver. This is usually secondary, and less easily fixed with expiration than are tumors of the stomach. A satisfactory means of differentiating is, where possible, to place the hand above the tumor. Then, if the liver can be felt still higher, the tumor is probably gastric; at all events it is not hepatic. The same is true if with inflation of the stomach the tumor alters its position. When the cancer of the liver is primary, the liver becomes rapidly large; jaundice is early and pronounced. The gastric signs are slight or absent and there is no hæmatemesis nor gastrectasis. Moreover, the usual signs after a test meal are not found in the contents of the stomach.

Other conditions which may simulate a gastric tumor are aneurism of the abdominal aorta, swollen glands about this artery, a movable kidney, and enlarged spleen, the last simulating a cancer of the fundus.

Prognosis.—The prognosis in nearly all cases of carcinoma is of extreme gravity. There are very few cases on record in which treatment has effected a cure. All medical treatment is purely symptomatic. Surgical treatment can only be of benefit by complete resection, and this can only be effected in those cases which are diagnosed extremely early. For this reason operation upon cases of carcinoma ventriculi is rather discountenanced by many, and Fitz regards the indiscriminate operation upon cases of carcinoma as of the utmost harm to the patients, causing no relief to the symptoms and only hastening the lethal termination.

Exploratory Laparotomy.—This is to be considered inadvisable where the cancerous nature of a gastric tumor is undoubted, or where the glands are secondarily involved, or other metastases are discovered. Only in doubtful cases, in which one feels sure from the general and local symptoms and signs that a progressive, slowly developing malady of the stomach is present, is one justified in making an abdominal exploration. Such an operation also should only be done with the expectation of carrying out still more radical measures, should the exploration afford any sure indication of its necessity.

In such conditions resection follows an exploratory laparotomy only when the pylorus or a small portion of the lesser curvature is alone involved. A good general condition of health, moreover, is essential to such an undertaking. Obviously, therefore, very few cases indeed ever gain benefit from radical treatment by the surgeon's knife.

Treatment.—This is both surgical and medical. The only rational treatment, so far as cure is concerned, is surgical. But in this respect a proper judgment in regard to the selection of cases for operation is of paramount importance.

The rational surgical treatment depends entirely upon the early diagnosis and the radical extirpation (resection) of the whole cancerous tissue.

Resection.—This is commendable only for cancers of the pylorus, or for more or less circumscribed cancers of the lesser curvature. There must be no adhesions to surrounding parts and no metastases. The general strength of the patient must be in a fair condition, and a certain amount of good motor power is also essential to a good result, in order that one may have thereafter a proper digestion. Without a good motor power the already diseased mucous membrane functionates badly, the undigested food remains too long in the stomach, and the previously existing suffering from dyspepsia continues.

Rosenheim claims to have shown that a motor insufficiency under certain conditions may be cured or much improved by the resection of a cancerous growth.

The failure to make an early diagnosis is the chief cause of failure of resection. In an overwhelming majority of cases resection is done too late and the results are correspondingly bad.

Gastro-enterostomy.—This is performed only when resection is not feasible, and is to be considered merely as a palliative measure. Even this should be undertaken only when the stenosis is so extreme as to render the combined use of lavage and gastric feeding useless to maintain an ordinary nutrition of the patient. The nature of operations indicated in the treatment of gastric cancer is mentioned in the article on the surgery of the stomach.

Gastrectomy is recommended only for cancer of the cardiac end of the stomach, and the operations recommended by Witzel and Frank would appear to be those most commended.

Statistics as to the results of operations vary very greatly, and the recent communication of Fitz should do much to aid the judgment of surgeons in the proper selection of cases for operation. His after-history of cases upon which laparotomies had been performed tends to show that in the majority of instances patients have become rapidly worse rather than improved by the treatment.

The Medical Treatment.—This concerns, of course, chiefly the inoperable cases, or those cases which, having been operated upon, require still further treatment for a cure.

Inoperable cases must be treated medically for various reasons. One is unable perhaps to resect on account of the advanced condition, or a gastro-enterostomy is not yet required; or, it may be, that a resection is difficult or inadvisable on account of the cachexia or metastases present; or, again, through refusal of the patient to allow an operation to be performed. And lastly, one must treat cases after a gastro-enterostomy has been performed, when the neoplasm and the symptoms reappear *de novo*.

The main treatment is dietetic. The diet, however, should not be too strict, and one must go rather upon general principles than upon any definite lists of foodstuffs. Inasmuch as one can but alleviate rather than cure, the patient's own tastes should be consulted even when spices and other apparently harmful foods are desired. The meals should be small and frequently given, rather than large and few in number. On account of the deficient hydrochloric acid, meat should be limited in amount. It should be finely divided and free from cartilage and other substances difficult of digestion. White meats are to be preferred; chicken, game, pigeon, veal, and beef in small quantity, and calves' brains and fish, are often well borne. All these proteid foods should be followed, after meals, by small quantities of hydrochloric acid (unless, of course, there is hyperacidity from a cancer engrafted upon an old ulcer).

One may give, as recommended by Fleiner, sauces containing hydrochloric acid, his special one consisting of: Beef juice, ℥ ss.; warm water, ℥ iij., to which has been added ten drops of dilute muriatic acid. Meat jellies and somatose are well borne.

Vegetables may be given in relatively large amounts, though one should avoid those which are coarse and indigestible; those, therefore, with shells, skins, fibres, etc., as well as those which are fermentable. The most suitable of all are perhaps spinach, artichokes, beans, peas, and carrots.

Bread may be allowed, as also gruels and vegetable soups, particularly rice, macaroni, barley, tapioca, sago, and oatmeal.

Milk containing nutrose, eucasin, or plasmon may also be taken, while buttermilk, kephir, and kumyss are likewise often well borne. The fats are best supplied by butter.

For beverages, apart from those mentioned above, one may take the light wines, weak brandy and whiskey. All fluid should be limited in amount because of the motor insufficiency. There is often great thirst because the tissues are dry and hot, and water may often relieve this condition. When the condition is extreme, it may be well to give daily enemata of plain water, one-half to one pint at each injection.

Lavage is the best means of treatment that we have in cases of inoperable carcinoma of the stomach. It helps to stimulate the appetite and the secretions; it washes away food remnants and prevents fermentation. One may use either plain water or water to which salicylic or boracic acid has been added. The lavage is performed in the morning, and if the condition be of an aggravated character a second lavage may be done in the evening.

Medicines.—No medicine is of any great value. Orexin in doses of five grains may help the appetite, as also may an infusion of condurango bark. One finds that alkaline mineral waters before meals sometimes stimulate the secretions, while hydrochloric acid after meals helps proteid digestion.

For the vomiting, especially of blood, rest to the stomach is essential. Nutrient enemata may be given, and then careful feeding by mouth may be begun with small quantities of fluid. For the ordinary vomiting lavage is the best form of treatment.

Diarrhœa should be treated by a proper diet where possible, and by the use of lavage to remove irritating substances which are the probable cause of the condition.

For the constipation, aloes, rhubarb, and cascara are the most effective remedies. Enemata should be given when the condition is aggravated, but this should not be persisted in too long. Authorities differ as to the use of saline purgatives, and doubtless in individual cases their use will have different effects.

For the pain, wet compresses upon the stomach, lavage, and the use of spirits of chloroform may be of value, and it is only in the extreme cases that morphine should be employed.

X. PYLORIC STENOSIS.

There are two main conditions—malignant pyloric stenosis (cancer of the stomach, *q.v.*) and benign pyloric stenosis.

Benign Pyloric Stenosis.

1. *Congenital Atresia.*—This is rapidly fatal. Soon after birth there is uncontrollable vomiting, even before food and drugs have been given. Sometimes there is a tiny opening only into the duodenum, and death is then more gradual and accompanied by inanition. The stomach may be hypertrophied in consequence.

This atresia may exist in the duodenum, and, if it be situated high up, the symptoms will then be, to all intents and purposes, similar to those mentioned.

2. *Hypertrophic stenosis*—that is, hypertrophy of the fibrous and muscular tissues; this develops slowly and lasts for years.

3. *Foreign body.*

4. *Benign tumors*, especially fibroma (polyp).

5. *Cicatrized Ulcer.*—Such ulcers are of various kinds.

6. *Pressure from Without.*—A movable kidney, as in the case of Dr. Bramwell's patient (*vide British Medical Journal*, October 19th, 1901), may be the cause of such pressure. Adhesions and fibrous bands, such as result from perihepatitis and from cirrhosis of the liver, as in the case of F. H. Murdoch's patient (*vide American Medicine*, January 11th, 1902), may also cause gastric stenosis through pressure.

7. *Duodenal obstruction*, especially when associated with great laxity of the abdominal walls, is competent to cause pyloric stenosis by drawing upon and twisting the horizontal portion of the stomach.

8. *Spasm of the Pylorus.*—This is mentioned, among causes, by Sir William Bennet (*British Medical Journal*, February 3d, 1900).

Symptoms.—The earliest signs of all are shown when dietetic errors, chiefly as regards the quantity of food, cause general gastric distress after meals. Soon afterward, however, other symptoms develop. The main signs in both the early and the late stages are pain and vomiting.

The pain at first is more of an indefinite gastric distress, which develops only after meals. This is followed in one or two hours by vomiting of solids which are excessively acid. This vomiting gives relief. Then, after a variable period of hours, days, or weeks, the symptoms recur and with exacerbations. The pain is greater, more frequent, and may be cramp-like if already hypertrophy of the gastric muscles has occurred. Later, the pain becomes more or less continuous, and is associated then with increased peristalsis, though it may in part be due to the hyperacidity, hypersecretion, fermentation, or an ulcer if present. In the later stages, when there is retention of food, the pain is often marked at night.

Ordinarily the vomiting increases synchronously with the pain. When the muscles are hypertrophied the vomiting which accompanies the cramps is more explosive; it may occur at any time and not merely after meals, and often there may be an interval of a day or more between the attacks. When the diet is not regulated and motor insufficiency increases to a great degree, the vomiting becomes less frequent (once every few days perhaps), more copious, and shows much evidence of fermentation.

The vomitus, on standing for a short time, separates into three layers, the lowest consisting of more or less digested chyme, the middle layer of turbid fluid, and the uppermost of frothy mucus and particles of undigested food.

With these two cardinal symptoms of pain and vomiting there is, in the early stages, a good appetite till fermentation becomes marked. On the other hand, thirst, which is at first not a prominent symptom, becomes distressing with increase of the motor insufficiency.

To the above symptoms loss of weight and strength should be added.

The general constitutional symptoms in such cases affect the heart action, which may be irregular, intermittent, or more rapid than normal. The movements of the diaphragm are limited; there are neurasthenia, anæmia, cold extremities, weak and flabby muscles, a dry scaly skin, progressively developing cachexia, marked constipation, and a diminished quantity of urine.

The Physical Signs.—The early stage may show nothing or merely a prominent epigastrium; peristalsis, though slight, may be visible early. There may be more resistance than normal over the area of the stomach, which may give a more cushion like sensation on palpation. If the abdomen be thin and flabby, a tumor may already be felt at a comparatively early stage.

Later, when the obstruction is more marked, one is more liable to see peristalsis, either spontaneously or after stimulation, as by flicking the abdomen with the fingers or an instrument. Succussion may be obtained during the period when gastric repose should exist, and a tumor may now be still more evident.

When retention has occurred the above signs will be still more marked and succussion may be obtained at any time during the twenty-four hours. The abdomen is prominent, especially when the stomach is filled with food or gas.

The Tumor.—The pylorus and the regio pylorica, normal or abnormal, are very often movable, and may be found in a great variety of positions. A tumor of this part, therefore, may be felt in various positions unless adhesions be present; and one must decide between a neoplasm, a hypertrophy of the pylorus, and a scarred ulcer. Or, again, the ill defined mass may be due to an inflammatory exudate, etc., around the outside of the pyloric ring.

The patient should be examined lying on his back. The stomach should be empty and the bowels evacuated. Especial care should be taken to look for the descent of the tumor with inspiratory efforts, as often happens when the tumor is adherent to the liver. Under such conditions the origin of the tumor may be hard to determine, unless one can dip the hand down between the tumor and the liver itself.

At other times the tumor may not only be felt in various parts of the epigastrium and to the right of the median line, but it may even be visible as a projecting lump above the general plane of the abdomen. It sometimes is found below the navel; or, again, because of adhesions, it may be displaced upward, beneath, or next to the liver.

At still other times the tumor is to be felt or seen only on inflation of the stomach with gas. A tumor in the neighborhood of the pyloric region, which upon inflation is displaced to the right and downward (more rarely upward), and which returns to its original position when the stomach is again empty of gas, is undoubtedly a tumor belonging to the pylorus.

The functional signs are more or less characteristic only during the time when stagnation or retention occurs. While the solids of a test dinner are delayed the fluids seem often to pass through the pyloric region much more rapidly than is usually the case with idiopathic gastrectasis. In this case the total acidity is usually high, from the presence of either lactic or hydrochloric acid. With hydrochloric acid there are usually the yeast fungi and perhaps acetic acid, while the sarcinæ ventriculi are also commonly present.

In benign obstruction hyperchlorhydria is the rule. When organic acids are present, malignancy is suggested.

Differential Diagnosis.—Cases are not usually recognized before stagnation has become marked. Suspicion should be aroused when there are recurrent attacks of indigestion, especially with pain and vomiting, in patients who have previously suffered from ulcer, gall-stones, etc.

When the motor insufficiency is advanced, we must decide whether this condition is due to an obstructed pylorus or is idiopathic. (For this differential diagnosis see the paragraph on motor insufficiency.)

From *supersecretion* the diagnosis is not difficult if the stomach can be thoroughly washed out at night and its contents examined again on the following morning. In the fasting stomach no contents should be found when obstruction alone exists; but, if supersecretion be present, more than 30 or 40 c.c. of fluid (which is probably hyperacid) can be removed.

It is by no means easy to decide whether the obstruction is pyloric or *duodenal*. Duodenal obstruction is usually associated with gastroptosis or with cancer, with pressure exerted by a benign tumor, with scarred ulcer, local peritonitis, gall-stones, or some congenital abnormality. If the obstruction be *above* the common duct, it cannot be differentiated from pyloric stenosis. Gastroptosis may be the cause, but it can only be suspected by exclusion. Obstructions *below* the duct are suspected when more than a normal quantity of bile is in the fluid vomited, and when it is found at an early stage of the vomiting.

To decide whether the obstruction is malignant or benign is sometimes easy, at other times quite impossible. The following table may be of some assistance in this respect:

	Benign.	Malignant.
History	Ulcer, toxic gastritis, etc.	
Tumor	Smooth, as a rule	Nodular, hard.
Secretions	Hydrochloric acid normal or in excess.	Hydrochloric acid usually absent or amount small.
	Lactic acid, usually absent	Usually present and with bacilli.
	Butyric acid, usually absent.	Butyric acid common.
Gases	SH_2	SH_2 uncommon.
Bacteria	Sarcinæ, long present	Absent or soon disappear when lactic acid is present.
Age	Any age	Above 20.
Course	Rapid	More rapid and progressive.
Therapeutic measures.	Rectal feeding benefits	Rectal feeding does not cause benefit.
Metastases	None	May soon appear.

Cancer of pancreas and gall bladder seldom diminish gastric secretion till cachexia is present.

Diagnosis of the Nature of the Benign Obstruction.—It may be (1) cicatricial tissue, the result of a *toxic gastritis*, and this should be revealed by the clinical history.

(2) *Congenital atresia or stenosis.* This should be suggested by the age of the patient, by the onset and the course of the disease, and by the general signs and symptoms.

(3) *Hypertrophic or hyperplastic stenosis,* which may be congenital or acquired. As a rule this is a developmental hypertrophy, but it may be due to spasm of the pylorus from various causes, or it may be the result of a congenital narrowing of the lumen and a secondary hypertrophy of the muscles. The lumen varies in size. The increased tissue is muscular and fibrous, and the mucosa shows often a catarrhal inflammation.

Congenital cases are rare (see *British Medical Journal*, April 28th, 1898). Less than fifty cases have been recorded, and they occurred usually under four months of age; they have been observed more often in male children, and the main signs of diagnosis are as follows:

1. Duration from infancy.
2. Persistent vomiting from no apparent cause, nor with any other sign of indigestion; occurring at variable times after food, or only after several meals have been taken; and sometimes ceasing temporarily with careful dieting and lavage.
3. Emaciation.
4. Constipation.
5. A palpable tumor.
6. Visible peristalsis.

In the acquired cases there is usually a history of persisting gastritis. Examination of the abdomen shows a smooth, non-adherent, regular tumor. The late course is rapid, and unless operation be performed a fatal issue is bound to ensue.

The degree of obstruction, as regards compensation, stagnation, or retention, is easily told by the ordinary tests for the motor power. The quantity of the urine, moreover, in the twenty-four hours, may aid somewhat in estimating the degree of obstruction, provided there be no great perspiration, diarrhœa, vomiting, or renal disease. The course of the disease is another guide in this particular.

The prognosis, unless operation is performed, is always grave and in proportion to the degree of obstruction and the cachexia which has developed.

The TREATMENT is both medical and surgical.

The *medical* treatment is symptomatic, not curative, and it is useful when operation is otherwise contraindicated or impossible.

The *dietetic* treatment: In the early stages there should be no excesses and the food should be finely divided. There should be a moderately dry diet consisting of albuminous foods, chiefly meat, poultry, fish, eggs, milk, a few cereals in purée form, and ordinary vegetables in moderation; and one should avoid coarse irritating solids and fermenting liquors, such as beer. The food should be given in small quantities, and nothing that is starchy or sweet should be permitted if hydrochloric acid be abundant. In some cases it is best to give three small concentrated meals. When vomiting persists it may be necessary to give nutrient enemata.

The *mechanical* treatment is to be used in the later stages. Rest is essential. Lavage should be thoroughly performed, either in the early morning or before the evening meal.

The three guiding principles are, first of all, that the stomach should be empty before each meal; second, that the food must be finely divided, readily soluble or easily rendered fluid, and not apt to disturb the secretory or motor functions; and, third, the diet must be varied and sufficient to support or improve nutrition (Van Valzah and Nisbet).

The *medicinal* treatment: For the persistent vomiting rectal feeding and, if pain persists, atropine in doses of gr. $\frac{1}{150}$ hypodermically, may be used. Morphine may be required, though codeine may cause less nausea and be equally effective.

For the constipation, enemata of soapsuds and of oil should be used, or glycerin suppositories may be tried. Purgatives, especially drastic purgatives, should be avoided, and even the mild purgatives should be given as infrequently as possible.

The *surgical* treatment: Many operations have been devised and as quickly rejected. Loreta's digital divulsion is inefficient and therefore not to be recommended.

Pylorectomy is not indicated in benign obstruction when a gastro-enterostomy can be equally well done, as the latter gives eminently satisfactory results, and is in all probability the less dangerous operation.

The two operations which have found most favor are the gastro-enterostomy and the pyloroplasty, as suggested by Heinecke and Mikulicz.

The operative treatment, however, in this condition has been considered in the article on the *Stomach and Œsophagus, (Surgical)*. The indications for operation, therefore, are mainly these—when the obstruction is continuous, and when the patient cannot be successfully nourished by other means, then operate.

XI. SIMPLE TUMORS.

Simple tumors play a very small part in the diseases of the stomach. There are several conditions which, by producing a tumor in its broadest sense, may cause some difficulty in diagnosis. Of these one may mention:

Tubercle in the stomach is excessively rare. Hale White in "Allbutt's System" reports five cases of tuberculosis in the stomach, in one of which, in a male aged seven years, there were found enlarged and caseous lymphatic glands at the lesser curvature.

Syphilitic gumma in the stomach is less rare, as first shown by Chiari, of Prague.

Phlegmonous gastritis, especially when going on to acute abscess, produces a mass within the stomach. This is extremely rare and generally rapidly fatal in several days. (*Vide* section on Gastritis.)

Hypertrophic stenosis of the pylorus is common in adults and produces tumor and dilatation. A series of forty-five cases in infancy has been reported (Rolleston and Crofton-Aikens), mostly in children under four months, with very few recoveries. Six were operated upon and one was cured. (*Vide* section on Pyloric Stenosis.)

The cicatrix following ulcer, though producing no swelling, may convey a sense of hardness to the touch. Such a cicatrix, although not classed among the new growths, is one in reality.

One form of tumor simulating gastric disease may be referred to, viz., preperitoneal *lipoma*. A young man, complaining only of moderate diarrhœa during five months, showed, on inspection of his abdomen, a small tumor in the epigastrium, discoid, slightly lobulated, and 3.5 cm. in diameter. It was too superficial to be elsewhere than in the abdominal wall, and did not in the slightest degree rise and fall with respiration. It was in fact a lipoma epigastrica. In the surgical department Dr. Archibald pointed out that one such case, which had come to operation, showed that the lipoma, originating in the preperitoneal fat, had become adherent to the omentum, and had so dragged on it as to cause the symptoms of which the patient complained until the operation removed the growth.

A full account of these herniæ is given in the "Handbuch der praktischen Chirurgie," Bd. iii., Th. t, where it is shown that the lipoma originates in the preperitoneal fat and grows forward, ever stretching more and more an opening in the lattice-work between the recti muscles, until a firm ring is formed, or several, up to four (Berger), through which as many herniæ are forced. On cutting down on such a lipoma one finds that it envelops a funnel-shaped cord of peritoneum or true sac, which is often empty, but which more frequently contains omentum adherent to the hernial sac. Rarely, the sac contains transverse colon. In 10,000 herniæ Berger counted 137 cases of hernia epigastrica (1.3 per cent.), of which 120 were in males generally with other herniæ, and mostly in elderly spare people. More than half the cases were traumatic in origin, sometimes a muscular strain, sometimes a direct blow on the abdomen, being the exciting cause. Of interest to us are the many "gastric" symptoms caused by these apparently innocent tumors, viz., violent pain, tearing or boring in character, in the gastric region, belching of air and vomiting, distention, and difficult bowel movement, dyspnœa, palpitation, faintness, diarrhœa.

The symptoms may eventually assume a nervous type (hypochondriasis), with loss of flesh. These symptoms suggest the stomach, but only one case is on record and this showed that a part of the stomach was in the sac. In fact, almost all the above symptoms have been reported in cases in which no part of the gut was directly involved, the sac containing only fat lobules together with vessels or nerves. The commonest content of the sac, then, is omentum; less commonly, part of the transverse colon. The symptoms are explained either by traction through the omentum on the colon and through the gastrocolic ligament on the stomach, or by traction and bruising of nerves. In some cases the lipoma is not in connection with peritoneum, but generally it is attached to a large diverticulum of peritoneum which embraces from time to time parts of the omentum, or of the bowel, or both. Careful palpation will reveal an irregularity in the linea alba and the pressure of a hazelnut-sized soft tumor, slightly tender perhaps, which gives way on deep pressure, leaving a pit and a distinct gap in the abdominal wall. Rarely, one can at the height of the paroxysmal pain feel a tension in the tumor, which is relieved by suitable posturing. The symptoms are generally referred by the patient, and indeed by the physician, to other causes, *e.g.*, gastric ulcer or gall stones. The case referred to above as having been operated on is reported in full by Roth in the *Archiv für klinische Chirurgie*, Bd. 42. After his accident the patient continued to have frequent paroxysms of incapacitating symptoms for seven years, during which time he suffered much of many physicians, and of bath and "cure institutions," until he sought a surgeon, who cut down and found the lipoma enveloping a funnel-shaped tube of peritoneum, to which a part of the omentum was adherent. It was radically treated and the ring accurately sutured. Fourteen days later the patient felt well and had remained so up to the date of the report.

Another case, in a male aged eighty-three, was seen post mortem; in this case the lipoma was no larger than a hazelnut, but the symptoms (pain, nausea, vomiting) had been prominent. The mass of fat was found adherent to the suspensory ligament of the liver, which, when drawn on by the lipoma, pulled the stomach down, producing, by constriction, a typical hour-glass shape in that viscus.

The true simple tumors in the stomach recorded are:

1. *Fibroma*—a congenital fibrous thickening at the pylorus, leaving a very small lumen—has been seen in the body of an infant five weeks old. Finkelstein reports several. These patients die within several months of birth.

2. *Fibromyoma*—very rare; it occurs up to the size of a pigeon's egg, and projects into the stomach. These tumors consist of unstriped muscle and fibrous tissue, sometimes pedunculated and in some cases multiple.

3. *Lipoma* has been very rarely described.

4. *Polyadenomata* are common and often numerous. Osler says one hundred and fifty were seen in one patient. They raise the mucous membrane into polypoid masses, the "polyadenome en nappe" of the French.

5. *Multiple cysts* in the wall of the stomach (and of the intestines) have been described by H. B. Anderson.

XII. FOREIGN BODIES IN THE STOMACH.

The question of foreign bodies in the stomach, apart from the perennial scares of the nursery, is a matter rather of the music halls and the footlights than of clinical import or medical literature. In the nursery children swallow small coins, buttons, and various hard objects of endless description. The more serious objects do not reach the stomach, being generally arrested at the level of the cricoid cartilage; while of those which reach the stomach the vast majority give no serious trouble, being passed by natural channels in due time. In most cases, then, especially when one has only the statements of surrounding children to go upon, the best treatment is a little judicious letting alone. Peabody, however, reports a case in which

FIG. 4547. Hair Bolus in the Stomach, Found at Autopsy. The specimen is preserved in the Medical Museum of McGill University, and mention of the case will be found in Osler's "Practice of Medicine," 1901.

a pin pierced the œsophagus and reached the heart, while Dock mentions an ear of barley reaching the liver. At an operation for appendicitis in the Royal Victoria Hospital Dr. Bell showed a large pin snugly embedded in the mucous membrane of the appendix. Music-hall artists do, apart from optical illusion actually swallow metallic objects, considering the plaudits of the gallery and an increased salary sufficient reward for their loss of internal comfort. The more experienced the performer is, so much the finer will be the collection which he makes,

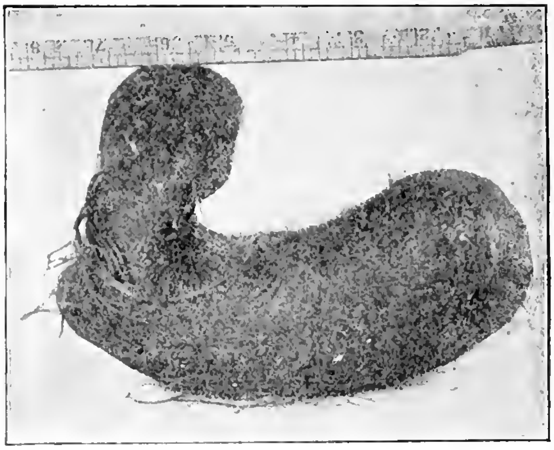


FIG. 4548.—Dr. James Bell's Case of Hair Bolus in the Stomach. Royal Victoria Hospital, Montreal.

and he need never feel that the loss of the treasures will be permanent, for at some period in his career his life will become intolerable, and he will by the aid of the surgeon recover the goods. In fact, every year one reads in literature, medical as well as lay, of several persons being admitted to hospital with slight, vague gastric symptoms. On opening the stomach a truly remarkable store of manufactured articles is revealed. Countless pins, nails, buttons, coins, false teeth, iron plate, buckles, and chains are among the favorite articles, while the knives or portions of other cutting instruments excite the greatest astonishment.

A medical friend assures me of having seen in the Dupuytren Museum in Paris a full-sized silver dinner fork which was found in the human stomach. It is well known that painters occasionally swallow spirituous shellac, which may harden and lodge in the stomach. In the Canadian Northwest there are Indians who, when suffering from lack of food, feel better with something in the stomach, and deliberately place there great pieces of caked earth.

Riegel mentions the fact that a stomach tube has been lost in the organ for long periods, and states that foreign bodies in the intestine may ulcerate into the stomach. Sarcina ventriculi has produced an obstructing tumor in the stomach (Riegel). The remarkable hair tumor in the stomach, common in cattle and swine, though rare in human beings, is well known. Osler, writing in 1901, states that there are only sixteen cases in the literature. He has made famous an example (Fig. 4547) of such in the McGill Medical Museum, Montreal. Such cases occur mostly in hysterical young women from fifteen years of age upward and in the insane. Several cases, however, have been reported in children who formed the habit of swallowing their own hair. One case is on record in which a young fair haired girl swallowed not only her own hair but also that of her black dog, and in her stomach was found a correspondingly variegated hair bolus. These bodies are puzzling, especially when only partially filling the stomach, and are generally overlooked or pronounced cancer. Of the 16 cases mentioned by Osler 9 were recognized only at autopsy, 7 were operated on, of which 6 recovered. The literature shows that, as a rule, there are masses of hair in the intestines also, and these commonly kill by perforating ulceration. A very remarkable case was reported (Montreal *Medical Journal*, February, 1903) by Dr. James Bell, in the person of a twelve year-old girl, who was admitted to the surgical wards of the Royal Victoria Hospital, November 13th, 1902, with a "tumor of the stomach," and complaining of vomiting and diarrhœa. She had had good health till January, 1901, when vomiting and diarrhœa were severe for ten days, and less so for the following three months. There was some pain in the lower part of the abdomen. The vomiting had no relation to eating, and brought up mostly frothy mucus. In May, 1901, she returned to school for a year (May, 1902), during which time she had fair health, with only occasional vomiting and diarrhœa. She then (May, 1902), however, had the same symptoms in very severe form, and left school. At this time a mass was felt, and was thought by a physician to be abscess of the liver. Through the summer of 1902 she was walking about, though showing some similar symptoms. Her appetite was very capricious; she took meals very irregularly and would never consent to eat much at a time. On admission, November 13th, 1902, she was a slight girl, weighing forty-nine pounds; temperature normal, pulse 144. In the position of the stomach there was a painless, hard mass, and a diagnosis of probable hairball was easily made. On November 17th, 1902, operation; abdomen opened in the median line, wound packed, and incision four inches long made in the anterior surface of the stomach, midway between the curvatures. The pyloric prolongation was hooked out and the mass delivered (Figs. 4548 and 4549). Some of the hairs were found to be eighteen inches long. A small detached mass was seized in the intestine. The stomach and the abdomen were closed without drainage. After operation some diarrhœa continued. The child was very intelligent at school, and she was known, three years previously, to break her hairs with her fingers, but was never seen to put them in her mouth. Mits were bound to her hands and the habit was apparently cured, for nothing was seen of it in the last two or three years. The hair in the stomach in this case is much darker than that on the patient's head; and the same fact has been noted by all previous observers. This is due to chemical action, the exact nature of which is a matter for theorizing. One can imagine, as Dr. Bruère points out to me, that some of the ample supply of sulphur in the keratin of the hair combines with hydrogen in the stomach to form sulphureted hydrogen, which latter, having a powerful affinity for iron, combines with the iron in the melanin granules occurring in and between the cells of the hair,

FIG. 4549.—Slightly Different View of the Hair Bolus Found in Dr. Bell's Case, showing a cast of the duodenum.

to form sulphide of iron. This sulphide may do the staining. Dr. Bell has kindly stated that after the operation (November 17th, 1902) occasional vomiting and considerable diarrhœa with fœtid stools persisted. On December 13th a hard mass was palpated in the right hypochondrium, and on December 15th the abdomen was reopened and a tear in the ileum found through which a tuft of hair protruded. The mass, when extracted, proved to be a cast, eight inches in length, of the intestine. On December 20th a third operation was performed and a new perforation was sewn with Lembert suture. On December 23d, at the fourth operation, the small intestine was found riddled with openings, and two inches of gut were removed and the cut ends were united by sutures. On December 26th a fæcal fistula established itself, and one hair came away in the dressing. At three more operations fresh perforations were found and closed. On January 22d a large opening was found, but the patient's condition prevented a resection. On January 29th it was found that sutures would not hold in the intestines. In March a resection was done and the divided ends of the bowel were united by a Murphy button, which has been passed since. Now (April 18th) there is no fæcal fistula, and the patient, after eleven operations, is apparently, on the high road to recovery.

XIII. DISPLACEMENT OF THE STOMACH.

In the fœtus, and in fact at birth, the stomach appears to be an ill-defined portion of the alimentary tract, or a mere loop, slightly dilated it is true, of the gut. At necropsy its limits are not readily made out, and in removing the organ in order to ligature its orifices and inflate the stomach, with the view of measuring its capacity or for teaching purposes, one is at a loss to know precisely where to place his ligatures. This is particularly true of the pyloric end, where the muscle is not yet concentrated into a sphincter-like mass as in the adult; while at the cardiac end one notes an absence of that expansion in the adult organ called the fundus. Furthermore, the entire stomach occupies a position much more nearly vertical than is the case in adult life.

Bearing this in mind, one is at times struck with the resemblance, in an abnormally placed adult stomach, to the fœtal form and position. At such a time one can think of a persistence of fœtal conditions.

Normally, the stomach is a large, flexible, hollow viscus, whose thin, mostly flaccid walls and more or less empty condition render it utterly unable to hold its own (position and form) against the many moving organs with which it is in immediate relation. It is ever completely at the mercy of the diaphragm. There is thus, accurately speaking, no one normal site for the stomach. It also falls a ready victim to pressure from an abnormally placed liver, spleen, or other abdominal organ, and has been seen dislocated by inflammatory disease or tumor in the pleura and the pericardium above, in the intestine below, in the gall bladder to the right, in the spleen to the left, in the abdominal wall to the front, and in the spinal column behind.

Physiologically, every demand on the stomach and every filling of it leads to a change in size and form; and the same holds for the intestine. There is thus a constant elbowing for room among the abdominal organs in the performance of their respective functions, and an equally constant accommodation to conditions of space on the part of each individual organ, especially the stomach.

One must think then of mere abnormal exaggeration of function in explaining some pathological displacements. Indeed, one finds the most typical dislocations in connection with what gives the greatest demands on the abdominal organs, namely, pregnancy.

Displacements of the stomach are (1) *congenital* and (2) *acquired.*

The *congenital* cases of medical interest or of any clinical importance are caused by two conditions, viz.: (1) Defect of the diaphragm, and (2) transposition of the viscera (thoracic and abdominal).

The *acquired* cases are comprised under:

1. Enteroptosis, or Glénard's disease.
2. Rupture of the diaphragm (traumatic).
3. True diaphragmatic hernia.
4. Descent of stomach owing to dilatation apart from general enteroptosis.
5. Displacement by corsets.

6. Displacement by neighboring disease.
7. Displacement resulting from pyloric obstruction by malignant disease, an ulcer's cicatrix, hypertrophic stenosis, etc.

Like most classifications, this is more convenient for teaching than rigidly accurate in application, for in nature its divisions occasionally overlap. This is true even in regard to the large divisions "congenital" and "acquired," for examples occur in which it is difficult to say to which class the case belongs, and one meets other cases in which he can definitely prove that the patient acquired by an exciting cause a pathological condition resulting in part from a congenitally inefficient organ. Such was true of a case, about to be related, of congenital defect of the diaphragm combined with true hernia.

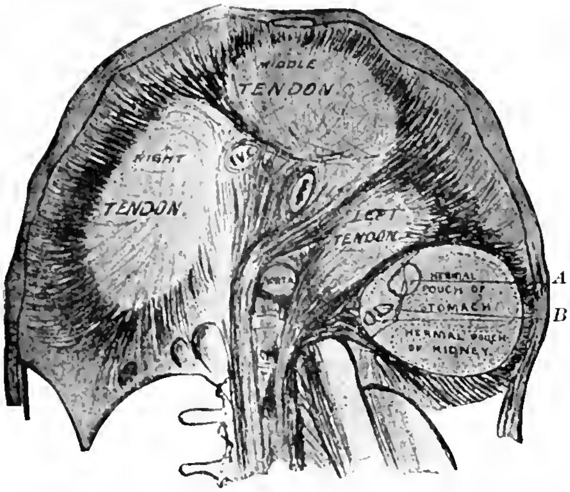


FIG. 4550.—Diagrammatic Representation of the Diaphragm seen from Below, showing the Position and Relative Size of the Hernia. *A*, Large, and *B*, the small communications between the thoracic and abdominal cavities. Over *A* and *B* is indicated the commencement of the omental overgrowth.

In connection with *defect of the diaphragm*, we have to distinguish between three conditions, viz.:

1. Absolute defect or congenital false hernia with free passage between the thoracic and the abdominal cavities. This is certainly extremely rare, almost undescribed, and of no clinical importance. One can suspect, however, that cases occur and are overlooked, since such a defect prevents any efficient establishment of respiration, thus killing at birth.

2. Acquired false hernia, or rupture of the diaphragm with protrusion of abdominal organs into the thoracic cavity, without, however, any hernial covering (peritoneum or thinned diaphragm). This is by far the commoner variety. Thus, of Leichtenstern's two hundred and fifty-two cases, two hundred and twenty-four were of the "false" type. It may be added here that any descent of thoracic organs into the abdominal cavity in such an accident is not known to occur. The vast majority of these cases are acute, following obvious violence or excessive muscular effort or strain. Thus they form a group of traumatisms, and their treatment, if any, is surgical. This is rendered all the more unsatisfactory, as exact diagnosis is generally difficult and often impossible. All abnormal openings in the diaphragm are much more common on the left side (five or more to one), owing chiefly to the liver's standing sentinel on the right side.

The organs most frequently displaced are the stomach and the transverse colon; next come the small intestine, spleen, left lobe of the liver, and pancreas. The displaced stomach gives the more prominent symptoms. The abdomen may be depressed while the affected part of the thorax may be prominent. Over a considerable area the breathing sounds are diminished or absent, and this area varies, under percussion, with the contents of the stomach. If the stomach contains mostly air the condition will simulate pneumothorax. The chief symptom is dyspnœa, generally with vomiting.

3. True diaphragmatic hernia, in which there is thinning of the diaphragm so that the abdominal organs, covered by a hernial sac of diaphragm or peritoneum, or both, protrude into the thoracic cavity.

This is the rarest variety, only eleven per cent. of Leichtenstern's two hundred and fifty-two cases being true herniæ. For the account of a remarkable case of true hernia, with displacement of the stomach, the reader is referred to the Montreal *Medical Journal*, August, 1895. "A Case of Diaphragmatic Hernia," by F. M. Fry.

Transposition of the Stomach.—One meets with displacement of the stomach in connection with transposition of the viscera in general, even more rarely than that due to defect of the diaphragm.

It is in the complete cases that one looks for displacement of the stomach, *i.e.*, a stomach whose cardia is to the right and the pylorus to the left. Arneill (*American Journal of the Medical Sciences*, November, 1902) gives interesting reports from experienced American clinicians, some of whom have never met with a case, while others have seen several only in many years. Arneill adds five cases seen since 1897, in which partial notes on the abdomen are given, and in one of which he mentions that the stomach, on inflation, was found transposed.

A case of complete transposition has recently come to Dr. Martin's notice at the Royal Victoria Hospital, Montreal. The skiagram of the case which I had taken shows the displacement of organs very well, while examination of the stomach by the ordinary methods showed its transposition.

Displacement by corsets is familiar, and we do not purpose enlarging on the widespread evils due to this cause. Certain it is, however, that it plays a great rôle in limiting the functions of the stomach and other organs, chiefly by compromising circulation and muscular action, thus leading to congestion and weak muscles with the resulting ills. The changes in the stomach, noted particularly by English observers, are a more vertically placed organ, narrowed and elongated. Treves insists on having seen these changes in patients in whom compression by corsets did not exist.

Displacement by neighboring disease calls for no lengthy mention here, though slight displacements are almost as numerous as the ills that flesh is heir to. Attention might be drawn to several cases recently recorded in which inflammatory disease of the gall bladder led to displacement of the stomach. Vague gastric symptoms occurred in a patient suffering from gall-stones, and persisted until at operation adhesions were found between the gall bladder and the pylorus, dragging the latter out of place and leading to symptoms due to partial obstruction and interference with circulation. A similar relation has been observed between the gall bladder and the duodenum, producing hypertrophy of the gastric muscle, as in cases of cicatricial contraction of the plyorus or duodenum. But such cases are surgical.

Displacement due to dilatation, apart from general enteroptosis, is common. The organ sags out of place in acute dilatation dependent on pyloric obstruction, malignant or benign. One frequently sees moderate dilatation and descent, especially in young women of the upper classes whose gastric muscle becomes inefficient, apparently on account of irregular and injudicious eating and drinking, lack of exercise and fresh air, constipation, and generally bad hygiene. In some of these cases one fails to find evidence of general enteroptosis, even a movable right kidney, and one gets excellent results from instituting light and dry diet, open-air exercise, regular meals and rest, with strychnine. The condition and the physical signs, however, are the same as in general enteroptosis.

Displacement due to fibrosis within the stomach itself is only too common in connection with malignant disease, in which extreme contraction and withdrawal upward are frequent. There are also cases in which a very small fibrous stomach is found after death without any ground for diagnosing cancer, and one thinks of atrophy and sclerosis following old chronic catarrhal gastritis or ulcer. These conditions are described under their respective headings.

Displacements occur in patients suffering from marked dilatation who lead their ordinary life and take their ordinary diet. That is to say, in a case of marked dilatation there is great difficulty and delay in emptying the organ and consequent undue stretching of the stomach by the weight of food and by gases, as well as by loading the organ with a meal before the previous meal has been removed. This, unless very early relieved, causes the organ to sag downward out of place. Any pyloric obstruction—which leads to dilatation, as it constantly does—may be an indirect cause of marked displacement. The most common causes of pyloric obstruction are, of course, malignant disease, cicatricial contraction following ulcer, hypertrophic stenosis, adhesion to neighboring organs, and compression from without. These are fully described elsewhere.

Gastroptosis (displacement downward of the stomach).—This nearly always is associated with enteroptosis (*q. v.*).

Direction of Displacements.—Displacement upward has been mentioned in connection with fibroid lung, tympanites, etc. Cases have been described in Germany extreme enough to cause narrowing of the cardiac orifice (Fleiner). Lateral displacement has been mentioned. In the downward displacement of enteroptosis, at first sight the entire organ seems lower. Strictly speaking, this is not the case, for the cardiac end remains a fixed point or hinge, the pylorus descending. The commonest form then is

FIG. 4551.—Subvertical Descent of the Stomach in a Nullipara, Aged Twenty-eight. (From Riegel.)

the subvertical. In this form the upper curvature, instead of lying horizontally across the abdomen with concavity upward, passes obliquely from the left of the patient downward to the right. Meinert found this surprisingly common in women. In fifty girls, aged about twelve years, fifty per cent. had this displacement, and in his gynecological clinic ninety per cent. had it, while in the males examined only five per cent. showed the condition. In a paralyzed chest, in pigeon breast, this is the form of displacement.

A common form is the loop or horn shape in which the part midway between the cardia and the pylorus sags and descends perpendicularly, while the line joining the extremities of the organ remains nearly horizontal.

In determining the nature of the dislocation it cannot be too strongly emphasized that one must consider the position of the pylorus and that of the lesser curvature. Only when these two are lower than normal can one speak of displacement downward—gastroptosis. The determination of the site of the lower border is valueless in attempting to prove a displacement downward, for a lowering of the greater curvature does not prove gastroptosis.

Normally, the pylorus is hidden under the right ribs at about the level of the ensiform process, and, as the lesser curvature begins at the pylorus, it too is invisible even

FIG. 4552.—Descent of a Loop- or Horn-shaped Stomach in a Married Woman, Aged Thirty-one. (From Riegel.)

when the stomach is inflated. This leaves the body of the stomach to round out into relief the upper epigastrium, which rounded prominence excludes marked gastroptosis.

In gastroptosis the epigastrium is flat or sunken, while below this area there is often a fulness which on further examination may be shown to be the descended stomach. This is pathognomonic of gastroptosis. In extreme cases one finds the lesser curvature at the level of the umbilicus. In an elderly multipara coming to the Outdoor Department of the Royal Victoria Hospital, with rather slight, vague, gastric symptoms, especially sense of weight, we found on inspection of the abdomen, the patient being supine, a relaxed abdominal wall, the upper epigastrium concave, and exactly at the level of the umbilicus a fulness began which moved freely with respiration—the lesser curvature. In another woman, middle-aged and nulliparous, of good color and nutrition, whose only complaint was "dyspepsie gazeuse," one heard on sharply tapping the abdomen a loud succussion, and on inflation of the stomach one saw the lesser curvature readily; the stomach was enormously dilated and the greater curvature reached to the brim of the pelvis.

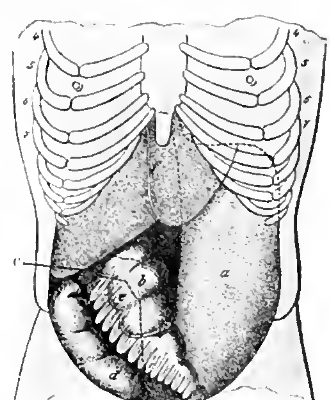


FIG. 4553. Vertical Stomach. (Kussmaul.) Extreme descent, the stomach hingeing on its cardiac orifice. The case illustrates the difficulty and delay which the organ experiences in naturally expelling its contents, and also the dilatation which is sure to result from this state of affairs. *a*, Stomach; *b*, pylorus (in dotted lines); *c*, gall bladder; *d*, caecum; *e*, transverse colon with the omentum majus rolled up; lower down, the omentum is wound around the colon.

This association of dilatation and displacement is very frequent and represents a causal relationship. R i e g e l ' s experience goes to show that dilatation plays a great rôle in the production of gastroptosis, and the dilated stomach very frequently, if not always, lies lower than normal. Sometimes it is impossible to say which is primary; for the mere overloading of the dilated stomach leads to gastroptosis, and it is also true that gastroptosis itself renders difficult and delayed the expulsion of food; hence distention and dilatation. Yet gastroptosis is frequent without dilatation, surprisingly frequent in young females without gastric symptoms or signs, and with no changes in the gastric secretion. Corsets are a common cause of this; kyphosis and scoliokyphosis have the same effect.

The more nearly vertical the stomach is, *i.e.*, the farther down the pylorus has descended, so much the more difficulty—as Kussmaul long ago pointed out and figured—has the stomach in emptying itself; and the fundus diminishes in capacity while the pyloric region increases. This leads to actual kinking in the lesser curvature and necessary retention, atony, and dilatation. Cases so extreme as that shown in Fig. 4553 are very rare. More common are the subvertical, or the loop-shaped displacements. All gradations occur, but never a descent of the entire organ, except in marked displacement downward of the entire diaphragm.

ETIOLOGY.—The very great variety of forms of displacement makes it very unlikely that one single cause accounts for all cases (as Glénard believed); and, what is more important, there are many cases of enteroptosis without any relaxation of the hepatico-colic ligament. Riegel believes that gastroptosis results from the stomach's accommodating itself to changes in the space conditions in the abdomen, by whatsoever process brought about.

DIAGNOSIS.—The condition is far oftener overlooked than recognized, mainly because we emphasize chemical tests and the position of the lower border, neglecting the motor power and the *site of the pylorus and of the lesser curvature*. Palpation and percussion alone almost never give accurately a diagnosis of gastroptosis. Percussion, after the patient has drunk water, gives information concerning the lower border, but it is not sufficient for a diagnosis of either displacement or enlargement.

There is only one method which is accurate and easy of performance, and that is inspection, with perhaps palpation and percussion, after inflation.

Electric transillumination is more complex and offers no greater accuracy.

Gastroptosis promptly affects other organs, and first, as a rule, the right kidney. In wellnigh all marked cases of gastroptosis, of any standing, one can readily feel the moving kidney, either the rounded lower extremity leaving its normal position a trifle, or nearly the entire organ which one can grasp and control, or the whole kidney which one can seize and move over a large area. A freely movable kidney does not prove the presence of a mesonephron, for this latter is very rare, while the former is fairly common.

The liver, too, comes in for displacement, in the recognition of which one must pay particular attention to the upper border as in the case of the stomach.

The colon, particularly the transverse colon, is frequently found similarly displaced, as may be demonstrated by rectal injections of air or water.

The etiology is fully discussed in the article on *Enteroptosis*, in THE APPENDIX.

SYMPTOMS.—Kussmaul believed that the nervous manifestations produced the motor insufficiency, Glénard the reverse. Most authorities now hold that gastroptosis plays an important part in causing nervous symptoms. There remains the fact that in persons having gastroptosis and other displacements, symptoms of gastric distress, as well as nervous, hysterical, or neurasthenic symptoms, are frequent, though such symptoms occur without gastroptosis, and vice versa. Gastroptosis and these symptoms belong as a rule to women only. If such nervous symptoms depended on gastroptosis we would expect to find them in the few males who suffer from gastroptosis, but Bial found that of the males with the complaint, fifty per cent. had no subjective symptoms. For this reason Riegel believes that a suitable disposition on the part of the central nervous system is essential to the production of these symptoms.

Gastroptosis itself has a train of symptoms—*e.g.*, a sense of fulness and weight after meals, an increase of the length of time required for digestion, eructations of gas a long time after meals, borborygmi, especially on the left side, and generally relieved by removing tight clothing. It not uncommonly leads to motor insufficiency, while the chemistry in the stomach is likewise sometimes disturbed. The chemical changes, however, are not always directly due to the displacement. The motor insufficiency, however, does lead to retention, fermentation, and gas, all of which rarely irritates the mucous membrane and affects the secretion. Much oftener the altered secretion is a complication. This gastroptosis is accompanied sometimes by increased, sometimes by diminished secretion. So chlorosis often has with it hyperchlorhydria. But hyperchlorhydria and gastroptosis, though associated, are independent, and both or either may accompany chlorosis.

TREATMENT.—The treatment of this displacement is multiform. Those examples which are due to the wearing of constricting clothing are preventable. After parturition a great deal can be done by aiding the abdominal muscles, combating tympanites, opening the bowels regularly, keeping the patient supine till the abdominal muscles are fit to do their work. The treatment of the gastroptosis itself, as of nephroptosis, is largely mechanical, and a well-fitting belt or properly adjusted corset gives great comfort and distinct assistance. Some mild cases are cured by the horizontal position assumed in the treatment of some other complaint. The German "fat cures" do increase the fat, but aid more probably by the horizontal position being more frequently chosen. In acute cases, lying down with the clothes loosened may be definitely prescribed.

The diet is all-important and should be light and dry, given in small amounts, easily digested and nourishing; for example, eggs, milk, cocoa, junket, toast, meat in small quantity, and greatly restricted carbohydrates; but it should always be adapted to the gastric juice in the individual case, as made out by chemical examination.

Surgeons have obtained good results by folding and stitching the enlarged and displaced stomach, reefing it in as it were, but results are not as yet satisfactory enough to warrant operative procedure in all cases that give symptoms.

Charles F. Martin.
F. Morley Fry.

STOMACH, THE SHAPE, POSITION, AND MOVEMENTS OF.—The best method of studying the form and size of the stomach is to remove the organ as soon after death as possible, to inflate it with air, then to tie off both extremities and permit it to dry. By this method the stomach is usually slightly overdistended, and attains a size not quite reached during life. The usual form of the stomach is represented by Fig. 4554, and cannot easily be described by a phrase. The part to the left of the œsophageal orifice is called the fundus; that part which lies nearest the pylorus is called the antrum pylori. The right half of the stomach is called the pyloric half; that to the left the cardiac half. The stomach is exceedingly variable in shape. When empty it contracts, and after a prolonged fast of many hours it may be almost cylindrical in shape. This cylindrical appearance is most marked in the pyloric half, so that this portion of the stomach may markedly resemble the transverse colon in contour. The same condition of the pyloric half may be found at the autopsy if death has occurred during the height of digestion. It is not uncommon, under such circumstances, to find a constriction near the middle of the stomach, separating in a greater or less degree the cardiac from the pyloric half.

The measurement of about two hundred adult stomachs gives the following average dimensions: Length, 25.5 cm.; vertical diameter, 12.5 cm.; antero-posterior diameter, 11.9 cm.

The length is a trifle more than twice the height, or as 100 to 49; the height is to the antero-posterior diameter as 100 to 95. Berry and Crawford state that the antero-posterior never exceeds the vertical diameter. I have found the antero-posterior diameter longer not infrequently, especially in very young children, and it may be that as the children grow older the vertical diameter develops more rapidly than the antero-posterior one.

The vertical diameter is subject to very marked variations; it may be so great as almost to equal the long diameter, or, on the other hand, it may be very short. The fundus also varies greatly. Nearly one-half of the stomach may lie to the left of the cardiac orifice; or the fundus may be altogether wanting. As an average the part to the left of the œsophagus is a little more than one-fourth of the total length of the stomach. This proportion holds true for all ages, from early fœtal life to old age. I have examined many fœtal and infantile stomachs, and cannot detect any peculiarities of outline belonging to any particular age. The fundus is developed very early in fœtal life, often as early as the third month of utero-gestation; and fœtal stomachs present as many variations of shape as do adult stomachs. If an inflated stomach is examined on its upper surface it will be noticed that the œsophagus does not enter the stomach at a point equidistant from its anterior and posterior surfaces. The cardiac orifice is invariably much nearer the anterior than the posterior wall of the stomach (see Fig. 4555). This asymmetry of insertion is constantly present, occurring in all the stomachs, both fœtal and adult, which I have examined; but it varies considerably in degree. In general it may be stated that about two-thirds of the antero-posterior diameter lies behind the cardiac orifice, and one-third in front. Rarely is the orifice very near the centre of the antero-posterior diameter; never at the centre or behind it.

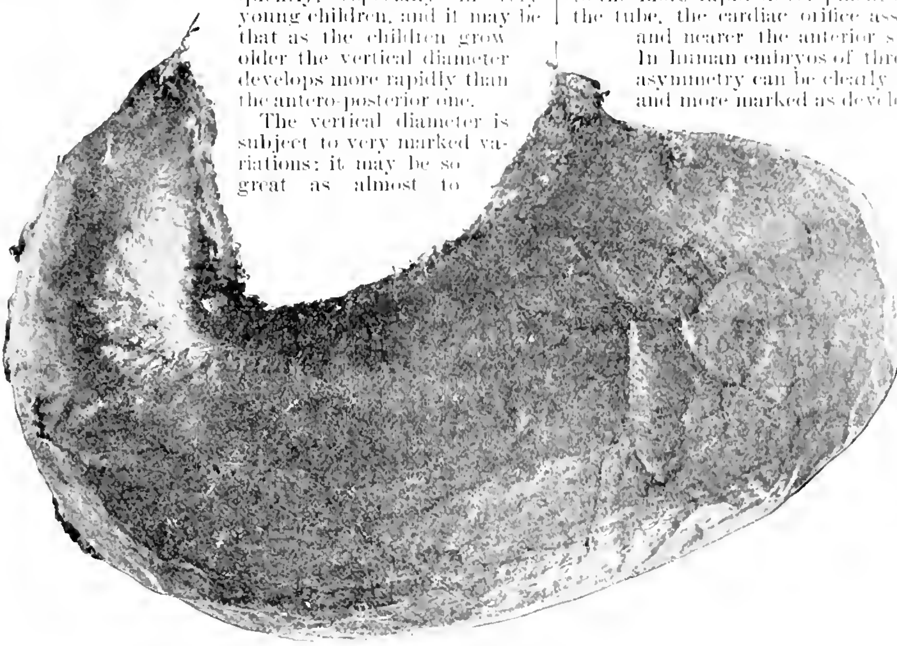


FIG. 4554.—Normal Adult Stomach.

An explanation of this anatomical peculiarity may be found by attention to the development of the stomach. Originally the stomach is a simple tubular prolongation of the œsophagus. In human embryos of the sixth week the form is no longer cylindrical. The posterior surface of the tube (that directed to the spinal column) bulges considerably (greater curvature); the anterior surface is slightly depressed (lesser curvature). During the third month the stomach undergoes decided change in position. In the first place it twists on its sagittal axis in such a manner that the long axis of the stomach instead of lying parallel with the spinal column thereafter lies obliquely, the fundus thereby moving to the left of the median line, the pylorus to the right.

In the second place, a twist occurs in the long axis of the stomach and lower part of the œsophagus in such a way that what was the left side becomes the anterior one; what was toward the right turns backward. Owing to the more rapid development of the posterior part of the tube, the cardiac orifice assumes a position nearer and nearer the anterior surface of the stomach. In human embryos of three and four months this asymmetry can be clearly seen, and becomes more and more marked as development progresses.

Position.—A simple way to study the position of the stomach is to make an œsophagotomy as soon after death as possible, to introduce a rubber tube through the orifice into the stomach, and then to fill the organ with water. When this method is employed the cardiac orifice is always found on the left side of the body in front of the tenth dorsal vertebra. It is there held firmly in position. The greater curvature ascending from this point rises as a rule to the upper border of the sixth rib in the anterior axillary line, sometimes so high as the fifth rib, causing the fundus to lie behind the heart. The greater curvature then sweeps around, descends vertically a short distance, then turns in its descent to the right, passing the free border of the ribs on about the level of the junction of the ninth and tenth ribs, runs from one to three inches above the umbilicus, and finally turns up and to the right to reach the pylorus.

The pylorus in the male lies as a rule on the body of the first lumbar vertebra, 4–6 cm. to the right of the median line. It is always more or less movable, usually not more than 2 cm. in any direction. The pylorus lies 6–8 cm. lower than the cardia, and about the same distance to the right of it. It is evident that the lesser curvature, which is the shortest line of the stomach connecting the cardia with the pylorus, must run, taking its course as a whole, downward and to the right. It would seem easy to describe the main axis of the stomach from these data, but matters are confused by the different degrees of distention in which the stomach is seen. I have called attention above to the contracted appearance of the stomach after a several days' fast. In these cases the long axis of the stomach runs directly from above and to the left, downward to the right, and the position of the stomach is unequivocally oblique.

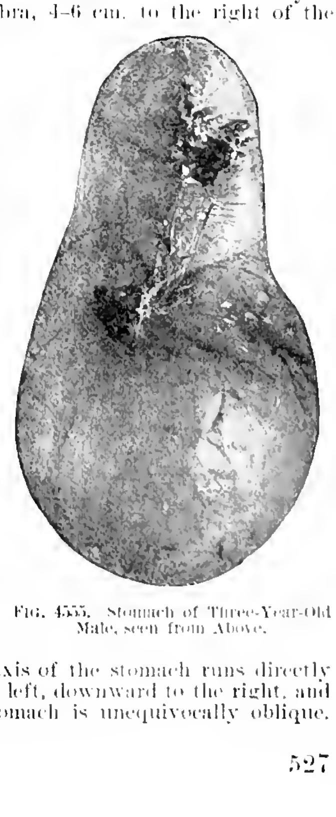
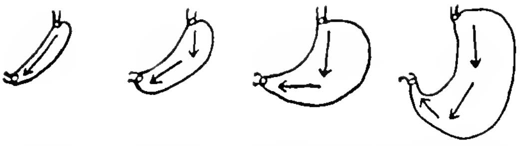


FIG. 4555.—Stomach of Three-Year-Old Male, seen from Above.

When the stomach fills it sinks slightly in the abdominal cavity, the greater curvature is rounded out, the lesser curvature becomes more acutely curved, and the long axis seems divided into two parts, the first part almost vertical, the second running obliquely downward to the right, and sometimes horizontal. If the stomach is fully distended the axis of the pyloric half runs upward and to the right, the axis of the cardiac half running at first vertical, then downward to the right. I have attempted to illustrate this change in the long axis of the stomach as the latter fills with fluid, by means of diagrammatic drawings made from life. Any one can verify the



1. 2. 3. 4.

FIG. 4556.—1, Contracted stomach; axis obliquely down and to the right; 2, stomach containing water; axis vertical, then oblique; 3, full stomach; axis vertical, then horizontal; 4, distended stomach; axis vertical, descending obliquely, ascending obliquely.

truth of this conception of the axis of the stomach by introducing a tube through the œsophagus into the stomach on the post-mortem table, and then watching the stomach fill with water. The most striking change is the increasing acuteness of the lesser curvature; the upper part of the stomach becomes at first doubtfully, then positively vertical; the axis of the pyloric half changes from obliquely descending to horizontal and finally to obliquely ascending (see Fig. 4556).

It is usually stated that the stomach in infants has a more vertical position than in adults. This is in the main true, but the bald statement is likely to give rise to misunderstanding. In a small proportion of infants the pylorus lies in the median line, or at least nearer the median line than in adults; but in the great majority of instances there is no decided difference. In young infants, however, the pyloric part of the stomach is relatively shorter than later in life, and it runs usually a straight course horizontally from left to right. As a result of the shortness of this horizontal part, the main portion of the stomach lies entirely to the left of the middle line, and appears therefore to be vertical. It is generally estimated that from three-fourths (Boas) to five-sixths (Hemmeter, Vierordt) of the adult stomach lies to the left of the middle line. In infants this proportion is considerably greater; in some instances so much as nine-tenths.

Movements.—The first great contribution to our knowledge of the movements of the stomach was made by Sir E. Home. He studied the stomachs of man and other mammals, and also experimented on dogs. His favorite method was to remove the stomach as soon after death as possible, turn it inside out, and thus gain an insight into the ante-mortem appearance of the stomach and of its mucous membrane. The following literal quotations from his writings will show how nearly his conclusions agree with those of later investigators. He says: "The true carnivorous stomach, as well as the human, which in its structure is closely allied to it, I found capable of dividing its cavity into two distinct portions by a transverse contraction of its coats, in which state the cardiac portion is, in length, two-thirds of the whole, but in capacity much greater." Later he writes: "I found also that the dog's stomach while digestion is going on was divided by a muscular contraction into two portions; that next the cardia the largest, and usually containing a quantity of liquid in which there was some solid food, but the other which extended to the pylorus being filled entirely with half-digested food of a uniform consistence."

"From these experiments the following facts are ascertained: That while the process of digestion is going on in the cavity of the stomach, it is divided by means of a muscular contraction of its coats into two portions; that the first receives the solids and fluids taken in by the mouth. The food is there mixed up with the secretion of the gastric glands and mucus, becomes coagulated, and by that means separated from the liquids contained in the cavity; these superfluous liquids are carried off without passing into the pyloric portion, which only receives the solid food with the necessary proportion of liquid, and in that portion of the stomach the change into chyle takes place."

Nineteen years after the appearance of Home's lectures Beaumont's classical exposition of gastric digestion was published. Beaumont was acquainted with the observations of Home. Seven pages of his treatise are devoted to the motions of the stomach. In his studies of the stomach of Alexis St. Martin he also clearly saw that the splenic and pyloric halves of the stomach had very different functions, and with great minuteness he described the mechanical processes in each part as he saw them. According to Beaumont there are two kinds of movement in the splenic half of the stomach, one causing the food to travel along a definite path, the other triturating or grinding the food and causing it to be intimately mixed. The food on entering the stomach turns to the left from the cardiac orifice, passes into the splenic extremity, follows the greater curvature to the pyloric end, and then returns along the lesser curvature to repeat the revolution again and again. Each revolution requires from one to three minutes and is produced by the circular muscles of the stomach. While these movements of the food are in progress trituration of the food is caused by a grinding motion of the stomach walls, leading to a perfect mixture of the food already in the stomach and the newly swallowed food. All of these movements are slow at first, but become more rapid as digestion progresses; the contractile force is increased in every direction, and the contained fluids are thereby given an impulse toward the pylorus. This is accomplished by the longitudinal fibres of the central and splenic parts of the stomach, aided by the circular fibres.

It is probable that, from the very moment food is received into the stomach, portions of chyme are constantly passing into the duodenum, slowly at first, more rapidly as digestion progresses. The pyloric end of the stomach can be shut off from the rest of the organ by the peculiar action of the transverse muscle, or rather of the *transverse band* (previously described, according to Beaumont, by Spallanzani, Haller, Cooper, Sir E. Home, and others). During digestion this band of circular muscle fibres alternately contracts and relaxes (at irregular intervals of from two to four or five minutes), temporarily dividing the cavity of the stomach into two parts, a cardiac half in which the food is being gently agitated and mixed, and a pyloric half which firmly presses upon the food, forcing it toward the pylorus. The action of the pyloric end can best be described in Beaumont's own words: "The longitudinal muscles of the whole stomach with the assistance of the transverse ones of the splenic and central portions carry the contents into the pyloric extremity. The circular or transverse muscles contract progressively from left to right. When the impulse arrives at the transverse band this is excited to a more forcible contraction, and, closing upon the alimentary matter and fluids contained in the pyloric end, prevents their regurgitation. The muscles of the pyloric end now contracting upon the contents detained there separate and expel some portion of the chyme. It appears that the crude food excites the contractile power of the pylorus so as to prevent its passage into the duodenum, while the thinner chymified portion is pressed through the valve into the intestine. After the contractile impulse is carried to the pyloric extremity the circular band and all the transverse muscles become relaxed and a contraction commences in a reverse direction from right to left, and carries the contents again to the splenic extremity to undergo similar revolutions."

Very little has our knowledge of the movements of the stomach advanced since Beaumont's observations were published. During the past fifteen years numerous experiments have been made on dogs without bringing many facts to light. Examination with the *x*-ray has been an exceedingly valuable means of extending our knowledge, and Cannon's contribution has been the most notable one since Beaumont's on the subject of the movements of the stomach.

The more important of the observations on dogs are here briefly reviewed: Hofmeister and Schütz removed the stomachs from freshly killed dogs and noted two kinds of contraction: (1) Very slight peristaltic waves traversing the cardiac half and most pronounced at the beginning of the antrum pylori; (2) vigorous contractions of the pyloric half which becomes entirely shut off at the antrum pylori from the cardiac half. These contractions narrow and shorten the pyloric end and press the food against the pylorus, which closes tightly. Only when solid particles are pressed against the pylorus is there any real antiperistaltic wave in the sense of Beaumont (*vide supra*).

Rossbach observed on dogs that, during digestion, no peristaltic waves of any kind occur in the fundal portion of the stomach, which simply remains passively contracted upon its contents. Peristaltic movements always begin at about the middle of the stomach and take twenty seconds to extend from there to the pylorus. This contraction of the pyloric half is so violent that it completely obliterates the lumen of that portion of the stomach. Rossbach noted that the pylorus remains closed during the whole process of digestion (from four to eight hours), and then the food is propelled into the duodenum in little jets.

Von Mering also states that the stomach of the dog empties itself rhythmically, contractions occurring every twenty seconds.

Moritz made duodenal fistulæ in dogs. He observed that water begins to be forced into the duodenum almost immediately after its ingestion, and that all the water leaves the stomach at latest twenty to thirty minutes after it is swallowed, being squirted into the duodenum rhythmically. Moritz, by manometric observations in the human stomach, showed that no peristaltic contractions occur in the cardiac half, but that rhythmic waves occur in the pyloric extremity.

Roux and Balthazard by means of the *x*-ray studied the movements of the stomach in dogs and men. They noted that the stomach during digestion is divided into a splenic and a pyloric part; that peristaltic contractions occur almost immediately after food is swallowed; that peristaltic waves pass over the stomach in man from left to right, traversing the stomach in twenty seconds, and recurring with great regularity every fifteen to twenty seconds.

Cannon has published the most extensive and valuable observations with the *x*-ray. He experimented on cats. The cats were starved for twelve hours, and were then fed on dry bread made pulpy with milk or gravy or hot water, and mixed with varying proportions of bismuth subnitrate. Within five minutes after food is taken a few constriction waves pass over the extreme pyloric end of the stomach. Two to three minutes later the stomach begins to be constricted near the middle, and slight peristaltic waves originate there and pass to the pylorus. As digestion proceeds the antrum pylori elongates, the depressions grow deeper, the peristaltic waves recurring with almost clock-like precision every ten seconds, and requiring thirty-six seconds to travel from the middle of the stomach to the pylorus. During digestion the cardiac half of the stomach acts as an active reservoir; the walls contract as the food gradually passes on into the pyloric half. There are no currents of food in the fundus. The part of the stomach which narrows its calibre first is the middle of the stomach, the so-called preantral portion. To the left the contractions of the fundus force the food very sluggishly onward into the preantrum, which in turn contracts much more vigorously, squeezing the food into the antrum pylori. In the antrum the food is thoroughly triturated and mixed with the gastric secretions, and expelled thence into the duodenum with considerable power. Ten to fifteen minutes after peristalsis begins food enters the duodenum. It is often squirted with force 2–3 cm. beyond the pylorus. Not every constriction wave forces food into the duodenum, except toward the end of digestion. One hour after food was given Cannon noted that three waves in succession forced food through the pylorus; then no food passed during eight subsequent waves; the next wave again forced food through; the next two did not; the next four waves again expelled food; then followed three ineffectual waves, and thus the food was squirted into the duodenum at rather irregular intervals.

The pylorus usually though not always stops solid particles, and often these are shot back with considerable rapidity several centimetres along the antrum. Occasionally solid pellets enter the duodenum. There is no true antiperistalsis. The food in its path from fundus to pylorus is not moved progressively forward. It follows a zigzag course forward and backward, requiring in the cat nine to twelve minutes to reach the pylorus after having reached the zone where the peristaltic waves affect it.

During vomiting the pyloric antrum contracts violently, expelling its contents into the relaxed fundal half, from where it is forced by contraction of the abdominal muscles into the œsophagus.

Henry Wald Bettmann.

BIBLIOGRAPHY.

Berry and Crawford: The Stomach and Pylorus. Journ. of Anatomy and Physiology, vol. xxxiv., 1900, pp. 153–8.
Bettmann: The Shape and Position of the Stomach. Philadelphia Monthly Medical Journal, March, 1899.
Sir E. Home: Lectures on Comparative Anatomy, two vols., London, 1814, Vol. I. Lectures ix. and x.
William Beaumont: Experiments and Observations on the Gastric Juice and the Physiology of Digestion, Plattsburg, 1833.
Hofmeister und Schütz: Ueber d. anat. Beweg. des Magens. Arch. f. exp. Path., Bd. xx., S. 1.
Rossbach: Beiträge z. Lehre v. d. Bewegungen des Magens, etc. Arch. f. klin. Med., Bd. xlvi., S. 296.
Moritz: Ueber die Functionen des Magens. Münch. med. Woch., 1895, pp. 1143–7.—Verh. d. Naturf. v. Nürnberg, 1893.
Roux et Balthazard: Fonctions motrices de l'estomac du chien. Séances et Mémoires de la Soc. d. Biologie, 1897, pp. 704–6.—Études des contractions de l'estomac chez l'homme à l'aide des rayons de Roentgen. *Ibid.*, pp. 785–7.
W. B. Cannon: The Movements of the Stomach Studied by Means of the Roentgen Rays. Amer. Journ. of Physiol., May, 1898.

STOMATITIS. See *Mouth, Diseases of*, in the Appendix.

STOOLS. See *Fæces*.

STORAX (*Styrax*, U. S. P., P. G.; *Styrax Præparatus*, B. P.; *Styrax liquide*, Cod. Med.) is a balsam prepared from the inner bark of *Liquidamber orientalis* Miller (fam. *Hamamelidaceæ*). This balsam is a disease product, resulting from wounds inflicted upon the bark of the medium-sized tree named above, which resembles the sweet-gum tree (*L. Styraciflua* L.) of the Eastern United States.

The styrax tree occupies a limited area in the southwestern districts of Asia Minor, where it forms forests. It is collected by bruising, and after some time removing the outer bark, then scraping off and boiling the inner bark with sea water. The oleoresin thus melted out rises to the top and is skimmed off. By pressure, an additional amount can be obtained from the remaining bark.

Storax is a semi-liquid, gray, sticky, opaque mass, depositing, on standing, a heavier dark-brown stratum; transparent in thin layers, and having an agreeable odor and a balsamic taste. Insoluble in water, but completely soluble (with the exception of accidental impurities) in an equal weight of warm alcohol. If the alcoholic solution, which has an acid reaction, is cooled, filtered, and evaporated, it should leave not less than seventy per cent. of the original weight of the balsam, in the form of a brown, semi-liquid residue, almost completely soluble in ether and in carbon disulphide, but insoluble in benzin. When heated on a water-bath, storax becomes more fluid, and if it be then agitated with warm benzin, the supernatant liquid, on being decanted and allowed to cool, will be colorless, and will deposit white crystals of cinnamic acid and cinnamic ethers. This balsam consists principally of an amorphous substance named *storesin*. It also contains several *cinnamic ethers* and *cinnamate of cinnamyl* (styracin), which can be prepared in rectangular prisms, and *cinnamic acid* and *styrol*.

Storax goes principally to the East, very little being used in European pharmacy; in its action it varies very little from a number of other balsamic substances; internally it has been used in bronchitis and similar conditions with but moderate success. As an ingredient of liniments, ointments, etc., it is quite useful. The compound tincture of benzoin contains eight per cent. of storax. Dose of storax, from three to five drops.

ALLIED PLANTS.—The Sweet Gum Tree, *Liquidamber Styraciflua* L., resembles the above species and supplies a non-drying sticky balsam resembling storax in medicinal properties, although not in color or opacity.

Henry H. Rusby.

STORM LAKE MINERAL SPRING.—Buena Vista County, Iowa.

POST-OFFICE.—Storm Lake. Good hotel accommodations.

This spring is located one mile from the village of Storm Lake, at an elevation of 900 feet above the Mississippi River. The surrounding country is level, and not especially interesting. The temperature ranges from about 70° F. in summer (average) to zero in winter. The following analysis is by Walter L. Brown, analytical chemist, of Chicago: One United States gallon contains (solids): Sodium chloride, gr. 0.18; potassium sulphate, gr. 3.02; sodium sulphate gr. 3.22; calcium sulphate, gr. 35.12; magnesium sulphate, gr. 3.40; magnesium bicarbonate, gr. 10.78; silica, gr. 3.56; iron oxide and alumina, gr. 0.18; organic matter, a trace. Total, 59.46 grains. There is also present a large amount of free carbonic-acid gas. The water is said to be efficacious in diseases of the liver, bowels, and kidneys.

James K. Crook.

STRABISMUS, or **SQUINT,** is that condition in which the visual axes are not both directed toward the point looked at. It causes diplopia, and the eyes may be seen to be turned in different directions.

Diplopia arising from strabismus is binocular, and is noticed only when light from the object looked at forms a sensible image on each retina; and when the visual centres are so related to each other as to possess the power of binocular fusion.

Normally, when a certain point is looked at, its image in each eye falls on the fovea; and the two produce the idea of a single point. When, however, the point looked at makes its impression on the fovea in one eye, but on

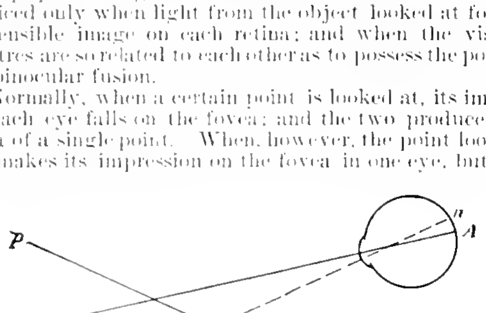


FIG. 4557.

some other portion of the retina in the other, it generates the idea of two distinct points some distance apart, the impression on the fovea being referred to a point directly in front of the eyes, while the impression on another part of the retina is referred in a different direction. Thus, in Fig. 4557, representing a case of convergent strabismus, the visual axis of the eye *A* being directed to the object *O*, the visual axis of the eye *B* is directed elsewhere, to *P*.

In the eye *A* the impression of the point *O* will be made at the fovea; but in the eye *B* the light from *O*, entering in the direction of the broken line *O m*, will make its im-

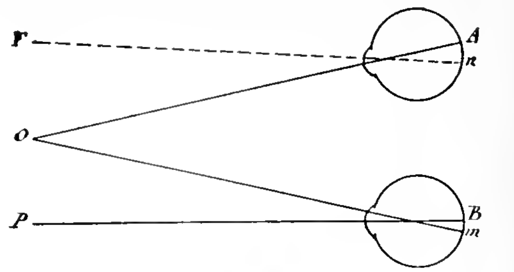


FIG. 4558.

pression on the point *m*, some distance from the fovea. Since the impression is made on *A* at the fovea, it will be correctly referred to the object looked at. But in *B* the impression made at *m* will be referred to a point to one side of the object looked at; its position relative to *O* being in the direction *n F*, which makes the same angle with the visual axis of *A* as *O m* makes with the visual axis of *B*. The image of the point received on *A*, and referred to its true position *O*, is called the *true image*. The image received at *m*, and referred to *F*, in the direction *n F*, is called the *false image*.

In Fig. 4558, representing what occurs in divergent squint, the eye *A*, turned toward the object *O*, receives on its fovea the true image, which is referred to its proper source; and the eye *B* receives at *m* the false image, which, with reference to the true image, is referred in the direction *n F* to *F*.

In general, *in whichever direction the squinting eye deviates, its false image appears to be situated to the opposite side of the true one.* When the image on the right belongs to the right eye, it is called *homonymous diplopia*. It occurs when the visual axes are crossed as in Fig. 4557. When the image on the right belongs to the left eye and the image seen to the left belongs to the right eye, it is *crossed diplopia*. This is represented in Fig. 4558, and occurs in divergent squint. To determine which image belongs to the right eye, and which to the left, cover one eye and the image belonging to it will instantly disappear. Or place before one eye a piece of colored glass, when the image belonging to that eye will appear colored.

Objective Symptoms.—If the squint be well marked, inspection will reveal the defect, and show which eye deviates. But there is a possibility of error. We judge of the direction of the visual axis by the direction of the cornea. Usually the visual axis pierces the cornea near its centre. But sometimes the visual axis deviates, so that, when properly directed, the centre of the cornea will be turned considerably to one side, and the eye will appear to squint.

To determine whether the eye really does squint, direct the patient to gaze steadily at a certain object, and cover first one eye and then the other. If both eyes are properly directed, there will be no change of position when either one is covered. If one eye have its visual axis turned elsewhere, covering it will not cause any change of position; but covering the eye which has been directed toward the object will cause the eyes or head to be turned, so that the eye which had looked elsewhere may now fix on the object. If, however, both eyes have been fixed on the object, but only by an undue effort, the covered eye will deviate and take such position as can be preserved without the undue effort. The test should be repeated until the observer is satisfied as to the presence or absence of squint. Having ascertained that squint is actually present, the first point to be settled is whether it is *comitant* (concomitant) or *paralytic*.

COMITANT STRABISMUS is a wrong, and usually variable, co-ordination of the movements of the eyes with reference to each other, without marked limitation of these movements in any particular direction. It commonly appears in early childhood; but may exist from birth, and more rarely begins during adult life.

Convergent squint is the most common form of comitant strabismus. In it the visual axes converge to a point nearer the eye than the one looked at, as in Fig. 4557. In it the diplopia is homonymous, and on covering the eye which is fixed on the object it turns in toward the nose, while the other turns from the nose and fixes the object.

Divergent squint comes next to the convergent in frequency. In this form the visual axes do not converge enough, either meeting at some point beyond the object looked at, or remaining parallel or even divergent. The diplopia is crossed. When the fixing eye is covered it turns out, and the other eye turns toward the nose and fixes the object. When the visual axes remain always divergent, the squint is said to be *absolutely divergent*. When the visual axes can be made to converge, but not enough, as in Fig. 4558, the squint is *relatively divergent*.

Parallel squint is applied to those cases in which the visual axes remain parallel when they should converge.

Vertical squint, in which one visual axis is directed more upward or more downward than the other, is rare, except as complicating one of the other forms of comitant squint.

Constant squint is always present, the visual axes never assuming normal relations. Opposed to it is *periodic* or *intermittent squint*, which is only present part of the time.

Periodic squint is apt to be most marked when the general tone of the nervous system is low, or at times of great excitement, or when the eyes are particularly taxed. A form of convergent squint, appearing only during strong effort of the accommodation, is called *accommodative squint*. Squint due to clonic spasm is *convulsive squint*. Closely allied to convulsive is *hysterical squint*.

Monolateral or *monocular squint* is the form in which it is always the same eye that fixes on the object looked at, while the other eye always deviates. If the fixing eye be covered it will deviate, while the ordinarily deviating eye fixes; but, upon uncovering, the deviation is soon transferred back to the eye which habitually presents it. The large majority of cases of comitant strabismus are in this sense monolateral. But it must not be supposed that only the deviating eye is at fault. The squint is a faulty co-ordination of the motions of the two eyes, and one eye deviates because the fixing eye has better vision, or sees with less effort.

Alternating squint is the variety in which the deviation is sometimes presented by one eye, and sometimes by the other: either of them becoming the fixing eye when the other is covered, and continuing to fix after the other is uncovered again.

Absence of Binocular Fusion.—Most persons with squint do not experience double vision. In some cases it is quite obvious why there is no diplopia, as where corneal opacity, or a high degree of ametropia, prevents the formation of a retinal image in the deviating eye. In other cases the reason is less obvious, yet not hard to understand; as here, although the deviating eye presents no abnormal appearance, the acuteness of vision is very low. But there is still another class of cases in which, although each eye is used, it is as an independent organ. What is called the power of binocular fusion or association is lacking.

Amblyopia with Squint.—In many cases of squint there is great defect of vision in one eye without any visible cause for it. This may be due to invisible defects in the cerebral connections of the eye, in which case it may be a cause of squint. It may also be due to failure to develop visual power through disuse, *amblyopia ex anopsia*. Or there may even have been deterioration of vision, by suppression, to prevent annoyance from diplopia.

Causes of Comitant Squint.—When binocular fusion is especially difficult or impossible, or the tendency to it unusually feeble, as where the vision of one or both eyes is very imperfect, the orbital muscles never attain that normal development which enables them to keep the visual axes properly directed to the point looked at. Anything which impairs the development of the visual centres or the acuteness of vision—as hereditary anomalies, convulsions, prolonged nutritive disorders, injury of the eyeball, keratitis, or high ametropia—becomes a cause of squint. But ametropia has an especial share in the causation of squint, as was first pointed out by Donders. Normally, the exertion of the power of accommodation is accompanied by convergence of the visual axes; the full power of the accommodation cannot be exerted without strong convergence. Hence in hyperopia, where the accommodation must be exerted more strongly, there is a special tendency to excessive convergence.

In myopia the need for complete relaxation of the accommodation, even when a near object is looked at, may lead to deficient convergence of the visual axes, or divergent squint. In myopia of high degree there is also antero-posterior elongation of the globe, which is often very marked. This makes the eyeball an oval, fitting in an oval socket, in which it cannot be turned without changing the shape or direction of the socket, by actual displacement of the orbital tissue. Hence convergence of the myopic eye requires excessive effort, while myopia, restricting the range of distinct vision, requires that the convergence should be especially great. In the highest degrees of myopia, the effort at convergence is abandoned, and a divergent strabismus permitted. This is at first relative and periodic, but, if associated with deficiencies of muscular development, is very likely to become absolute and constant.

Treatment of Comitant Squint.—The preventive treatment would include all measures favoring the normal development of the general nervous and muscular systems, or calculated to improve the acuteness of vision. Both to influence the acuteness of vision, and to give the normal accommodation and range of distinct vision, *errors of refraction are to be corrected*. In convergent squint with hyperopia, the convex lenses fully correcting the latter should be worn constantly. They should be carefully determined and put on at the earliest date possible. Children of two or three years will wear accurate correcting lenses with the greatest benefit. To make the necessary measurements for lenses, and to enforce their use, it is advisable to place the eyes under the influence of a *mydriatic*, as: Atropine sulphate, gr. i.; distilled water, ℥ ij.—one drop to be placed in each eye three times a day. This should be kept up for some time after the squint has disappeared, or for some weeks, until it is clearly demonstrated that the deviation is not being favorably influenced by it.

The mydriatic acts by paralyzing the accommodation, and so preventing any attempt to use it which may bring about excess of convergence. Care must be taken that the solution used is strong enough, and is efficiently applied. If only enough of the mydriatic is instilled to somewhat weaken the accommodation, the effect will be not to prevent, but to increase the accommodative effort, and therefore the accompanying convergence.

In myopia concave lenses, correcting it, may be used to prevent divergent squint; or, if the squint is already established, to bring about convergence.

As aiding in the proper development of the muscles concerned, what are called *orthoptic exercises* are recommended. They consist usually in looking through some form of stereoscope at lines, letters, or figures, a part of each being seen by one eye, and the remainder being presented to the other eye; by an effort these are to be fused into one picture. A reading bar or a ruler may be placed vertically between the page and the eye. The ruler cuts off a part of the page for each eye, but by using both eyes all parts may be seen. The reading of each line necessitates the alternate use of both eyes. The fusion tubes of Priestley Smith may be used for children who cannot read. Orthoptic exercises are mainly of use to cultivate the faculty of binocular fusion where that exists, but is deficient in comparison with the obstacles it has to overcome.

As a palliative of comitant squint, prisms may be worn in rare instances. They are so used as to cause the rays to enter the squinting eye in the direction of its visual axis and thus avoid diplopia, while the squint remains unchanged. Or they may be used as a sort of orthoptic apparatus, to bring the rays so nearly in the direction of the visual axis of the deviating eye that, by a little additional effort, the visual axis will be brought to coincide with their direction and the squint thus lessened. In either case the strength of prismatic effect required is to be determined by trial, and secured by placing prisms of equal strength before both eyes, with the refracting angle or thin edge of the prism in the direction in which the eyes deviate.

Operative measures are intended so to change the connection of the muscles to the eyeball that the visual axes may assume approximately their proper positions. Division of the tendon of the muscle toward which the cornea is turned allows the eyeball to be turned toward the proper position by its opponent. This is called *tenotomy of the rectus*, or *strabotomy*. *Advancement of the tendon* of the muscle which has exerted too little influence on the direction of the eye allows it to acquire a new insertion closer to the cornea, and to exert a relatively greater influence in determining the direction of the visual axis. Operative procedures should only be resorted to after other means have been carefully tried and have failed to give relief.

In determining the operation to be done the amount of deviation is to be considered. This may be measured in degrees on the arc of a perimeter, by placing the deviating eye at the centre of the arc, making the visual axis of the fixing eye parallel to the axis of the instrument, and noting the number of degrees from the axis of the perimeter to the visual axis of the deviating eye. In place of the perimeter arc, the deviation may be measured on a metre stick or tape, held one metre from the eyes. It can also be measured by placing a scale along the edge of the lower lid of the squinting eye, covering the good eye so that the other may fix, and then uncovering it and watching the deviation. As a rule, the inward deviation that can be remedied by a tenotomy of the internal rectus is greater than the outward deviation that can be overcome by a tenotomy of the external rectus; and the effect of the former operation tends to increase for a certain time after its performance, while the effect of the latter rather tends to diminish.

To perform *tenotomy* of one of the recti muscles the instruments required are a pair of scissors with fine but slightly blunt points, a pair of strabismus forceps (a form of fixation forceps with narrow-toothed jaws), a strabismus hook, and a lid elevator or speculum. A drop of a four-per-cent. solution of cocaine is to be placed over the insertion of the tendon to be cut. This is repeated every two minutes for ten minutes. The lid elevator or retractor is then introduced beneath the upper lid and confided to the assistant, who may stand behind the patient, steadying the head against his own breast. The operator with the forceps seizes a fold of conjunctiva 5 mm. back from the margin of the cornea, and over the tendon to be divided. With the scissors this fold in the conjunctiva is snipped so as to make an opening which, when stretched out, will be from 5 to 8 mm. in length. The forceps then drop the conjunctiva, are introduced through the cut, and made to grasp the subconjunctival tissue. This is also divided freely with the scissors. The hook is then introduced, the point in contact with the sclerotic, and pushed under the tendon. The forceps are now removed and the hook depended upon to fix the eyeball. The points of the scissors are introduced, one beneath the tendon and close to its insertion, the other over the tendon and immediately beneath the conjunctiva. The blades being brought together, the tendon is divided and the hook can be pushed forward without hindrance to the margin of the cornea. The point of the hook is then turned and the remaining part of the tendon taken up and divided in a similar manner. When no bands remain to prevent the hook from freely slipping forward to the corneal margin, it is removed and the motility of the eye is tested. If motion is not decidedly limited in the direction of the cut tendon, the hook is to be introduced again and other bands searched for and divided. The effect of the operation can be enhanced by freely dividing the subconjunctival tissue around the tendon.

For *advancement of the tendon* of one of the recti muscles, there are required, in addition to the instruments used for tenotomy, fine needles and silk sutures, and a needle-holder. It is better to have the patient recumbent, and, after the use of cocaine, an incision is made with the scissors in the conjunctiva, parallel to the corneal margin, 5 mm. from it and 10 mm. in length. The tendon is now to be isolated and raised on the hook. A needle armed with the silk should then be passed through one margin of the tendon from without inward, some distance back from its insertion; and, having been drawn through, is to be introduced beneath the conjunctiva near the corneal margin opposite the middle of the tendon insertion, where it is to be carried for 2 or 3 mm., in the firm scleral tissue but not through it. Then the needle is carried beneath the other edge of the tendon, and brought out opposite the first point of entrance, and the loops of suture drawn aside. The tendon is then severed at its insertion, and a small piece of it may be cut off if a decided change of the direction of the eyeball is desired. The suture is then tightened and tied, bringing the tendon forward to the desired position. The eye is closed and bandaged. The stitches are allowed to remain several days, unless it is feared that too great an effect will be produced. Tenotomy of the opposing muscle is combined with advancement to produce a marked change of direction.

In a large proportion of cases, the *result* of operative interference is only an approximate correction of the deformity, which may sometimes be improved by the subsequent use of glasses, or orthoptic training. Only where good binocular fusion can be obtained may a perfect result be hoped for.

Paralytic Squint is a lagging behind of one eye when the patient attempts to look in a certain direction; it is due to loss of power in the muscle or muscles which should turn the eye in that direction.

Such palsies may arise from lesions of the muscle itself, of the centres governing its action, or of the connecting nerve tracts. Usually they have the latter origin. Early, in a case of uncomplicated paralytic squint, movements which do not depend on the muscle or muscles affected may be normal; and, so long as no demand is made on these muscles, no diplopia or inconvenience results. The squint and diplopia appear only when the eyes are turned in a certain direction. In periodic comitant squint the squint is sometimes absent, but when present it is so irrespective of the direction of the object fixed; in paralytic strabismus the squint, though sometimes absent, is always present when the eyes are turned in a certain direction, and always absent when they are turned in another. After paralysis of one of the muscles has existed for some time, its elastic tension is no longer sufficient to balance the elastic tension of its opponent. The latter turns the eye toward itself, so that it cannot assume the normal position, even when the muscles are relaxed as much as possible. When this occurs the deviation becomes more or less constant, and if some power of voluntary contraction be recovered by the paralyzed muscle, the case assumes somewhat the character of comitant strabismus. It is convenient to classify paralytic strabismus by the nervous supply of the muscles involved.

Paralysis of the abducens nerve, or *external rectus muscle*, causes a most frequent and simple form of paralytic squint. Strabismus occurs when the patient tries to look toward the side on which the affected muscle is situated. If the paralysis be complete, diplopia begins as soon as the object fixed passes the median line; if it be but partial, it may not appear until the eyes have been directed somewhat toward the affected side. Congenital paralysis of both of the abducens nerves, causing a constant convergent squint with inability to turn the eyes to either side, has been occasionally observed.

Paralysis of the Patheticus, Fourth Nerve; the Superior Oblique Muscle.—The deviation and diplopia appear mainly when the eyes are turned toward the affected side and downward. The false image is lower, and appears so inclined that its upper end is close to the upper end of the true image.

Oculomotor Paralysis.—The involvement of all the extra-ocular branches causes drooping of the lid (ptosis), and leaves the eye unable to move in any direction except outward and a little downward. On attempting to look toward the sound side, or upward or far downward, deviation and diplopia appear, and increase *pari passu* with the effort to turn the visual axes in either of these directions. The same thing occurs when any attempt is made to converge for a near object. According to the movements attempted does the squint assume more the character of a divergent or a vertical strabismus.

When the affected eye participates in the act of vision there is experienced a great uncertainty as to the position of objects, which amounts to a kind of vertigo. If the palsy has lasted more than a few days, a permanent outward deviation of the visual axis is usually established. Oculomotor palsy may involve only a part of the muscles supplied by the nerve, or may even be limited to a single one.

Recurrent attacks of oculomotor paralysis, usually attended with intense headache, may occur. The earlier attacks are followed by recovery, but later the paralysis becomes permanent.

Ophthalmoplegia externa is the term applied to a paralysis of all the muscles attached to the eyeball.

Treatment of Paralytic Squint.—The largest number of these palsies come from some syphilitic new growth, involving the sheath of the nerve or adjoining structures, or from syphilitic disease of the nerve itself. A few come from rheumatic disease in the course of the nerve trunk, and a considerable number arise from a focus of disease in cerebro-spinal or spinal sclerosis. If there is a clear history of rheumatism, or collateral evidence of the rheumatic nature of the attack, anti-rheumatic remedies should be carefully tried. But in other cases it is best to assume that the lesion is syphilitic, and to treat it with increasing doses of potassium iodide until there is improvement, or until symptoms of iodism appear.

It is scarcely practicable to pass through the affected muscles electric currents powerful enough to have much effect on them, without endangering the optic nerve and retina.

Prisms and tenotomy are not generally of any use. Where the deformity is very great, cosmetic improvement may sometimes be obtained by making an advancement of the tendon of the paralyzed muscle and the neighboring portion of the capsule of Tenon, with a tenotomy or exsection of the opponent. The immediate effect, obtained in this way, should be a deviation toward the paralyzed muscle. In cases of incomplete recovery passive motion has been used with apparent benefit. Cocaine having been applied to the eye, the insertion of the paralyzed muscle is seized with the fixation forceps and the eyeball dragged back and forth in the direction in which the muscle would act, so that the muscle is alternately stretched and relaxed to its utmost. This is continued for about two minutes, and repeated every two or three days.

HETEROPHORIA OR LATENT SQUINT.—The perfect coordination of the movements of the two eyes, called *orthophoria*, is only effected by the demand for single vision. In a large majority of persons the withdrawal of the influence of binocular fusion leaves a perceptible squint. Such squint is called latent or dynamic, or is spoken of as an *insufficiency* of the weaker of the opposed muscles, or as *heterophoria*, a tending of the visual axes toward different points. If not great, the latent deviation will cause no trouble to a person with a well-developed musculo-nervous system. But in persons of inferior development and small reserve of nerve force, even moderate degrees of insufficiency may give rise to the symptoms of eye strain, especially if the eyes are required to do large amounts of work, or to work under unfavorable conditions.

Diagnosis of Heterophoria.—On covering one eye so that it can no longer take part in binocular vision, if there is heterophoria the excluded eye will deviate. Upon uncovering the eye, it quickly assumes again the position in which its visual axis will pass through the point fixed. In this way, by repeated trials and close watching of the eyes, quite low degrees of latent squint can be detected. The Maddox rod test is still more delicate. A glass rod held before one eye causes a distant point of light to appear as a streak. If this streak seems to go directly across the light as seen by the other eye, orthophoria is present. If the streak does not cross the light, heterophoria is present, and the direction in which the streak is displaced tells the variety of heterophoria.

To test the muscle balance at a near point a dot or figure, like that shown in Fig. 4559, is viewed through

1. 2. 3.

FIG. 4559.

a 10° prism with its base up, causing a vertical diplopia. If the balance be perfect, the false image will be exactly below the true one, as in 1, otherwise the false image will be displaced to the right or left. With the prism before the right eye, 2 will indicate esophoria, and 3, exophoria.

Varieties of Heterophoria.—*Exophoria*, or insufficiency of the interni, occurs with high myopia, and from excessive near work, or as an inherent deficiency of convergence power. *Esophoria*, excessive tendency to convergence, is more often seen in hyperopes, but not exclusively. *Hyperphoria*, or vertical insufficiency, generally goes with one of the other varieties. It is right or left, according to the eye which tends to turn higher than its fellow.

Either of the above may cause headache, a "drawn feeling about the eyes," or other symptoms of eye strain. But such symptoms should not be ascribed to this cause until errors of refraction have been accurately corrected.

Treatment.—All remedial measures for squint may be resorted to. On account of the lesser extent of the deviation, prisms are particularly available. On the same account tenotomy and advancement require more accurate and delicate adjustment to the needs of the case, and are to be resorted to only after a thorough and prolonged acquaintance with those needs. Reduction of the amount of trying eyework, and hygienic measures calculated to improve the condition of the nervous system generally, are of the utmost importance in such cases.

Mixed Forms of Squint.—While nearly all cases of strabismus are readily referred to one or the other of the foregoing classes, and while it is of the first importance to have clear conceptions as to the special characteristics of each class, it should not be forgotten that many cases present the peculiar features of more than one class. In strabismus, therefore, each case is a subject for individual study. *Edward Jackson.*

BIBLIOGRAPHY.

Bull, C. S.: Passive Motion in the Treatment of Paralysis of the Ocular Muscles. Medical Record, August 6th, 1887.
Culgnet: L'Appareil antistrabique. Recueil d'Ophthalmologie, October, 1887.

Donders, F. C.: The Anomalies of Accommodation and Refraction of the Eye, London, 1864.
Dyer, E.: Asthenopia not Connected with Hypermetropia. Transactions of the American Ophthalmological Society, 1865, p. 28.
Harlan, G. C.: Congenital Paralysis of both Abducens and both Facial Nerves. Transactions of the American Ophthalmological Society, 1881, p. 216, and 1885, p. 48.
Landolt: Refraction and Accommodation of the Eye. Translated by C. M. Culver, Edinburgh, 1886.
Noyes, H. D.: A Treatise on Diseases of the Eye, New York, 1881.—On the Tests for Muscular Asthenopia, and on Insufficiency of the External Recti Muscles. Transactions of the Eighth International Medical Congress, held at Copenhagen, 1884.
Prince, A. E.: Operation for the Advancement of the Rectus with the Capsule. Ophthalmic Review, 1887, p. 249.
Schweigger: Handbook of Ophthalmology. Translated by Porter Farley, Philadelphia, 1878.—Clinical Investigations on Squint, edited by G. Hartridge, London, 1887.
Stevens, G. T.: Terms for the Designation of So-called Muscular Insufficiencies. New York Medical Journal, December 8th, 1886.
Theobald, S.: The Amblyopia of Squinting Eyes, with Discussion. Transactions of the American Ophthalmological Society, 1886, p. 279.

STRAMONIUM LEAVES AND SEED.—(*Stramonii Folia*, U. S., Br.; *Folia Stramonii*, P. G.; *Stramonii Semen*, U. S. P.; *Stramonii Semina*, Br.; *Stramoine* or

FIG. 4560.—Flowering Branch of Datura Stramonium, with Fruit. (Baillon.)

Pomme epineuse, Cod. Med.; *Jamestown Weed*, *Thorn-apple*, *Apple of Peru*, *Stinkweed*, etc.). The two drugs are defined respectively as the dried leaves and the dried seeds of *Datura Stramonium* L. (fam. *Solanaceæ*). The stramonium plant is probably a native of Southern Asia, but it has become abundantly naturalized in nearly all subtropical and temperate regions. It is very common in rich soil of waste places in the Eastern United States. It is a coarse, smooth annual, from one to six feet high, with an upright tri- and dichotomously branched, smooth, green, more or less hollow stem, branching at, say, a foot from the ground, and forming a spreading crown. The habit of the flowering and fruiting branches, and the structure of the large, white, fragrant flowers, and of the fruit, are shown in the accompanying illustrations.

DESCRIPTION.—*The Leaves.*—A much-wrinkled, deep or somewhat grayish-green, rarely very slightly brownish mass, consisting of petioled leaves, the blades from 12 to 25 cm. (5–10 in.) long, and about two thirds as broad, inequilaterally ovate, very oblique at the base, acuminate and

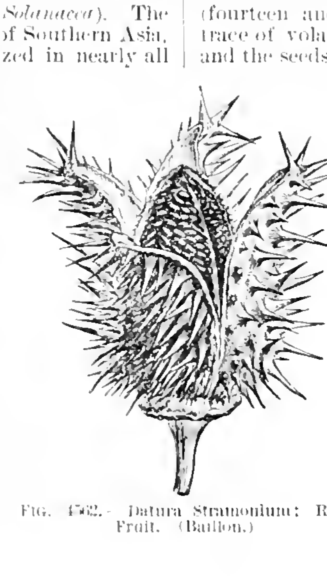


FIG. 4562.—Datura Stramonium: Ripe Fruit. (Baillon.)

acute at the apex, very coarsely dentate or sublobed, the large teeth few, acute, with rounded sinuses, thin, smooth; the principal veins few and coarse; odor slight, narcotic when bruised; taste bitter and disagreeable.

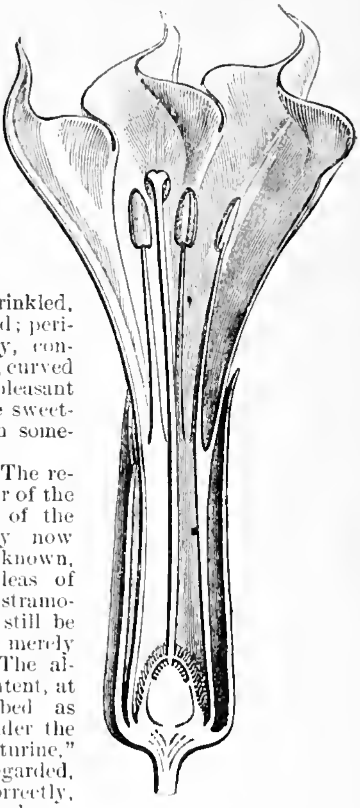


FIG. 4561.—Longitudinal Section of Flower of Datura Stramonium. (Baillon.)

The Seeds.—About 3.5 mm. ($\frac{1}{7}$ in.) long and two-thirds as broad, flattened reniform, the hilum at one side of the concavity; testa dull black or blackish, hard, coarsely and shallowly reticulate-wrinkled, and very finely pitted; perisperm whitish, oily, concealing a cylindrical, curved embryo; odor unpleasant when bruised; taste sweetish and bitter, then somewhat acrid.

CONSTITUENTS.—The relations to one another of the mydriatic alkaloids of the *Solanaceæ* are only now becoming known, and our ideas of those of stramonium must still be regarded as merely tentative. The alkaloidal content, at first described as distinct, under the name "Daturine," is now regarded, doubtless correctly, as being largely one of the *hyoscyamines* (see *Scopola*), but which one, and in what proportions, and how far, and under what conditions mixed with atropine, are matters largely of conjecture. Even the percentage of total alkaloid is not well known. It is generally considered that the seeds contain about one-fourth of one per cent., the leaves not more than one-third as much. Besides these, the leaves contain a large amount of ash (fourteen and one-half per cent.), nitre, asparagin, a trace of volatile oil, and other unimportant substances, and the seeds about twenty-five per cent. of fixed oil.

ACTION AND USE.—From the above analysis it will be seen that stramonium can exhibit but little difference in action from hyoscyamus, and but little from belladonna. It is indeed capable of being used for exactly the same purposes, only it is more quieting and hypnotic than the latter, which may indicate the presence in it of some hyoscine or other alkaloid distinct from atropine or hyoscyamine. Custom, perhaps, as much as anything, has directed the leaves of this species, instead of those of the others named, to be used in the local antispasmodic treatment of asthma, for which purpose it is almost entirely prescribed. The common method is to administer it by smoking. The leaves may be burnt in a pipe or on the cover of a hot stove, or they may be made more inflammable by being soaked in a strong solution of saltpetre and dried, after which they will burn steadily, without flame and without requiring any apparatus; prepared in this way and flavored with aromatics and balsams, they are the foundation of most of the "asthma cigarettes" and "pastils," which are often better products than extemporaneous preparations are apt to be. The French Codex gives directions for making cigarettes of stramonium, containing 1 gm. each of leaves, without any admixture. For internal administration stramonium may be considered as about the equivalent of hyoscyamus. The following preparations are official, all made from the seed, the leaves being only used for smoking (1 or 2 gm.): Extract (*Extractum Stramonii*), strength about $\frac{4}{1}$: Fluid Extract (*Extractum Stramonii Fluidum*), strength, $\frac{1}{1}$; Tincture (*Tinctura Stramonii*), strength $\frac{1}{15}$; and the Ointment (*Unguentum Stramonii*), strength (of the extract), $\frac{1}{10}$ in benzoinated lard. All these have similar properties and uses to the corresponding preparations of hyoscyamus and belladonna, but are more hypnotic than the latter. Dose of fluid extract about 0.2 c.c.; of the other preparations, according to their relative strength.

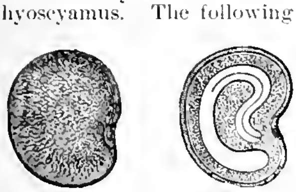


FIG. 4563.—Seed, Entire and in Section, of Datura Stramonium.

ALLIED PLANTS.—*Datura*, of which the present plant is a characteristic species, consists of a dozen, mostly large, rank herbs, most of which have similar medical properties to the above. *D. Tatula*, with purple stems and flowers, scarcely distinct from *D. Stramonium*, and *D. alba*, of India, are used for the same purposes.

Henry H. Rusby.

STRANGULATION AND HANGING, EVIDENCES OF DEATH FROM.—Suffocation is the name applied to both the act and the result of deprivation of atmospheric air. When this deprivation is due to mechanical interference the term *mechanical suffocation* is used.

Mechanical interference may occur through pressure on or obstruction within some portion of the respiratory tract. Suffocation by pressure on the neck is called *hanging* when the constricting force is the weight of the body itself, and *strangulation* in all other cases. The term suffocation is also used in a more special sense where breathing is prevented by pressure on the mouth, nose, chest, or abdomen; or by obstruction within the respiratory tract; or by pressure on the tract from the œsophagus; or through inhaling irrespirable gases.

Strangulation may therefore be defined to include all cases of suffocation by *pressure on the neck* whether by cords or the hand, but excluding hanging. The Germans distinguish strangulation by the hand as *Erwürgung*, and by ropes, cords, etc., as *Erdrosselung*. The words garroting and throttling are often used in place of strangulation. In this article the word ligature will be used to include the very varied forms of constricting materials. Hard substances are sometimes placed in the ligature to increase the pressure.

Strangulation is almost always homicidal, hanging almost always suicidal, and the other forms of suffocation usually accidental, but often also homicidal. Both suicides and murderers are usually more violent than is really necessary to destroy life; murderers more so than suicides.

Death from strangulation as well as all other forms of suffocation, including hanging, is mainly by asphyxia; to some extent by coma or syncope or both. The post-mortem appearances will vary somewhat, depending on whether the deprivation of air is sudden or gradual, partial or complete, and whether there is coincident pressure on the great arteries, veins, and nerves. According to Hofmann, a pressure of 2 kgm. on the neck stops the flow of blood in the jugular veins; one of 5 kgm., in the carotid arteries; one of 15 kgm. stops the movement of air in the air passages, and one of 30 kgm. the flow of blood in the vertebrals.

The *evidences* of death from strangulation are *external* and *internal*. The principal external evidence is the mark of the cord or hand on the neck. Tidy says that nothing short of distinct external marks would justify a medical jurist in pronouncing death to be due to strangulation, while on the other hand Taylor considers the condition of the lungs (see *infra*) as characteristic. Liman does not think there are any internal appearances which can distinguish suffocation, strangulation, and hanging from each other. This statement is made the more probable in view of the fact that death in each case is generally by asphyxia.

All marks on the body should be carefully noted, the cavities of the skull, thorax, and abdomen carefully examined; the possibility of death having occurred from other causes, even in strangulation, must be considered. In all cases the cord or strangulating ligature should be carefully examined for marks of blood, for adherent hair or other substances. The precise manner in which the cord has been tied should be noted. Putrefaction may cause external marks to disappear. In some fatal cases there are either no marks at all or they are but slight; this is more likely to be the case in suicide than in homicide, and is usually due to the ligature being soft and yielding. The victim of a homicide may, however, first be stunned and afterward strangled. A person while intoxicated or in an epileptic or hysterical paroxysm may grasp his neck in gasping for air and thus leave finger marks. Marks are said to be plainer after the body has become cold and when subjects have recovered from attempts at suicide.

The mark of the ligature in strangulation usually encircles the neck more completely and is more horizontal than in hanging. These conditions may, however, be reversed, because a body may be dragged by the neck after strangulation, and there have been suicides by hanging in whom the mark of the cord was horizontal. As a rule, however, a horizontal mark with the knot on the same level as the cord, especially if below the larynx, suggests strangulation rather than hanging; and if there are several marks the probability is even greater. In compression with the fingers the marks are not in a horizontal but in an oblique line. The mark of the ligature is usually circular, well defined, and corresponds closely to the breadth of the ligature; rather depressed and usually below the larynx. As a rule this depression is not deep; the skin at the bottom of the groove is usually very pale, while the adjacent parts are red or livid. Sometimes the bottom of the groove shows ecchymoses. Neyding says that suggillations in the groove made by the ligature on the neck are rare, but are oftener found in strangulation than in hanging, because the conditions favoring their formation are oftener found in strangulation. In most cases the skin and connective tissue of the groove and of the parts in the vicinity show, microscopically, hyperæmia and hemorrhages. Liman states that when we find suggillation in the groove or its vicinity we may know that some other form of violence has been applied at the same time as that of the ligature or hand. He had not seen suggillation in the furrow either in strangulation or in hanging, except when the injured persons had lived some time. The absence of suggillation and ecchymosis was due, he thought, to pressure on the capillaries. Bremme says that there is no hemorrhage in the subcutaneous tissues of the mark of the ligature, either in strangulation or in hanging, if death occurs at once and the cord is removed soon after death; but if the cord remains for some time after death there may be hemorrhages, or if death does not occur at once, whether the ligature is removed or not. It is impossible to distinguish ante-mortem from post-mortem hemorrhage. Different constricting agents may make quite similar marks. Taylor mentions a case in which a soft silk handkerchief was used and the appearance was the same as that of a narrow cord, due to the tightness with which it was tied. Marks may be made on the neck within a limited time after death similar to those made during life. Tidy's experiments led him to fix this limit at three hours for ecchymosis and six hours for non-ecchymosed marks. Taylor, however, doubts if such marks can be made one hour after death. He says that the period cannot be positively stated, and probably varies according to the rapidity with which the body cools.

A cord may be found near a body or even around its neck, there may even be a mark around the neck. These may be attempts at deception. Marks much like those of violence may be made by tight collars and handkerchiefs remaining till the body is cold. Cases are reported of bodies having been strangled and then burnt or hung, to cover the crime; and of partial suffocation by gags followed by or coincident with strangulation. Where a hard substance like a piece of coal or stone is inserted into the ligature (usually a soft cloth) and presses against some part of the neck, there is usually a corresponding bruise. Marks of pressure by the thumb and fingers are usually on the front of the neck, and either just above or just below the larynx. In many cases these marks are only those of the finger tips with some scratches, and show definitely the probable size of the assaulting hand and whether right or left. Marks of strangulation may disappear rapidly after removal of the ligature. Assailants usually constrict the neck much more violently than is sufficient to cause death. Marks of violence on the neck are therefore greater in strangulation than in hanging. A great variety of external injuries other than those on the neck have been found in the different cases reported, where other forms of violence were also used. With few exceptions such additional injuries indicate homicide.

Since the evidences of death in hanging are so similar to those in strangulation, and since "hanging" is not considered elsewhere in this Handbook, these evidences will be pretty freely treated here.

The external appearances in *hanging* are those due to the action of the ligature on the neck and to other violence, if any has been done, and those due to asphyxia or syncope. If the suspension is very brief and the ligature soft and supple and the body instantly cut down after death, there may be no mark. Allison questions the value of the mark, contending that it is post mortem, and reports cases; he says it is present only if the drop is considerable or the suspension continues after death. Tidy says that the mark is in a measure independent of the ligature and duration of suspension and does not usually acquire its color for some hours after death; sometimes, however, it has occurred in a much shorter time. It may be slight because the ligature has been placed over the clothing. The longer a body hangs after death the plainer is the mark. It can be produced on the cadaver. Harvey says that the characteristic mark was found in 8 non-fatal cases in nearly 1,500 cases of hanging. Coutagne, in 21 necropsies on subjects hung, found 17 in which the lesions of the neck were plain.

The *direction* of the mark in hanging is usually oblique, following the line of the lower jaw upward and backward behind the mastoid process; it may, however, be horizontal. If the ligature encircles the neck more than once, one mark may be circular, the other oblique. If a running noose is used, the mark may be circular and be seen all the way round the neck, looking like the mark of strangulation. Taylor states that if the noose should be in front, the mark may be circular, the jaw preventing the ligature from rising upward in front as much as it would behind. If it encircles the neck but once, its continuity is apt to be broken by the prominence of the hyoid bone, thyroid cartilage, sterno mastoid muscles, etc. In 117 out of 143 cases Tardieu found the mark between the chin and the larynx; in nearly all the remainder, over the larynx; in a very few, below the larynx; the last position was due to the protection of the neck by a handkerchief or beard, or there was some anatomical or pathological peculiarity which prevented the ligature going higher. Hofmann saw 2 cases of tumor of the neck; one in a woman where the cord was below the larynx, and the other in a man where it was over the larynx. Remer found the cord above the larynx in 38, over the larynx in 7, below in 2. Devergie found it above the larynx in 20, over it in 7, below in 1. Casper found it above the larynx in 59, over it in 9. Roth in 49 cases found the ligature above the hyoid bone in 5, between the bone and larynx in 31, over the larynx in 8, below it in 1. Hackel found the ligature, in 40 per cent. of cases, between the hyoid bone and larynx; in 60 per cent., lower down. The ligature always appears lower after the body is laid down than it was in suspension. Maschka found the furrow above the larynx 147 times in 153 cases.

The *character* of the mark in hanging will vary according to the kind of ligature used, its mode of application, the vitality of the tissues, and the period that has elapsed since death. The result is different according as the knot or loop is single or double, a running or slip knot. The mark may differ in character in one part of the neck from what it is in another. The same furrow may be soft in one part and dry in another. The width of the mark does not necessarily correspond to the diameter of the ligature. A double mark usually means that the ligature has been twice passed around the neck, although the marks may not be continuous or parallel. Tardieu states that a large single leather thong pressing on the neck only by the borders may make a double mark. The mark is usually depressed. The depth of the depression, groove, or furrow, as it is called, is greater the narrower and firmer the ligature, the longer the suspension, and the greater the weight of the body. The mark may be merely a slight depression, without color, or only a red blush if the subject is young, tissues are healthy, and suspension is brief. Roth in 49 cases found that the furrow of the ligature was brown in 40, red brown in 6, and 3 times bluish. In about two-thirds of the cases of hanging, as generally observed, the bottom of the furrow, the place of greatest pressure, is white, especially so where the knot is tied; while the edges of the furrow are usually slightly raised and red or livid. If the subject is very fat there may be only a slight depression. Harvey says that this hard, white, shining, translucent band from compression of the connective tissue is the first stage of the *parchment* or vellum skin, and is chiefly noticed in fresh bodies. The borders are swollen and œdematous, called by Lacassagne *bourrelet de sillon.* The skin *below* the furrow is usually violet. Authors differ as to whether this is due to congestion or to hemorrhage. Roth in 49 cases found swelling below the furrow 27 times. Hackel found ecchymoses above the mark in 35 per cent. of the cases of hanging. Hofmann thinks that the lividity of the upper border of the furrow is due to the stopping of the venous blood descending from the head.

The dry, hard, yellowish-brown, or reddish-brown *parchment furrow* described by writers on hanging is said to be common. Ogston found it in one-third of his cases. It is found only when the body has remained suspended for several hours after death; indeed, it may be produced by applying the ligature to the cadaver; is not at all, therefore, a proof of suspension during life. Liman states that constriction by a ligature even for some time does not necessarily cause a mummified or excoriated furrow. He saw cases in which the mark was soft, flat, scarcely colored, but little interrupted, and not parchmenty. Its appearance can be prevented or delayed by examining a body soon after death or by rehanging it; and after it has appeared it will disappear on the application of some liquid. Taylor compares this parchment mark to the cutis from which the cuticle has been removed for two or three days. The parchment skin is seldom seen in strangulation, though Liman has seen it. Neyding says that it depends mainly on the amount of excoriation of the skin, and that this is greater in hanging. Tardieu explains this frequency as being due to the fact that the constriction in hanging lasts longer.

The violence used in hanging may cause ecchymoses and abrasions of the skin of the neck adjacent to the mark of the ligature. Slight abrasions and ecchymoses are sometimes found in the furrow. Ecchymoses alone do not indicate whether suspension has been before or after death; but abrasion with hemorrhage strongly suggests suspension during life. Devergie regards ecchymoses of the neck as strongly suggestive of homicide. Neyding says that suggillation in the groove is oftener found in strangulation than in hanging, and Bremme that there is no hemorrhage in the subcutaneous tissue of the mark if death occurs at once and the cord is removed at once after death; but if the cord remains for some time after death there may be hemorrhage, or if death does not occur at once, whether the ligature is removed or not. Roth found ecchymoses or small bladders at the lower margin of the furrow 9 times in 49 cases. Riechke found only once in 30 cases a hemorrhage beneath and on both sides of the mark. Chevers did not find ecchymoses of the skin of the mark in cases of hanging. Coutagne found hemorrhage into the connective tissue or muscle. Casper found no ecchymoses in 50 out of 71 cases. Maschka saw 2 cases where burns on the neck resembled the mark of a ligature.

The furrow when once distinct remains constant for a long time after death even in putrefaction. Marks from soft substances, however, disappear sooner than those from strong and uniform compression. The value of the presence or absence of marks on the neck and the character of the marks have been questioned. Orfila, Casper, and Vrolik have shown by experiment that if a body is hanged within one or two hours after death the furrow, parchment skin, lividity, and the density of the connective tissue will appear just as is seen when suspension has occurred during life; but ecchymoses and infiltration, clotted blood in the skin and connective tissue and muscles of the neck, suggest suspension during life.

The marks of topical medical applications, as plasters, sinapisms, etc., must not be confounded with marks of violence. In apoplectics with short, full necks we may find at the borders of the folds of the skin in the neck one or more red or livid depressions that bear some resemblance to the marks of a ligature; but on section there are no ecchymoses.

The neck nearly always appears stretched in hanging. According to Roth, the mobility of the head is increased by this stretching. The head also is always inclined to the side opposite to that of the knot. In suicides the head is usually bent forward on the chest.

Usually in *strangulation* there is hemorrhage into the loose connective tissue under the mark and in the subjacent muscles; in most cases isolated and circumscribed, but sometimes extending beyond the line of the mark. Hemorrhage from compression by the fingers is more marked than that from ligature. Sometimes there is only fulness of the subcutaneous veins.

In *hanging*, the connective tissue under the mark is usually white and condensed, the more so if the body has been long suspended. This dryness or condensation was found by Hackel in 52 per cent. of hangings. Deeper-seated parts are injured only when the hanging has been violently done. The muscles, especially the sterno-mastoid, are sometimes ruptured; Hofmann reports several cases. In 50 hangings Lesser saw 11 ruptures of muscle. Maschka never saw the rupture in suicides. Hackel in 67 cases failed to find the muscle ruptured. Hofmann believes that the rupture of the muscle is sometimes post mortem. Coutagne found the sterno-mastoid ruptured once in 24 cases.

The neck occasionally suffers extreme injury, and owing to the violence used (Tidy) this occurs oftener in strangulation than in hanging. Occasionally the neck is broken. The *hyoid bone* may be broken; Maschka saw it once in 18 of *Erdrosselung* and in 5 of *Erwürgung*. The bone is rarely dislocated in hanging. Orfila mentions a case of fracture. Barker usually found the bone fractured in judicial cases. Pellier reports 2 cases. Hofmann says the hyoid cornua are often fractured, especially when the ligature is between the hyoid bone and thyroid cartilage. Coutagne found fracture of the bone 8 times in 24 cases; he attributes the fracture to the pressure against the spine. Pellier speaks of fracture of the styloid process.

In *strangulation* the *carotid arteries* may suffer rupture of their inner and middle coats, especially in atheromatous subjects and when compression has been great. Friedberg states that the injury of the carotid is a proof that the strangulation occurred during life, and probably from pressure of the fingers on the neck without any regard to any disease of the artery. He reports two cases. The examiner should be careful not to injure the artery with the forceps. The vessels may contain clots. In *hanging* also the carotid arteries may be injured; usually the inner and middle coats are torn; and hemorrhage may occur into the wall of the vessel. The common carotids are those usually affected and just below the bifurcation, but the external carotid is also occasionally injured. The injury is said to be due to the stretching and squeezing of the artery, stretching being the most effective, since the rupture often occurs at a distance from the mark of the ligature. Such injury of the artery does not prove that hanging took place during life, because it has been produced on the cadaver; but hemorrhage into the wall of the vessel, or wound or rupture after death, is very improbable. Maschka says the lesion is very rare. Tardieu says it is rare and therefore unimportant. Pellier reports 4 cases of rupture of the carotid in a total of 23. Levy records the experiments of Hofmann of Vienna and Brouardel and himself of Paris, 5 in number, and concludes that compression of the carotids, if it produces obliteration, can cause rapid loss of consciousness and death; and explains why in incomplete suicide the subject is unable to help himself. Coutagne found rupture of carotids 10 times in 24 cases, and insists on the importance of the lesion.

In all forms of asphyxiation the *hands* are usually clinched, and may have articles in their grasp which under the circumstances have a medico-legal value. In hanging, the hands are often clinched so tightly that the nails are driven into the palms; this occurs more especially when the hanging has been done with violence. When the feet touch the ground, as often occurs in suicides, the hands may be stretched out. Roth found the hands and feet flexed in 14 of 49 cases. Taylor says that we may expect to find the hands clinched when constriction of the neck is sudden and violent. The legs are usually livid.

In *asphyxia* the *tongue* is often swollen, dark, protruding, and sometimes bitten. Maschka states that if the ligature lies above the hyoid bone the tongue will be drawn backward; if over or below the bone, the tip of the tongue may appear more or less between the jaws. In hanging the tongue is usually livid and swollen, especially at the base. According to Tidy, Dr. Guy looks on this as showing that suspension took place very probably during life. In about one-third of the cases the tongue is protruded and compressed between the teeth; sometimes bitten. Some observers found it protruded only as a result of putrefaction. The protrusion is not believed to depend on the position of the ligature. Hackel in 67 cases found the tongue lying forward in all cases in which the cord was between the larynx and hyoid; in 55 per cent. in front of the teeth, in 18 per cent. between the teeth; where the ligature was lower down the tongue was behind the teeth. He found by experiment that in the spasmodic expiratory effort the tongue was thrust forward; in the inspiratory movement drawn backward; and he concluded that the forward movement was the result of reflex action. Maschka found the tongue between the teeth 58 times in 149 cases. Roth in 49 cases found the tongue projecting and bitten in 22, the teeth shut in 15 others; in 15 the mouth was open; the tongue was retracted in 30.

In *asphyxia* the *face* usually shows pain and suffering, although sometimes the features are calm. In the latter case there may have been syncope. The face varies in color from violet to black, and may be swollen. Casper says that the face has the same appearance as in any other corpse. Liman found the face livid in only 1 of 14 cases of strangulation. Hofmann says that the cyanosis appears during the agony, because of the paralysis of the circulation and the gravitation of blood. The cyanosis of the face with projection of the eyes and the congestion of the conjunctivæ are due to the expiratory effort, and these signs are also seen in fat persons who do not die of strangulation. Tardieu mentions a dotted redness or minute ecchymosis of the conjunctivæ and skin of the face, neck, and chest as constant; but this cannot be considered characteristic, because it has been seen, though not so well marked, in death from other causes. It has been found in suffocation from compression of chest and belly, and also where there was respiratory interference in the prolonged efforts of tedious labor and in convulsions. Liman found it in those who were hanged; in the conjunctivæ, lips, back of mouth, and in the muscles. It is due, according to Hofmann, to increased blood pressure and consequent hemorrhages. It is of importance as tending to show that there was a stasis of blood in the head and face during life. Maschka in 234 cases of asphyxia found capillary hemorrhages of eyes and eyelids 87 times.

Dastre and Morat claim that in asphyxia the cutaneous circulation becomes much more active than in the normal state, while at the same time the vessels of the abdominal cavity are contracted.

Post-mortem stainings (hypostases) are usually darker in strangulation than in other forms of death. They appear soon, as does also putrefaction, because of the quantity and fluidity of the blood.

In *hanging* the appearance of the face varies with the duration of the suspension; at first it is pale, afterward livid; congested and swollen if the subject has been long suspended. Roth found the face pale in 43 of 49 cases. In about one-half of the cases the features are calm and placid (syncope). Maschka found the lips bluish in 98 of 153 cases. Harvey, after examining reports of nearly 1,500 hangings, says: "In the majority of instances, immediately after death, the features were placid, the face pale, the eyes not unduly prominent, the mouth closed or half open, the tongue pressed against the teeth but not protruding, the superficial veins full, but the head, neck, and trunk free from lividity. After a longer or shorter time, however, and apparently after a few hours (in India), all this is changed. Livid patches appear about the chest, back, and shoulders, the face and head become bloated and puffy, and the tongue and eyes protrude."

In *asphyxia* the *eyes* are usually staring, prominent, and congested, and the pupils dilated. Casper doubts their prominence. Budin and Coyne state that in asphyxia the dilatation of the pupil progresses to a maximum, and then convulsions occur. Ophthalmoscopic examination during the dyspnœa of asphyxia shows a lessened fulness of the retinal vessels. In hanging, the eyes are often prominent, staring, and congested, and usually the pupils are dilated. Lacassagne and Maschka look on ecchymosis of the eyelids and conjunctivæ, *piqueté scarlatin*, as important, favoring the idea of hanging or strangulation. Roth found in 49 cases that the eyelids were closed in 28, half open in 12, congested in 6, ecchymosed in 2; pupils dilated in 31, narrowed in 2. There was dilatation of pupils in 97½ per cent. of Ogston's cases; in 2 cases there was rupture of crystalline lens.

Signs of hemorrhage from the nose, eyes, and mouth may be visible in asphyxia, as also bloody froth from the mouth and nose. Chevers saw bleeding from the ears in strangulation. Taylor states that Dr. Geoghegan informed him of a case of suicidal strangulation by a ribbon; the violence was great, there was bleeding from the ear, and the drum was found ruptured; the mark on the neck, which was deep, nearly disappeared after the ligature was removed. Taylor also says that Wilde, of Dublin, saw a rupture of the drum and hemorrhage in strangulation. Pellier says that Littré mentions a case of rupture of the tympanic membrane in strangulation. Harvey says the blood was found flowing from the ear in 6 cases out of nearly 1,500 hangings, but no details were given. Hofmann saw a case in which there was bleeding from the ears. He says that this is not due, as has been supposed, to rupture of the tympanic membrane, but to hemorrhage from subcutaneous vessels.

In *asphyxia* the *veins* of the entire body are distended with very dark and very fluid blood, while the arteries, especially in the young, are mostly empty. Experiments on the lower animals have shown that the pulmonary artery and systemic veins to the finest ramifications are distended with dark blood.

The *mucous membranes* in asphyxia are generally much congested. Serum is found in the serous cavities. Tidy, comparing strangulation and hanging, concludes that because strangulation is usually homicidal and greater violence is used, therefore the external marks are more complete in strangulation and the congestion of the air passages is invariably much greater. Maschka found the pharynx cyanotic in 216 of 234 cases of asphyxia. Ecker reported a case of judicial hanging in a man, aged forty, where the soft palate was swollen and filled up the passage so that the air evidently could not enter.

The lining membrane of the *larynx* and *trachea* is always congested in asphyxia and may be livid; the tube may contain bloody froth or blood alone. Froth tinged with blood in the air passages is considered by Tardieu one of the most constant signs of strangulation. In strangulation the trachea is sometimes torn or may be folded on itself. The cartilages of the larynx, especially if calcareous, may be broken; this is more likely to affect the thyroid than the cricoid. The fracture would seem to occur only as the result of enormous force, especially in the young, in whom the cartilages are so elastic. The experiments of Keiller on cadavers led him to conclude that falls on the larynx, even from a height and with superadded force, are unlikely to fracture this organ; severe pressure or a violent blow against the larynx from before backward may cause fracture, but severe *lateral* pressure, as in ordinary throttling, is more likely than other forms of violence to fracture the alæ of the thyroid or even the cricoid cartilages and also the hyoid bone. Taylor states that Dr. Inman, of Liverpool, had informed him of a case of splitting of rings of the windpipe from pressure. Maschka, in 15 cases of choking, found 6 fractures of the larynx. Chailloux has collected 8 cases of fracture of the larynx in strangulation; they were all made by the fingers. The experiments of Cavasse seem to show that there is no great difficulty in fracturing the thyroid in strangulation.

Langreuter made some experiments on a cadaver from which enough of the posterior part had been removed to enable him to view the throat. He saw that lateral digital pressure on the larynx closed the glottis; stronger pressure made the vocal cords override each other. Similar pressure between the larynx and hyoid bone caused apposition of the aryepiglottic folds and occlusion of air passages. He experimented on 16 bodies to ascertain the effects of blows and pressure on the larynx, with the following results: In 8 cases, women, the thyroid cartilage was injured 3 times, the cricoid 4; in 8 men the thyroid 8 times, and cricoid 5. Whence he concluded that the larynx is better protected in women. In the 16 cases the hyoid was fractured 10 times.

In *hanging*, the larynx and trachea are usually deeply congested, of a red color; a violet color indicates putrefaction. Ogston reports mucus but not bloody froth 9 times in the pharynx, 6 in the trachea, and 4 in the lungs in a total of 40 cases. In 1 case there was a quantity of blood in the larynx and pharynx. Taylor thinks that pinkish froth in the trachea indicates incomplete obstruction; and Chevers that it is due to spasmodic efforts to breathe when the obstruction is nearly complete. Chevers always found clear mucus in the larynx and upper part of the trachea, each follicle being marked by a minute globule of mucus. Harvey states that this was noted a few times in his reports. The larynx may be fractured or dislocated. These lesions are very rare in suicide, more frequent in homicide and judicial hanging, and in the old in whom the cartilages are calcareous. Remer found the injury in but 1 case of 101 of suicidal hanging. Barker found the larynx lacerated in his judicial cases. Harvey says that the trachea was reported lacerated 11 times in nearly 1,500 cases; twice the laryngeal cartilages were separated from each other; in 5 these cartilages were fractured, but there was nothing to show under what conditions; hemorrhage in the vicinity of the larynx 43 times. Pellier reports 1 case, and adds that the lesion easily escapes notice because of the mobility of the cornua. Roth in 49 cases failed to find any fracture. Pellier found that the cricoid was injured oftener than the thyroid, which is the reverse of what is found in strangulation. Cavasse was unable to cause fracture of the larynx by hanging the cadaver. Chailloux collected 6 cases of fracture of the larynx in hanging; he concluded that the fracture could not be produced on the cadaver by hanging, and is therefore caused during life. Coutagne in 24 cases found fracture of the thyroid cartilage 8 times.

In *asphyxia* the *lungs* are usually much congested, resembling red hepatization, except that the blood is darker. Hemorrhages (apoplexies) into the substance of the lungs are common. Tardieu found patches of emphysema due to rupture of the air vesicles, giving the surface of the lung the appearance of a layer of white false membrane. Ogston admits that this occurs in pure strangulation, but to a less extent in mixed cases. Liman found the lung surface uneven, bosselated, the prominences being of a clearer color and due to emphysema; the lungs were in the same condition of congestion and emphysema in strangulation, suffocation, and hanging. He failed to find the apoplexies described. The lungs are sometimes anæmic. In healthy young subjects, especially children, the blood-vessels of the lungs often empty themselves after the heart stops. The lungs may therefore be bloodless but emphysematous from the violent efforts to breathe. Page's experiments on the lower animals showed the lungs of a pale, reddish color, and not much distended; occasionally a few dilated air cells were seen toward their anterior borders, and small hemorrhages over the surface. His experiments appear to show that subpleural ecchymoses occur as a result of violent and repeated efforts to breathe. Among other experiments he stopped the mouth and nostrils of a young calf long enough to excite violent efforts at respiration; it was then instantly killed by pithing. The lungs were found pale red, not congested, but showing subpleural ecchymoses. Page believed that these were due to the changed relation between the capacity of the thorax and volume of the lungs. Liman found these ecchymoses in cases of strangulation, hanging, drowning, poisoning, hemorrhage, and œdema of the brain in the new-born, etc. He failed to find them in some cases of suffocation. He believes them due to blood pressure from stasis in the blood-vessels. Ssabinski made many experiments on dogs and cats to ascertain the presence or absence of subpleural ecchymoses in strangulation, drowning, section of pneumogastrics, opening of pleural sacs, compression of chest and abdomen, closure of mouth and nose, burial in pulverulent materials, etc. Similar hemorrhages may appear on the mucous and serous membranes; on the respiratory, digestive, and genito-urinary tracts, and pleuræ, pericardium, and peritoneum, membrane of brain, and the ependyma. They are sometimes minute and stellate, at other times irregular in shape; many are bright-colored. According to Tardieu, the punctiform ecchymoses are rarely present except in suffocation. Maschka, in 234 cases of asphxyia, found the lungs congested 135 times, anæmic 10, and œdematous 42. He thinks the subpleural ecchymoses are valuable signs of asphxyia.

Page experimented on six kittens, strangling three by the hand, the other three by ligature. The results of the post-mortem examinations were nearly similar. The veins were full of dark fluid blood; the right cavities of the heart were similarly gorged, the left empty; lungs pale red, not congested nor distended. Brain normal. The differences were in the lungs: in the first series there were many small, irregular, circumscribed, dark-red ecchymoses scattered over the general surface; in the second a small number of bright-red ecchymoses somewhat larger than a large pinhead.

The bronchial tubes are usually full of frothy bloody mucus, and the mucous membrane is much congested and shows abundant ecchymoses.

In *hanging* the condition of the lungs and heart varies according to whether death is due to syncope or to asphyxia. Ogston found in 22 cases that the lungs were expanded in 1 and collapsed in 2. Harvey says the lungs are congested in over seven-eighths of the cases, emphysematous in a few, and subpleural ecchymoses present in a few. Patenko experimented on dogs by hanging them; when the constriction occurred after expiration, the lungs were congested; after inspiration, not congested. In the first case the blood flows from the periphery to the heart and thence to the lungs, but cannot flow from the lungs because of the difficult circulation in the dilated pulmonary vessels and deficiency of intrathoracic pressure. There is in both cases cerebral congestion in the region of the bulb. Tardieu holds that punctiform ecchymoses and apoplexies do not occur in hanging unless suffocation has preceded. Pellier, however, found these ecchymoses 14 times in 22 cases. He says that the lesion is not characteristic of suffocation, and quotes Lacassagne, Grosclaude, Dechoudans, Vicq, Chassaing, and Legroux to the same purpose. Hofmann says that the ecchymoses are relatively rare in adults. Maschka found them 18 times in 153 cases.

In *asphyxia* the right side of the *heart*, especially the auricle, is usually full of dark fluid blood due to the mechanical impediment to the passage of blood through the lungs. If the heart continues to beat after respiration has ceased, the right ventricle is commonly well contracted like the left cavities and nearly empty, the lungs being much congested. Sometimes the left cavities of the heart contain blood. This would most likely occur if the heart should stop in diastole. Sometimes clots are found in the right ventricle. Maschka found clots in the heart 25 times in 234 cases of asphyxia. Harvey states that in *hanging* the presence of serum in the pericardium seems more a matter of time elapsed after death than anything else. But it is found much oftener in strangulation than in hanging. The difference is explained by the comparative slowness of death in strangulation. Harvey finds that in about one-half the cases if the body is fresh the right side of the heart, pulmonary artery, and venæ cavæ are full of dark fluid blood, the lungs being also much congested, and the signs of death by asphyxia well marked. When blood is found in both sides of the heart, it is probable that death is due to neuro paralysis. When decomposition is advanced all the cavities are often empty. Taylor says that if the examination is delayed several days the distention may not be observed.

In *asphyxia* the *external generative organs* are sometimes congested; erection of the penis may have taken place and have persisted. The vagina may be moist. Tardieu, Devergie, and Casper deny that these appearances are usual. In about one-fourth of the cases of *hanging* the genital organs are congested. The penis is large and more or less erect; seminal fluid, generally prostatic and sometimes mixed with blood, is often expelled. The fluid may pass only into the urethra and it may be necessary to press the urethra to secure it. The clitoris may be found erect and there may be a sort of menstrual flow. Orfila showed by experiment that swelling of the sexual organs and emission of semen can be produced after death in those who have been suspended during life. The flow of semen is found in all kinds of death from violence. Roth, in 39 cases of hanging of men, found the penis enlarged 18 times and ejaculation in 19. Hackel found the penis swollen in 13 per cent. of cases of asphyxia. Erection may come on soon or late, even days after death. Involuntary discharges of urine, fæces, and seminal fluid may occur in all kinds of violent death. There is nothing characteristic in their appearance. Tardieu found them, however, but twice in 41 cases of hanging. Roth, in 49 cases, found discharges of fæces in 17 and of urine in 4; in 15 cases, not noticed.

Harvey mentions a case in which internal piles had burst and there were stains and clots of blood about the perineum and anus. In such cases without careful examination there would naturally be a suspicion of violence.

The *abdominal organs* are generally darkly congested in *asphyxia*, although Maschka denies this for the liver and spleen. The congestion of the viscera generally is doubtless due largely to the prior congestion of the lungs and engorgement of the heart. In hanging, the stomach is often much congested, and this fact might sometimes suggest the possibility of poisoning. The liver, spleen, and kidneys are usually much congested; Hofmann says that this occurs in the kidney only when the body has been hung a long time.

Maschka considers the rounded pinhead ecchymoses of the inner surface of the *scalp* and *pericranium* valuable evidence of asphyxia. The *brain* and membranes are sometimes congested, occasionally apoplectic. Maschka found congestion of brain and membrane 48 times, and anæmia 30 times in 234 cases. In hanging, the brain is rarely much congested. In 101 cases Remer found hemorrhage but once, and in 106 cases Casper failed to find it. Tardieu says the brain is oftenest anæmic. If, however, the body is cut down and placed horizontally, the blood-vessels of the brain may fill up. Evidence may be found in the brain suggesting insanity and therefore an explanation of a probable suicide. Harvey says that hemorrhages in or about the brain are found in a much larger proportion of cases of hanging in India than in Europe. "No common condition likely to cause extravasation is apparent, only one man being noted as plethoric, but in many the rope seemed to have been very tight." Wilkie reports a judicial hanging in which a man, aged about twenty-five, fell about three and one-half feet; a recent clot was found in the brain. The experiments of Brouardel of hanging rabbits showed the brain anæmic.

The conjunction of the following appearances would suggest that the hanging has been of some duration: lividity of face, congestion and prominence of eyes, dryness of skin under the ligature, deep furrow, congestion of sexual organs, swelling and lividity of lower limbs, hypostatic congestion of lungs.

Page experimented on a young cat and young dog; both were hung in the same way. Examination of the cat showed the veins generally engorged; sublingual veins much engorged; tongue protruded slightly and much swollen; no frothy mucus in bronchi. In the dog the tongue did not protrude and was not swollen; right cavities of heart contained blood, left empty; brain and other organs normal. In the cat the lungs were uniformly congested, dark red; no ecchymoses. In the dog the lungs were much distended, posterior borders mottled violet; emphysematous patches on surface; no apoplectic effusions; subpleural ecchymoses bright red, irregular, clearly defined in outer surface, most numerous toward the roots and on the lower lobes.

Pellereau gives an account of hanging as seen by him in warm climates. He had not seen the elongation of the neck described nor the erection of the penis, subconjunctival ecchymoses, fracture of larynx, rupture of walls of carotid artery, subpleural ecchymoses, nor fracture of vertebræ. He always found a mark on the neck; the left cavities of the heart always empty, the right always full of black blood. Mackenzie says that in 130 cases of suicidal hanging the protrusion of the tongue between the teeth, the open and protruding eyes, clinched hands, and blue nails were very frequent; the tongue was found bitten many times; there were urethral and rectal discharges and rupture of the carotid artery. The penis was found erect several times. The hyoid bone was fractured 24 times in 93 cases. In no case was the larynx or vertebra fractured. In 73 cases ropes were used; in 30, portions of clothing. The marks of ropes were always well defined, indented, and parchment-like; the marks of soft ligatures faint and reddish. In no case were the muscles of the neck, the larynx, trachea, or large bronchi injured, and in none was there subcutaneous hemorrhage or blister.

Hofmann says that the rupture of the carotid in hanging is always transverse, may be simple or multiple, and may occur in suicides; more apt to occur when the ligature is thin. Lesser tabulated 50 fatal cases of suicidal hanging; in 29 he was satisfied that the hanging occurred during life; in 3 of these the skin of the neck alone showed any lesion; there was a double mark, the skin being otherwise bloodless; in 5 the deeper soft parts were the only ones affected; in 3 the skin showed lesions, the deeper soft parts none, but either the hyoid bone, larynx, or vertebræ were involved; in 12 the skin showed no mark, but the deeper soft parts and either the larynx or hyoid bone were involved; and in 6 the hyoid bone only or the bone and larynx were injured. In the remainder it was not possible to say that the hanging occurred during life. In two cases there were no marks at all; in 9 there were changes in the skin; in 4, changes in the skin and deeper parts; in 2, changes in the skin, deeper parts, and hyoid bone or larynx; in 3, changes in the skin and hyoid bone, or larynx, or both. In 14 of the 50 cases the hyoid bone was fractured; in 20, the larynx; and in 1, the vertebræ. The common carotid arteries were injured in 6. The number and severity of the lesions bore no constant relation to the thickness of the ligature nor to the force used, but rather to the position of the body.

Daniel S. Lamb.

STRAWBERRY. See *Rosaceæ*.

STRONTIA MINERAL SPRING.—Baltimore County, Maryland.

Post-Office address, 305 and 307 Exchange Place, Baltimore. No hotel near springs.

This spring is located about nine miles from the heart of the city of Baltimore. It is reached by the Green Spring branch of the Northern Central Railroad to Strontia Spring station, thence one-half mile to springs. The elevation of the locality is about six hundred feet above the sea-level, and the average summer temperature is about ten degrees lower than that of Baltimore. An analysis of the spring water made in 1887 by Prof. W. W. Simon, of Baltimore, resulted as follows: One United States gallon contains (solids): Potassium nitrate, gr. 2.71; sodium nitrate, gr. 0.83; sodium chloride, gr. 7.59; magnesium chloride, gr. 3.91; calcium chloride, gr. 20.67; calcium bicarbonate, gr. 3.93; strontium sulphate, gr. 0.13; strontium bicarbonate, gr. 1.08; iron bicarbonate, gr. 0.51; alumina, gr. 1.08; silicic acid, gr. 1.19; and traces of phosphoric acid, iodine, ammonia, and organic matter. Total, 43.54 grains. Gases: Oxygen, cub. in. 0.48; nitrogen, cub. in. 0.71; carbonic acid, cub. in. 2.04.

Since 1876, when the properties of this water were discovered, it has acquired a wide reputation in the treatment of sea-sickness, dyspepsia, gout, rheumatism, and diabetes. It is used commercially and as a table water. It has found its way into many of the leading hotels, clubs, and cafés of New York, Baltimore, and other cities. It is a saline-calcic, and has tonic, diuretic, and alterative properties. It is probable that the considerable quantity of strontium in the water modifies its action to some extent, but in what way cannot be explained in the present state of our knowledge.*

James K. Crook.

STRONTIUM.—*General Medicinal Properties of Compounds of Strontium.*—Salts of strontium resemble those of calcium in being practically non-poisonous to the human system and in tending to improve nutrition. Also they are of low diffusion power, and accordingly are comparatively slow of absorption. Strontium has been proposed in medicine as affording a base for medicinal salts that is non-poisonous and even agreeable to the stomach. Accordingly strontium has been suggested for

* Some of the strontium salts are now used in the treatment of epilepsy, diabetes, parenchymatous nephritis, muscular and subacute articular rheumatism, and acute gastritis.

the basic carrier of bromine, iodine, and salicylic acid, and the bromide, iodide, and salicylate of the metal are considered preferable to the corresponding potassium and sodium salts, because better borne by the stomach. The United States Pharmacopœia recognizes strontium bromide and iodide (see *Bromides* and *Iodides*), and also the *lactate*, which latter salt will be considered here, since its effects are not due specifically to its acid radical.

Strontium Lactate.—The salt is official in the United States Pharmacopœia under the title *Strontii Lactas*, Strontium Lactate. It occurs as a white, granular powder, permanent in the air. It is odorless, with a bitterish, salty taste. It dissolves in about four parts of cold water, and freely in boiling water and in alcohol. Strontium lactate is a harmless salt, whose use in medicine is because of a reputation, in chronic Bright's disease, for diminishing the albumin in the urine and improving the patient's condition generally. In the form of the disease accompanying rheumatism and gout, it is praised, but it should not be used in conditions of acute inflammation with high fever. In albuminuria from heart disease, also, the medicine is reported to diminish the albumin. The drug may be given in doses of from 1.3 to 2 gm. (gr. xx. to xxx.) or more, two or three times daily. *Edward Curtis.*

STROPHANTHUS.—(*Kombe, Arrow Poison, Inée, Onaye*, etc.) The dried ripe seed of *Strophanthus Kombe* Oliver, and perhaps of other species (fam. *Apocynaceæ*), deprived of its long awn. The British Pharmacopœia names the plant as above, under the title *Strophanthi Semina*. The German, under the title *Semen Strophanthi*, says "very probably from *Strophanthus Kombe*." The United States Pharmacopœia, because at the time of its revision ten years ago information on this point was very imperfect, specifies the seeds of *S. hispidus* De C., which we now know to be incorrect.

The strophanthus plants are woody climbers of tropical Africa, where an extract of the seeds of several of them is used as an arrow poison and in other ways for poisoning. The seeds occur in lanceolate or lance-ovoid follicles, of which two develop from each flower. These are 15 to 30 cm. (6 to 12 in.) long, and about a sixth or a fifth as thick. They are densely filled with seeds, the bodies of which are embedded among the long, white, plumose awns. The seeds are imported either in the pods or after removal, and in the latter case either with or freed from their awns. They should be imported and reach the consumer in the pods, since this permits the identification of the contents by the testing of one seed from each pod. This is an almost necessary method of examination, since good and poor varieties of seeds so closely resemble one another that an admixture is very difficult to detect in the cleaned seeds. Some varieties are practically inert, while others are extremely powerful, and in different ways, so that the employment of correct methods of identification of the seeds is of vital importance to the patient. Although all parts of the plant are bitter, the seeds alone have been investigated.

Description.—Good strophanthus seeds are of a peculiar pale greenish-brown color, and are densely covered with very fine, closely appressed silky hairs. This appearance of the surface constitutes the best guide to selection, outside of chemical examination. Two classes which should be rejected are those of a distinctly brown to dark brown color, and those of a very pale yellowish or yellowish-white, without greenish tinge, and the hairs coarse and more or less roughening the surface by their irregular projection. Strophanthus seeds are about 1.25 cm. or a little more in length, and one-fourth to one-third as thick, lanceolate, obtuse at the base, gradually pointed at the summit; they are somewhat flattened or even a little hollowish on one side, and have a narrow ridge running along the other, and are often warped or even semi-twisted. They are brittle, the fracture whitish and oily, the kernel consisting of rather long cotyledons, enclosed in sparse albumen. They have a slight odor and an extremely bitter taste. On being crushed and tested with strong sulphuric acid, a green color should quickly develop, due to the reaction of the strophanthin, which is mostly contained in the albumen or endosperm. In this way, the testing of a single seed taken from a pod determines the identity and quality of the entire contents. However, should the test fail, it should be repeated with one or two more seeds from other parts of the pod, as individual seeds sometimes occur which are imperfect.

Constituents.—With various ordinary constituents of seeds, strophanthus contains two or three bodies of therapeutical interest. The important medicinal constituent is two to three per cent. of strophanthin, considered below. The properties of the twenty-five to thirty per cent. of fixed oil are not known with certainty. We should expect it to be inert, but indications of its irritating and toxic properties are not wanting. On the other hand, these are more likely due to contained substances than to the oil itself. Some species of the seeds contain the very poisonous glucoside *pseudostrophanthin*, and, since the commercial seeds are almost always mixed, it may be the presence of this in the oil which makes the latter poisonous. The poisonous properties referred to are not the same as those of over-doses of strophanthin, since the greater toxicity is not accompanied by a correspondingly greater cardiac tonic effect, but often by a lesser one. *Kombic acid* is present, but its properties have not been investigated, and the name has apparently been applied to more than one substance. Other constituents reported are uncertain, since the specific identity and freedom from admixture of the seeds analyzed has not been determined. *Strophanthin* is a crystalline glucoside, usually appearing amorphous, as a fine white powder, soluble in alcohol and water, especially the latter, insoluble in ether and chloroform. The formula usually given ($C_{31}H_{48}O_{12}$) cannot be considered as fully established. Upon decomposition, it yields *strophanthidin*. Commercial strophanthin is very rarely, if ever, pure.

Action and Uses.—The therapeutical action of strophanthus is that of strophanthin, and is directly and almost wholly referable to the heart. It is commonly stated as being identical with digitalis, but the statement is very misleading, unless certain differences in other directions are carefully considered. Although its direct action is almost identical with that of digitalis, the resultant effect is quite different, owing to the absence of those complications from arterial effects which result from the use of digitalis. Strophanthus does not contract the arteries, hence none of the gain from cardiac stimulus is counteracted, and there is none of that danger of damming back the blood upon an incompetent heart, which sometimes exists when digitalis is used. Another very important difference between the two is the great promptness with which strophanthus gets to work, its effects being observed in from a third to a half of the time required for digitalis. This is partly due to its purely cardiac action, partly to the fact that the absorption of strophanthin is very rapid. Strophanthus strengthens and slows the heart beat, prolonging the diastolic period, and it is especially valued for its power of restoring rhythm to an irregular beat. It is thus especially useful when a very prompt action is desired, and also where cardiac action is weak relatively to arterial. Even in those cases in which digitalis is properly called for, a great gain may be secured by giving an initial dose of strophanthus, following it with the digitalis.

On the other hand, the effect of strophanthus is far less prolonged than that of digitalis, and is not cumulative like the latter. Hence, small doses, repeated at frequent intervals, is the rule for the administration of strophanthus. Even in this way its effects cannot be prolonged like those of digitalis, for the beneficial effects first seen soon decrease. It cannot therefore be regarded, like digitalis, as a mainstay, but rather as an emergency remedy. The effect upon the stomach is far less irritating than that of digitalis, hence there is not the same tendency to emesis. The same principle applies to the kidneys, the local effect upon the latter being very slight. Yet strophanthus is an indirect diuretic, through increased cardiac action. It is often even more strongly diuretic than digitalis, owing probably to the absence of obstruction by vascular contraction. For the same reason, the danger of damage in cases of complication with organic kidney disease is wanting. Strophanthus is also a safer and more comfortable remedy for children.

ADMINISTRATION.—Owing to the facts stated above, it is not so difficult to secure genuine and pure strophanthus seeds, and therefore corresponding preparations of them, as it is to secure pure strophanthin, and the former are to be preferred in all ordinary cases. The official preparation is a five-per-cent. tincture of the seeds, made with sixty-five-per-cent. alcohol, and the dose ranges from three to ten minims. When larger doses are required, it is usually because the very inferior "brown seeds" have been employed. These are several times cheaper and they have been used extensively even by some large manufacturers. On the other hand, a preparation of the "white seeds" will prove irritating and will act as a poison without a corresponding increase in therapeutic effect. Strophanthin may be given in doses of 0.0006 to 0.0012 gm. (gr. $\frac{1}{100}$ to $\frac{1}{50}$). *Henry H. Rusby.*

STRUMA.—This term has been used in a general way to indicate a swelling or protuberance in any part of the body, but particularly with reference to enlargements of the lymph glands and the thyroid gland. Since such enlargements are most frequently due in the case of the lymph glands to tuberculosis, and in the thyroid to goitre, the word struma has come to be largely used as a synonym for both scrofula and goitre. Further, it has been applied to enlargements of the lymph glands other than those of a tuberculous nature, also to enlargements of the thymus, to enlargements of the kidneys and suprarenal bodies due to tumors arising from adrenal tissue, and in rare cases to splenic enlargement. Such a widespread application of the term, as well as its failure to convey any definite idea concerning the etiology or pathological nature of the conditions so designated, would appear to be sufficient reason for its abandonment, and in pathology it is gradually falling out of use. At present there occur in the literature the following different applications of the term, given in the order of frequency of usage.

1. As a synonym for *scrofula*. So common is this usage in the literature of a generation ago that the term strumous has come to be used almost entirely in the sense of scrofulous (see *Scrofula* and *Tuberculosis*).

2. As a designation for *goitre* or *bronchocele*. At the present day the term struma is probably more frequently applied by clinicians to enlargements of the thyroid than to tuberculous enlargements of the lymph glands, and in this connection a great number of modifying terms occur in the literature: *struma colloides*, colloid goitre; *struma gelatinosa*, also applied to colloid degeneration of the thyroid; *struma hyperplastica*, an enlargement of the thyroid due to hyperplasia either of the parenchyma (*s. parenchymatosa*) or of the interstitial connective tissue (*s. fibrosa*); *struma cystica*, colloid degeneration of the thyroid with cyst formation; *struma follicularis*, synonym for colloid, hyperplastic, or parenchymatous struma; *struma mollis*, soft or colloid goitre; *struma petrosa*, hard or hyaline goitre; *struma cystica petrosa*, cystic goitre with hyaline change in the interstitial connective tissue; *struma cystica ossea*, cystic goitre with calcification in the hyaline connective tissue; *struma hyperplastica vascularis* or *aneurysmatica*, a vascular goitre with hyperplasia of the connective tissue; *struma aneurysmatica, pulsans* or *cavernosa*, vascular goitre with dilated vessels; *struma hypertrophica simplex*, simple colloid or parenchymatous goitre; *struma intrauterina congenita*, a simple parenchymatous hyperplasia of the thyroid in the new-born as distinguished from the swelling of the thyroid region in face presentations; *struma congenita*, congenital goitre; *struma maligna*, sarcoma or carcinoma of the thyroid; *struma amyloidea*, supposed amyloid goitre, incorrectly applied to hyaline goitre; *struma glandulosa*, enlargement of a portion of the thyroid separated from the main gland; *struma endothoracica*, enlargement of isolated or accessory thyroid tissue or of a deeply lying thyroid in the anterior mediastinum (retrosternal or retroclavicular struma); *struma chlorotica*, the enlargement of the thyroid frequently seen in chlorosis, and sometimes, when associated with prominence of the eyeballs, mistaken for exophthalmic goitre; etc.

3. *Struma lymphatica*, a synonym for *status lymphaticus* or *lymphatic constitution* (see *Status Lymphaticus*).

4. *Thymus struma*, the enlargement or persistence of the thymus after the period at which this organ usually undergoes retrograde change. As this condition is associated with lymphatic struma, it is usually included under that designation.

5. *Strumæ lipomatodes aberratæ renis*, or *hepatis*, *strumæ lipomatodes suprarenales*, *adrenal struma*, are terms applied to the tumors of adrenal tissue arising within the kidney or its capsules, in the adrenals, or in the neighborhood of these organs or in the liver (see *Hypernephroma*).

6. The vicarious use of struma to indicate enlargements in other parts of the body, as of the spleen, bones, etc., may in the majority of cases be traced to the influence of the association of the term with scrofula or diathesis.

Aldred Scott Warthin.

STRYCHNINE.*—*Strychnina* ($C_{21}H_{22}N_2O_2 = 333.31$). "An alkaloid obtained from nux vomica, and also obtainable from other plants of the family *Loganiaceæ*."—U. S. P.

The origin of strychnine has been fully discussed under *Nux Vomica*. Its extraction from the seed is accompanied by much difficulty, owing to its strong retention in the cells of the horny albumen. Naturally, various methods have been employed for overcoming this difficulty. The seeds are either powdered in their original condition, or first subjected to a steaming process and then dried. The strychnine can be dissolved out by alcohol in the form of its natural salt or by water acidulated with hydrochloric acid. The concentrated and filtered solution is then treated with an alkali, such as acetate of lead or lime, to decompose the alkaloid, which is then precipitated and purified. The principal impurity liable to exist is brucine, the tests for which are indicated in the following description:

Colorless, transparent, octahedral or prismatic crystals, or a white, crystalline powder, odorless, and having an intensely bitter taste perceptible even in highly dilute (1 in 700,000) solution. Permanent in the air.

Soluble, at 15° C. (59° F.), in 6,700 parts of water and in 110 parts of alcohol; in 2,500 parts of boiling water and in 12 parts of boiling alcohol. Also soluble in 7 parts of chloroform, but almost insoluble in ether.

When heated to 268° C. (514.4° F.) strychnine melts. Upon ignition it is consumed, leaving no residue.

Strychnine has an alkaline reaction upon litmus paper.

If a minute quantity of strychnine be dissolved in about 0.5 c.c. of concentrated sulphuric acid on a white porcelain surface, and a small crystal of potassium dichromate slowly drawn across the liquid with a glass rod, there will be produced at first, momentarily, a blue color, which quickly changes to purplish-blue, then gradually to violet, purplish-red, and cherry-red, and finally to orange or yellow.

On dissolving 0.02 gm. of strychnine in 2 c.c. of nitric acid (specific gravity 1.300), in a small test-tube, the acid should not turn more than faintly yellow (limit of *brucine*).

ACTION AND USES.—Strychnine is one of the most intense and energetic of poisons, acting deleteriously upon nearly all forms of animal and vegetable life. There are, however, considerable differences in the susceptibility of different creatures to its influence, and in general those which are destitute of or have but a primitive nervous system withstand it better than the higher organisms.

* Also spelled strychnin.

On this account, its antiseptic and antizymotic properties, though distinct, are decidedly weaker than those of quinine and some similar substances; for this reason and because of their being but a little poisonous, the latter are far more desirable of employment for such purposes.

Absorption and Elimination.—Strychnine is promptly absorbed from the mucous membrane and rather freely from abraded surfaces and from the subcutaneous tissue. It circulates in the blood as strychnine and is thus eliminated, though a small part of it is oxidized. Elimination is principally by the kidneys, to a considerable extent through the saliva, and to a slight extent through most of the other channels. This prompt absorption and slow elimination render it one of the most notoriously cumulative drugs, a fact which is considered more at length in the article on *Nux Vomica*. Tolerance, by its continued use, is not much increased.

Local Action.—The disinfectant properties of strychnine are noticed above. It exerts a prompt though mild stimulant action upon the tissues with which it comes into contact. In the mouth and stomach it acts like the ordinary simple bitters, in promoting the appetite, but, unlike the most of them, its presence in the stomach promotes rather than inhibits digestion, so that it is probably the most valuable of all stomachic bitters, especially in view of the fact that its local effects are strongly reinforced as soon as absorption begins. In the intestine, its local effect is to stimulate peristalsis, making it a valuable laxative, and this effect is again reinforced by its systemic action through the spinal centres.

Upon the heart the operation is somewhat different, since the local effect of stimulating the rate, through its action on the muscle, is just about counteracted by its systemic effect upon the vagus centres, which checks such increase.

Systemic Action.—The effects of strychnine upon all the bodily systems are to be understood by regarding it as a direct and pure stimulant, its action upon the motor centres of the cord, and to a lesser extent upon those of the brain, vastly predominating. Thus it stimulates the circulation (the vagal effect having been considered above), both through the heart and through the vasomotor system, promptly and strongly increasing blood pressure; it powerfully stimulates the respiration, increasing both the rate and the strength of the respiration; it increases metabolism and waste and raises the temperature moderately; it increases the activity of all muscular tissue, both voluntary and involuntary, partly, as already stated, by direct action, increasing excitability, but to a far greater extent through stimulation of the motor centres. Thus, slighter stimuli are required to set the movements going, and the movements themselves exhibit increased strength. All the special senses are sharpened, especially that of sight, and this more particularly for blue colors. All of these effects will be more thoroughly understood by consulting our account of strychnine poisoning under the head of *Nux Vomica*, which account will serve also to explain the reverse symptoms, occurring as after-effects in that condition.

Therapeutical Uses.—The very numerous therapeutical uses for strychnine may, for the most part, be inferred from what has preceded. It can be employed to stimulate almost any of the lagging vital powers. It is so employed, most largely perhaps, in promoting the functions in the aged. It is also very valuable in the stimulation of those persons whose habits of life are unnatural, in that they do not take sufficient exercise or perform other ordinary hygienic duties. If careful attention be given to the patient, the most valuable effects can be secured from strychnine by utilizing its action as an aid in inducing the indolent to take needed exercise while under its influence. While it cannot be relied upon for overcoming a condition of chronic constipation, it becomes, in connection with other drugs, a most valuable aid in this direction. Its uterine stimulation cannot be overlooked, either from the standpoint of undesirable effects or from that of desirable effects. It is a pronounced aphrodisiac. In rendering cardiac support in such exhausting diseases as pneumonia, it is of the utmost value. Its value as a tonic in all ordinary forms of impaired digestion has been indicated above.

Although these beneficial effects from the use of strychnine are almost marvellous, it is to be remembered that, since its action is purely stimulating, it can easily be so used as to result in the most damaging way. It must never be relied upon to take the place of natural powers and conditions, but should always be considered as a means of inducing their activity. Otherwise the system can easily become exhausted, a condition of depression made to follow that of stimulation, it being then found extremely difficult to discover any other means for again stimulating them.

COMPOUNDS, PREPARATIONS, AND DOSES.—Strychnine, because of its high insolubility, is rarely used except in the form of its salts, of which the sulphate is official. It occurs in intensely bitter, white, prismatic crystals, which effloresce in the atmosphere. It is soluble in fifty parts of water, and in one hundred and nine parts of alcohol, but is nearly insoluble in ether. The dose of strychnine itself is 0.001 to 0.006 gm. (gr. $\frac{1}{60}$ to $\frac{1}{10}$). Strychnine is combined in many popular formulæ with the hypophosphites, and with iron, quinine, and other tonics. Two such are official: the Citrate of Iron and Quinine (Ferri et Strychninæ Citras), containing one per cent. each of strychnine and citric acid, with ninety-eight per cent. of iron and ammonium citrate, the dose 0.06 to 0.2 gm. (gr. i. to iij.); and the Syrup of the Phosphates of Iron, Quinine, and Strychnine (Syrupus Ferri, Quininæ et Strychninæ Phosphatum), containing 0.02 per cent. of strychnine, two per cent. of soluble ferric phosphate, three per cent. of quinine sulphate, 4.8 per cent. of phosphoric acid, ten per cent. of glycerin, and five per cent. of water, in syrup, the dose 2 to 4 c.c. (fl. ʒ ss.–i.).

Henry H. Rusby.

STRYCHNIN AND NUX VOMICA, POISONING BY.—The poisonous quality of nux vomica was referred to by Wepfer and by Valentine in the latter part of the seventeenth century. Strychnin was discovered by Pelletier and Caventou in 1818. Blumhardt, in 1837, was probably the first to report the death of a human being by this poison. Although Wainwright probably used strychnin as an instrument of murder in 1831, the first homicidal case which was the subject of a trial of which we find record occurred in Canada in 1851.

A collation of 529 cases of strychnin poisoning shows a relatively high proportion of homicidal and suicidal poisonings. Of the whole number, 264, or 49.9 per cent., were suicidal; 100, or 18.9 per cent., homicidal; and 150, or 28.3 per cent., accidental. Poisonings by strychnin are of more frequent occurrence in Great Britain than in the United States, owing to the fact that rat poisons used in the former usually contain strychnin, while those used in this country contain arsenic or phosphorus.

SYMPTOMS.—The symptoms of poisoning by strychnin or nux vomica are very characteristic.

If the dose be relatively small, although capable of causing death, there is frequently at first an initiatory stage of nervous exaltation without any violent symptoms, whose duration varies inversely with the magnitude of the dose and the rapidity of absorption. The special senses are much more acute than normally, the mental functions are active, the patient is restless, and experiences a sensation of itching. But with large doses the onset is usually very sudden.

Soon twitchings of individual groups of muscles occur, followed by violent tetanic convulsions. During the spasms there is, in the great majority of cases, marked opisthotonos. The head is thrown sharply back, the body bent backward, the abdominal and thoracic muscles firmly contracted, the lower extremities rigid, and the soles of the feet bent inward and strongly arched. The lower jaw is fixed, the eyeballs are protruded, the pupils dilated, the expression of the countenance is distorted, the lips are cyanotic, the mouth is marked with froth—frequently bloody from the tongue being caught between the closing teeth—and the neck is swollen. In some exceptional cases emprosthotonos or pleurothotonos is observed instead of opisthotonos.

The spasm gradually passes off, the muscles relax, the eyes and pupils become normal, and respiration is resumed. The patient speaks, usually calls for air, desires to be held, and is in dread of impending death. Indeed, consciousness and intellectual activity do not seem to be impaired during the spasms.

After the first convulsion others, similar in character, occur, either spontaneously or in consequence of very slight unexpected excitation. An attempt to move the patient, a slight jarring of the floor or bed, a sudden noise, a slight draught of air, or even a flash of light, is sufficient to provoke a spasm if the patient do not expect it. On the other hand, much more active excitation fails to call forth a spasm if the patient be not taken unawares; and he frequently asks to be rubbed, held down, or moved. When the spasm recurs spontaneously, the patient usually announces its coming some seconds in advance, and asks to be held.

The number of convulsions usually varies from three to ten, but in prolonged cases, whether fatal or non-fatal, the number may be much greater. Their duration is from thirty seconds to five or even fifteen minutes. The intervals vary in duration from forty-five seconds to one hour, or even to one hour and a half; usually they last for from five to fifteen minutes.

In cases terminating in recovery the interval between the spasms increases in length and the convulsions become less active and shorter in duration, and finally cease, leaving the patient in a condition of great muscular fatigue, and with increased reflex irritability. In fatal cases death results from one of two causes: In some cases death is due to asphyxia by fixation of the muscles of respiration during a protracted spasm; in others it is due to exhaustion, and occurs during the non-tetanic period. In most fatal cases death occurs during or after the fourth or fifth tetanic seizure, although cases have occurred in which the patient has succumbed at a later period, and others in which life was extinguished during the third, second, or first convulsion.

Duration.—The rapidity of action of strychnin is modified by the form in which it is taken, whether in solution or in a hard and difficultly soluble pill, and by the length of time which is allowed to elapse before treatment is resorted to.

In 78 cases, in which the time of first appearance of the symptoms was noted, the period was "directly, or very soon," in 20; from three to thirty minutes in 40; from thirty minutes to one hour in 7; from one to two hours in 6; and from two to three hours in 5. The average period of delay is, therefore, within twenty minutes. The extremes are "directly" and three hours. The appearance of strychnin symptoms is delayed when large doses of opiates are taken with it.

The total duration of strychnin poisoning is also short, whether it terminate in death or in recovery. Of 143 fatal cases of which the duration is stated, 77 died within one hour; 32 in from one to two hours; 10 in from two to three hours; and 24 in from three to eighteen hours. In the majority of these cases the entire duration was less than one hour. The extremes were "immediately" (from a dose of one and three-fourths grain, combined with an equal quantity of nux vomica), and eighteen hours (from a dose of three grains), both adult males.

In non-fatal cases recovery is usually rapid, the active symptoms cease within a few hours, and, after cessation of the spasms, the patient may be considered as out of danger, although in exceptional cases great muscular prostration and occasional involuntary muscular contractions continue for some days.

Differential Diagnosis.—The disease bearing the closest resemblance to strychnin poisoning is traumatic tetanus. In poisoning by strychnin the attack is more sudden than in tetanus, and the entire history of the case is compassed within a few hours, in place of lasting for days. The spasms follow each other at shorter intervals, and are of shorter duration, in strychnin poisoning than in tetanus. In the latter, trismus is one of the earliest and most prominent of the characters, while in the former it occurs later, if any succession of symptoms be observable, and may be insignificant as compared with the violent tetanic contraction of the respiratory muscles. During the intervals between the convulsions due to strychnin the muscles are usually relaxed, while in tetanus they remain more or less rigid, particularly those of the lower jaw. The chief points of distinction are in the much more rapid progress of strychnin poisoning, and, in the great majority of cases, in the history of the onset, which, in the poisoning, follows, with very little warning, within two hours or less, the ingestion of some bitter substance, but in tetanus is gradually developed several hours or days after an injury.

Uncertainty concerning the diagnosis between epilepsy and strychnin poisoning can only occur in the very exceptional case of an unknown person dying during a single convulsion. In such an event chemical analysis would decide the question definitely. In other cases the history of the case, the much longer interval between the paroxysms in epilepsy, and the more distinctly tonic character of the spasms in strychnin poisoning, are sufficient to establish the distinction.

In cases of poisoning of pregnant women by strychnin (two such are cited by Wharton and Stillé, pp. 443, 625) the distinctions between the effects of the poison and puerperal convulsions are of importance. The principal diagnostic point is in the fact that in puerperal convulsions the patient is entirely unconscious of what occurs, either during or between the convulsions, while in strychnin poisoning consciousness remains unimpaired, except immediately before death. The detection or non-detection of strychnin in the body would remove all doubts.

Lethal Dose.—The smallest amount of strychnin which has been known to cause the death of an adult is 0.016 gm. (= gr. $\frac{1}{4}$), which produced violent symptoms in ten minutes in a female, aged thirty-six, and death in one hour and forty-five minutes (*Medical Times and Gazette*, 1854, p. 376). Double this quantity, 0.032 gm. (=gr. ss.), caused death in two cases. In one of these (case of Dr. Warner) a physician took by mistake half a grain of the sulfate, was violently convulsed in five minutes, and died in twenty minutes. Less quantities have produced dangerous poisoning in adults. Christison cites the case of a child of three years which was killed in four hours by 0.004 gm. (= gr. $\frac{1}{16}$).

On the other hand, numerous cases are on record in which much larger doses have been taken without causing death. Thus Campbell (*Lancet*, 1856, ii., 695) relates a case in which a man, aged thirty, took 0.65 gm. (= gr. x.) of strychnin and recovered. Shaw (*American Journal of the Medical Sciences*, 1856, 547) cites the case of an adult female who recovered from the effects of a dose of 0.65 to 0.97 gm. (= gr. x. to xv.). Tschepke (*Deut. Klin.*, 1861, ex "Maschka Handb.," ii., 613) gives a case of a pharmacist who took from 0.48 to 0.72 gm. (= gr. viiss. to xi.) of strychnium nitrate dissolved in about 30 gm.)= fl. ℥ i.) of bitter-almond water, and, after half an hour, having experienced no symptoms, 0.6 gm. = gr. ix.$\frac{1}{4}$) of morphium acetate, also dissolved in bitter-almond water. Subsequently, being still capable of locomotion, he poured chloroform upon his pillow and lay with his face upon it. An hour and a quarter after taking the first dose he suffered violent symptoms of strychnin poisoning, from which he, however, recovered under treatment by emetics and tannin. Wilson (*American Journal of the Medical Sciences*, 1864, N. S., xlviii., 70) cites a case in which the amount taken was 2.6 gm. (= gr. xl.), probably the largest not causing death.

Treatment.—The ends to be aimed at are the removal of any unabsorbed poison from the stomach, if possible, and the prevention or mitigation of the paroxysms. Chloral should be generously administered, followed by inhalations of chloroform sufficient, and sufficiently prolonged, to control the convulsions until the poison shall have been eliminated, as it is with considerable rapidity. In the exceptional cases in which the patient is seen before the tetanizing action of the poison has been established, the stomach should be washed out as expeditiously as possible with a strong infusion of tea, or a solution of tannin in some form, or water holding powdered charcoal in suspension. Usually stomach lavage must be deferred until the patient has been brought, at least partially, under the influence of the anæsthetic. No reliance is to be placed upon camphor, albumen, opium, aconite, cannabis indica, or tobacco, which have been suggested as so-called physiological antidotes.

Post-mortem Appearances.—There are no peculiarities discoverable, on external or internal examination, which are characteristic of this form of poisoning. Rigor mortis is more rapidly established and continues for a longer period in most cases. According to Wharton and Stillé, rigor mortis was very marked in the body of a woman exhumed two weeks after death (*Medical Jurisprudence*, ii., 445). Taylor ("Poisons," third American edition, 676) states that cadaveric rigidity was well marked in the body of Cook two months after death. Usually the body is relaxed at death and soon stiffens, but in some cases the tetanic spasm merges into rigor mortis. But instances are met with in which cadaveric rigidity has disappeared in from twenty-four to forty-eight hours. In some cases the hands are firmly clenched and the soles arched after the other muscles have become relaxed. Rigidity is of shorter duration in the bodies of those in whom the spasms have been more or less controlled by treatment during life, than in those who have died without medical interference. The surface is usually livid, but not in all cases. Sometimes lividity is confined to the fingers, and in some cases the inner surfaces of the thighs and arms assume a red color.

The internal appearances are still less characteristic. The blood is usually fluid and dark. The vessels of the scalp, the brain and its coverings, and of the spinal cord, as well as the lungs, are in most cases congested. The heart is usually empty and sometimes firmly contracted, the right side being less so than the left, and sometimes distended with dark, fluid blood. The bladder is usually empty, though in some cases it has been found to be nearly full of urine. Occasionally ecchymotic spots or patches of congestion are observed in the stomach.

Analysis.—In cases in which the analysis is not to be limited to a search for strychnin, the systematic method of Dragendorff for the separation of alkaloids and glucosids from organic mixtures should be followed. By this method any strychnin which may be present in the substances examined will be found in the residues of evaporation of the benzene extract from the alkaline aqueous solution.

In all cases it is advisable to resort to Dragendorff's method, even when the history of the case points very directly to strychnin, as any question subsequently arising as to the presence or absence of another alkaloidal or glucosidal poison can then be determined.

In some exceptional chemico-legal cases, and when the physician wishes to determine the presence or absence of strychnin in the urine during the life of the patient, an abridged modification may be used. If the substances to be examined be solid, they should be finely divided and placed in a flask, to which water, rendered distinctly acid with sulfuric acid, is added in sufficient quantity to cover the solid. After agitation, the reaction of the liquid is to be determined, and, if not distinctly acid, it is to be rendered so by the addition of dilute sulfuric acid. The flask and its contents are then to be heated to 40°–50° C. for six or eight hours, after which the liquid is to be filtered off. The extraction should be repeated four or five times with water. The united acid filtrates, which contain any strychnin that may be present in the form of the sulfate, are then evaporated to the consistence of a thin syrup over the water-bath. The residue is mixed with four volumes of strong alcohol, gradually added during stirring, and allowed to macerate twenty-four hours. The cold alcoholic liquid is filtered off, the residue on the filter washed with strong alcohol, and the filtrates and washings evaporated over the water-bath until free of alcohol. The residue, thinned with water if necessary, is transferred to a stoppered cylinder. The solution should not exceed 50 c.c. in bulk, and may be less. About 50 c.c. of benzene (boiling-point not over 85° C.) are then added and the cylinder strongly agitated once every five minutes for about half an hour. The benzene layer is then removed by the separatory funnel and a fresh portion added to the aqueous liquid, which has been returned to the cylinder. This extraction of the acid aqueous liquid is repeated (usually four or five times) until the benzene no longer leaves a residue on evaporation. The purpose of this extraction is to remove pigmentary and other substances, whose presence materially interferes with the reactions. The aqueous liquid is now rendered distinctly alkaline with ammonium hydroxid, and again repeatedly extracted with benzene as described above, but the benzene layers now separated are evaporated in several watch-glasses, and it is to the residues so obtained that the tests for strychnin are to be applied.

If the substance to be examined be a liquid, it should either be evaporated to dryness, the residue extracted with acidulated water, and the filtered aqueous extract treated with benzene, the watery solution being first acid, then alkaline, as above described; or, in the case of a simple aqueous solution, the treatment with benzene may be applied directly, care being had as to the reaction.

In order that the tests may be relied upon, particularly when the alkaloid is present in small amount, as in the case of absorbed strychnin, it is essential that foreign substances be removed as completely as possible. Therefore, if the benzene residue from the alkaline solution be colored, it should be purified by dissolving it in a small quantity of dilute sulfuric acid, agitating with benzene, rendering alkaline, and again extracting with benzene.

Tests.—1. Strychnin crystallizes from an alcoholic solution in small, four-sided, orthorhombic prisms, terminating in four-sided pyramids; sometimes also in small hexagonal plates. Precipitated by ammonia from solutions of its salts, it forms slender, needle-like, four-sided prisms.

2. The taste of strychnin is intensely and persistently bitter, with a faintly metallic after-taste. The bitter taste is still perceptible in a solution containing only one part of strychnin in two hundred thousand of water.

3. Strychnin dissolves in concentrated sulfuric acid, forming a colorless solution of the sulfate. If, now, nascent oxygen be generated in the solution, a peculiar play of colors is produced; at first, and but for an instant, blue (this is sometimes absent), then violet, which gradually changes to red, and then to yellow.

This test, which is most delicate and characteristic, may be applied in a variety of ways.

The sulfuric-acid solution may be placed upon a strip of platinum foil connected with the positive (platinum) pole of a single Grove cell, and a platinum wire, connected with the negative (zinc) pole, brought into contact with the upper surface of the drop of liquid. The nascent oxygen liberated at the foil produces a purple-violet blotch.

The sulfuric-acid solution may be placed in a watch-glass upon a white background, and a minute fragment of some solid substance capable of yielding oxygen by contact with sulfuric acid drawn through it with a stirring rod. The path of the solid is marked by a streak of color passing through the shades above mentioned. Either manganese dioxid, cerium oxid, potassium permanganate, dichromate or ferricyanid, or lead peroxid may be used. Manganese dioxid, potassium permanganate, and cerium oxid are preferable to the other substances mentioned, and each should be used with separate portions of the residue, if there be sufficient. The dichromate acts quite rapidly, the blue color is not produced, and in solutions containing no strychnin only a yellow color is communicated to the liquid. The manganese dioxid acts much more slowly by reason of its less solubility, the blue color is developed, and, in the absence of strychnin, the liquid remains colorless. If the reaction is obtained as above described another portion of the residue is moistened with concentrated sulfuric acid and heated in an air oven at 130° C. for five minutes, cooled, and treated with the dichromate or peroxid. Strychnin is not affected by the acid at this temperature, but other substances giving color reactions not unlike those belonging to strychnin are either colored by the acid alone or are destroyed. If the material be too highly darkened or blackened when heated with the acid, the cooled liquid should be rendered faintly alkaline, extracted with chloroform, and the residue tested for strychnin. (See Witthaus and Becker, *Med. Jur.*, iv., 808.)

The reaction is interfered with to a greater or less degree by the presence of sugar, morphin, or other reducing agents, brucin, and other substances; therefore the foreign bodies should be removed as completely as possible before the test is applied.

This color reaction is distinct with gr. $\frac{1}{60000}$ of strychnin.

4. The physiological test, first suggested by Marshall Hall, is also extremely delicate. A small frog is held by the hind legs, the skin of the back over the coccyx is raised by a pair of forceps, and a small incision made through the skin into the lymph pouch with a pair of pointed scissors. A few drops of the solution under examination are then allowed to flow from a pipette into the lymph pouch, and the animal is placed under a glass shade. If the liquid contain strychnin, the animal becomes uneasy in about ten minutes; the respiration is accelerated; and violent tetanic convulsions are provoked by striking upon the table, by blowing upon the animal, or by other slight irritations.

5. A solution of iodic acid in concentrated sulfuric acid colors strychnin brick-red, the color changing to violet.

6. Solution of potassium dichromate causes a yellow, crystalline precipitate in solutions of strychnin or of its salts. If this precipitate be moistened with sulfuric acid, the play of colors described in 3 is produced.

Other reactions of strychnin are the following: With solutions of the alkalies, or alkaline carbonates, a crystalline precipitate of strychnin from moderately concentrated solutions of its salts. With tincture of iodin, or a solution of iodin in potassium iodid solution, a dark red-brown precipitate. With platinic chlorid and with auric chlorid, light-yellow precipitates, gradually becoming crystalline. With potassium-iridium chlorid, a dark brown precipitate, which disappears on agitation, but gradually reappears in the form of crystals. With potassium platinocyanid, a white, crystalline precipitate. With potassium-cadmium iodid, a white, flocculent precipitate. With potassium iodhydrargyrate, a fine, white precipitate. With phosphomolybdic acid, a yellowish-white precipitate. With picric acid, a yellow precipitate, which gradually becomes crystalline. With tannic acid, an abundant, white precipitate.

Failure of Detection.—The reactions of strychnin are clearly defined, and it is difficult to suppose a case of death from the effects of this poison in which a properly conducted analysis would not reveal the presence of the alkaloid in the cadaver. It is unquestionable that death may result from the action of certain corrosives and poisons, without any trace of the substance remaining in the body after death. In cases in which a mineral acid or alkali destroys life by starvation, weeks or months after the corrosive has been taken, and in cases of death from digitalis, on the fifth or sixth day, the agent which was the remote cause of death has been eliminated before the fatal termination, and consequently will not be detectable by analysis. The duration of a fatal case of strychnin-poisoning is, however, so short (the maximum lapse of time being six and a half hours, and the average less than one hour from the taking of the poison) that it is, to say the least, highly improbable that a person should die from the effects of this poison and no trace of it remain in the body.

Yet cases have occurred in which death has been undoubtedly due to strychnin, and an analysis has nevertheless failed to reveal the presence of the alkaloid in the cadaver. An historical instance is the case of Palmer, tried in London in 1856, in which Professor Taylor, who made the analysis, did not obtain chemical evidence of the presence of strychnin, although the deceased, Cook, was seized with violent tetanic convulsions fifty-five minutes after taking the poison, and died in about fifteen minutes thereafter. The failure of this analysis (for such it must be considered, as complete elimination in so short a time is not possible) was the subject of much bitter controversy, and seems to have permanently warped the mind of Dr. Taylor on the subject of chemico legal evidence. It was due to two causes, both avoidable. The autopsy was conducted without the commonest precautions necessary in such cases. The defendant was present, and accidentally (?) caused the loss of the contents of the stomach; and the solid viscera were only obtained for analysis at a later date. But the loss of the contents of the stomach, although they probably contained strychnin in larger quantity than the tissues, would not have caused complete failure of the analysis had the analytical processes been properly conducted.

When the amount of strychnin present is large, positive reactions may be obtained even in the unpurified residues; but when the amount is small, as it must necessarily be when absorbed, it is imperative that the alkaloid be freed from other substances as completely as possible before the tests are applied.

Influence of Putrefaction.—Strychnin is one of the most stable of the alkaloids, and remains unaltered in contact with putrefying animal substances for a long time. Cloetta obtained distinct reactions from viscera containing strychnin which had been buried three, six, and eleven and a half months (*Arch. f. path. Anat.*, Bd. xxv., p. 369). Rieckher (*Zeitsch. f. anal. Chem.*, vii., 400) demonstrated the presence of strychnin in a mass of heart, lung, and liver exposed to the ordinary variations of temperature, with which it had been mixed eleven years previously. (See *Ptomains*, Vol. VI., p. 792).

Rudolph A. Witthaus.

STRYKER MINERAL SPRINGS.—Williams County, Ohio.

Post-Office.—Stryker. Visitors received in private families.

The village of Stryker is located on the Air Line division of the Lake Shore and Michigan Southern Railroad. The springs are pleasantly located in the village. They have been allowed to languish somewhat, but we are informed that they have recently passed into the hands of Dr. C. F. Mignin, who proposes to repair and refit the bath-houses, with the intention of establishing a first-class sanitarium. The following analysis of the water was made in 1870 by S. H. Douglas, analytical chemist:

One United States gallon contains (solids): Calcium bicarbonate, gr. 68.30; iron bicarbonate, gr. 9.93; potassium sulphate, gr. 185.34; sodium chloride, gr. 231.86; magnesium chloride, gr. 118.96; silica, gr. 2.63; hydrosulphuric acid, gr. 4.49; total, 621.51 grains.

This water is very rich in valuable chemical compounds. It possesses an exceptionally large quantity of potassium sulphate, which with chloride of magnesium gives it efficient laxative and cathartic properties. The water is also a rich chalybeate, and should be valuable in anaemic and debilitated states, especially when attended by sluggishness of the liver and constipation. *James K. Crook.*

STYPTICIN, cotarnine hydrochloride ($C_{12}H_{13}NO_3.HCl.H_2O$), obtained by the oxidation of narcotine, an opium alkaloid, occurs in bitter yellow crystals which are soluble in water and alcohol. The solutions slowly darken on exposure to light. Chemically it differs but slightly from hydrastinine hydrochloride ($C_{11}H_{11}NO_2.HCl.H_2O$); and clinically it exerts a similar action on uterine hemorrhage.

Falk, of the Pharmacological Institute of Berlin, states that it paralyzes the motor cells of the spinal cord, is mildly narcotic, and stimulates peristalsis. It has no direct effect upon the circulation and is depressing to respiration, death being due to respiratory paralysis.

Rousse and Walton, Marfori, and others, however, assert that it stimulates the heart, and that it controls hemorrhage by vaso-constriction. It does not coagulate the blood. As to its effect on uterine contraction there are conflicting statements, MacNaughton Jones and a few other writers believing it contraindicated in pregnancy, while d'Alessandro, Beadles, and many other obstetricians, have found it most useful in threatened abortion.

The only use of stypticin is to control hemorrhage, and the conditions in which it is especially indicated are: menorrhagia, puerperal hemorrhage, subinvolution, climacteric hemorrhage and hemorrhage dependent upon peri-uterine or adnexial disease. Boldt recommends it highly in the profuse and irregular menstruation of virgins in whom there is no detectable pathological lesion. In hypertrophic endometritis and uterine fibroid it seems to act successfully in only a limited number of cases, though in the latter condition H. D. Ingraham found it better than ergot, hydrastis or thyroid, and MacNaughton-Jones writes: "The hemorrhages in which it proves of most service are those due to uterine interstitial fibroid," . . . etc. The drug has been given with apparent good result in hæmoptysis, hæmatemesis, hæmaturia, and the menstrual neuroses.

The dose is 0.02–0.06 gm. (gr. $\frac{1}{3}$–i.) several times a day in pearl, capsule, or solution. In menorrhagia the larger dose is given for two or three days before the expected menstruation. The only ill effects noted by Goldschmidt from a dose of 0.03–0.06 gm. (gr. ss.–i) every two or three hours for a week, were nausea, and heaviness and constriction in the stomach. Where a prompt effect is desired 2 c.c. (♏xxx) of the ten-per-cent. solution may be administered hypodermatically in the gluteal region. The injection is non-irritating (d'Alessandro).

Locally stypticin has been applied to the cavity of the uterus and to bleeding tooth cavities; and it is used in rectal hemorrhage, nosebleed, and following small operations. A very useful form for local employment is the stypticin-gauze or stypticin-cotton, made by soaking the gauze or cotton in a ten-to-fifty-per-cent. solution of stypticin and allowing it to dry. *W. A. Bastedo.*

STYPTICS. See *Hæmostatics.*

STYRON, phenyl-allyl alcohol, ($C_6H_5CH:CH.CH_2.OH$), is a thick brown oily fluid, used as an antiseptic and deodorizer. *W. A. Bastedo.*

SUBARACHNOID COCAINE INJECTIONS. See *Spinal Cocainization and Lumbar Puncture.*

SUBLAMINE, ethylene diamine mercury sulphate, is a red, very soluble salt of mercury, which is employed as a non-irritant antiseptic substitute for corrosive sublimate. It is not decomposed by soap, does not readily coagulate albumen, and does not harden the skin; yet many experiments have shown it to possess marked bactericidal properties, with a greater penetrating power than has mercuric bichloride. Being non-irritating, it may be used in concentrated solution. Bischof, Swinburne, Dunlap, Reineke, and many others have spoken highly of its advantages in general surgery. Moir has employed it as a vaginal douche. It is ordinarily used in the same strength as the bichloride.

The ethylene diamine mercury citrate has practically the same properties, but is a liquid. It is used by Zweifel in his obstetric wards, and by Kronig and by Blumberg in gynecology. *W. A. Bastedo.*

SUCCUS ENTERICUS.—This fluid is the secretion of the minute glands present in the wall of the small intestine, and it is probably furnished chiefly by the cells of the glands of Lieberkühn. It was first obtained in a pure condition by Thiry, who employed for this purpose an artificial tube of intestine prepared by cutting across the small intestine at two points about 20 to 30 cm. apart, without interfering with the mesentery, restoring the continuity of the intestine by stitching the upper border of the upper incision to the lower border of the lower incision, and then, after closing the lower end of the isolated portion of gut, attaching the upper end of it to the abdominal wound. In this way a living test tube of intestine is obtained, in which the effects of stimulation upon the secretion can also be studied. This procedure was later modified by Vella, who left both ends of the isolated piece of gut open and attached to the abdominal incision. A fistula obtained by the latter method is commonly called a Thiry-Vella fistula, and is the form now usually employed in experimental work.

Opportunity has also been taken by clinicians of studying the succus entericus in man, in cases in which accidental isolation of loops of gut has occurred.

A different method of observation was introduced by Hermann, who closed both ends of the isolated loop so as to form a ring and then restored it to the abdomen and examined it after several days had elapsed. Voit has also used a similar method, merely suturing the two ends of the loop up and then replacing in the abdomen. In both modes of experiment the continuity of the shortened gut is of course restored, as in making a Thiry-Vella fistula.

Such isolated loops left in the intestine for some days are found to be filled with a solid core of a yellowish-gray color, consisting of inspissated succus entericus and débris of intestinal cells; it also yields a large amount of ethereal extractives which probably are produced in the degenerative changes of the intestinal mucous membrane.

The succus entericus secreted into a Thiry-Vella fistula has frequently been described; it is a limpid, opalescent, light-yellow-colored fluid, of strongly alkaline reaction, and effervesces on the addition of acids. It contains coagulable proteid and mucin. It is yielded more abundantly by the lower part of the small intestine than by the upper, and it is stated that the more copious secretion of the lower end contains less mucin.

Human succus entericus has been investigated by Tubby and Manning, who obtained an average daily yield of 27 c.c. during a period of some months from a length of three and one-half inches of gut situated eight inches above the ileo-cæcal valve. This fluid was opalescent, brown in color, and strongly alkaline to litmus. It contained proteid, and did not reduce Fehling's solution, or give any color tests with iodine. The presence of lactates was shown by increase in color of very dilute ferric chloride solution and by a positive effect with Uffelmann's reagent.

It inverted both cane sugar and maltose, and had a certain amount of diastatic action upon starch. The inverting ferment present in the juice adhered mechanically to the mucin, which was often thrown out of solution.

All authors are agreed as to the presence of an inverting enzyme for disaccharides, but some deny a diastatic action on starch, and there is little doubt that the action here is much feebler than that of the absorbing intestinal cells. Thus Röhmann found that starch disappears from a Thiry-Vella fistula much more rapidly than could be accounted for by the feeble action of the succus entericus, and Brown and Heron state that the dried mucous membrane hydrolyzes starch much more rapidly than do clear watery infusions of the mucous membrane.

The conditions of secretion appear to vary in different animals; thus in the sheep, according to Pregl, secretion occurs continually, although it is augmented in the first two or three hours after a meal, while in dogs in which fistulæ have been established little secretion occurs except when the intestine is stimulated. The taking of food acts as a reflex stimulus, as do also mechanical or electrical stimuli when applied directly to the mucous membrane. The introduction of such substances as starch, sugar, or peptone also evokes a secretion. Certain drugs, such as pilocarpine, also cause a secretion.

If all the nervous connections of a loop of gut are severed, it has been shown that this becomes distended by secretion; but if the inferior ganglia of the solar plexus and their connections on the superior mesenteric artery are left in connection with the gut this paralytic secretion does not take place.

It has recently been shown that the succus entericus contains, in addition to the digestive enzymes above mentioned, others of a peculiar and interesting type.

Thus Cohnheim has shown that it contains an enzyme which he has named *erepsin*, which possesses the power of converting albumoses and peptones into amido-acids which no longer give the biuret reaction. The presence of this enzyme would appear to furnish a safeguard against the loading up of the organism by excess of digested proteids which could not be dealt with by the absorbing cells.

A still more interesting enzyme is that named *enterokinase* by its discoverer Pawlow.

It would appear from these researches that the greater part of the proteolytic enzyme of the pancreatic juice is discharged into the intestine in the inert form of trypsinogen, and that this enzyme, enterokinase, which is present in the succus entericus, possesses the power of converting the trypsinogen into trypsin.

The experimental basis for this view is that pancreatic juice alone is almost inert with regard to proteids, so also is succus entericus; but if the two fluids be mixed, an energetic action at once commences. This power of conferring activity upon the pancreatic juice is lost if the succus entericus has been previously boiled. Extracts of the intestinal mucous membrane also confer activity upon inactive pancreatic juice.

Benjamin Moore.

SUCRAMINE is a soluble ammonium salt of saccharin.

W. A. Bastedo.

SUET.—(*Sevum*, U. S. P.; *Sevum Præparatum* B. P.; *Sebum Ovile*, P. G.; *Suif de Mouton*, Codex Med.; mutton suet, mutton tallow. The Codex also recognizes the similar product of the ox, *Suif de Bœuf, Suif de Veau*, as well as the marrow, *Moelle de Bœuf*.) The part of the animal taken for suet is the same that yields the hardest and best lard, or beef tallow, namely, the thick mass of fat lying along the loins and surrounding the kidneys. The whole tissue is suet; the fat melted out and purified is tallow.

The preparation of suet is exceedingly simple, although not always carefully performed. It consists in first cleaning the suet from connective tissue, vessels, blood, etc., then cutting it in small pieces and washing in cold water, or allowing it to soak for a few hours in water; then it is boiled with a little water until the tissue is broken up, strained, and poured away to cool; the last portion of water is then removed by prolonged, moderate heat, which should not be allowed to rise above the boiling point of water. In the laboratory the steam kettles offer the most perfect means of "trying out" lard and tallow.

Mutton suet has no medicinal properties not common also to the other animal fats, excepting greater hardness, a higher melting point, and perhaps superior keeping qualities to most of them. It consists of the usual glycerin fats, *stearin, palmitin, olein*, etc., with the former in excess, and the latter at a minimum. The pharmacopœial description is as follows:

A white, solid fat, nearly inodorous, and having a bland taste when fresh, but becoming rancid on prolonged exposure to the air.

Insoluble in water or cold alcohol; soluble in forty-four parts of boiling alcohol, in about sixty parts of ether, and slowly in two parts of benzin. From its solution in the latter, kept in a stoppered flask, it slowly separates in a crystalline form on standing.

An alcoholic solution of suet is neutral or has only a slightly acid reaction to litmus paper moistened with alcohol.

Suet melts between 45° and 50° C. (113° and 122° F.), and congeals between 37° and 40° C. (98.6 and 104° F.).

Suet forms about one-fourth of mercurial ointment and one-half of tar ointment. It is also an extensively used domestic cerate.

Allied Substances.—Numerous fats of domestic and wild animals are in common household estimation for one purpose or another, with very little real difference from each other except in odor and hardness. Goose, chicken, and skunk oils are extensively used in country families all over New England. Something more distinctive, and having peculiar claims to attention, are the preparations of grease obtained from the wool of sheep, for which see *Lanolinum*.

W. P. Bolles.

SUGAR.—(*Cane Sugar, Saccharum*—$C_{12}H_{22}O_{11} = 341.2$, U. S., Ger., *Saccharum Purificatum*, Br., *Sucrose, Saccharose*.)

The refined sugar obtained from *Saccharum officinarum* L. and from various species or varieties of *Sorghum* (fam. *Gramineæ*); also from one or more varieties of *Beta vulgaris* L. (fam. *Chenopodiaceæ*).

Common sugar is one of a group of similar substances formed in plants and animals, distinguished by their sweetness, solubility in water and diluted alcohol, and insolubility in ether. Like starch, their function in the plant is nutritive. They represent carbohydrate nutriment, in a condition ready for use, as starch represents it in a condition for permanent storage, and they represent the latter substance in a transformed condition. Cane sugar is very widely distributed in the vegetable kingdom, being the variety generally characteristic of stems and roots. In a few plants the percentage is so large as to render the process of extraction and refining commercially profitable. The more important sources are as follows:

Saccharum officinarum L., the *sugar cane*, native of Southern Asia and cultivated in all tropical countries, is the most important. The yield of sugar from a good article is from fifteen to eighteen per cent. Comparatively recent operations in the development of new varieties from seed have resulted in the production of a much greater yield (up to nearly twenty-five per cent.), and the seedlings are in many cases far more vigorous and better capable of resisting disease than the old varieties, which were wholly the product of stem propagation.

Beta vulgaris L. (fam. *Chenopodiaceæ*) yields a number of varieties collectively known as *sugar beet*, which are especially rich in sugar, yielding upward of twelve per cent. For a long time the production of beet sugar was little more than an experiment, but recently the industry has made great strides and beet sugar has come to be a very formidable rival of that from the sugar cane.

Acer Saccharum Marsh. (*A. saccharinum* Wang,—non L.; *A. barbatum* Mich.), the *sugar* or *rock maple* of Eastern and Central North America, is next in importance to the above as a sugar producer in the United States. Maple sugar, as it is called, especially when somewhat imperfectly refined, possesses a peculiar flavor, aside from its sweetness, in which it differs from the other varieties of sugar here considered. This flavor, while not affecting its medicinal or pharmaceutical properties, renders it a great favorite with many persons for table use.

Sorghum sugar, formerly a very important article of domestic manufacture in the Central United States, has declined greatly in production, owing to the increasing cheapness of sugar cane and beet sugars. It is the product of *S. vulgare* Pers. (*Andropogon Sorghum* Brop.; *A. sativus* Hack.), of which there are many varieties. It is believed that broom-corn is merely a variety of the same plant. That which yields sugar is distinguished as *var. saccharatum* (L.) Gray. (*Holcus s.*—L.; *Andropogon s.*—Roxb.) This plant is often known as *Chinese sugar cane*. In tropical Asia and in other tropical countries considerable quantities of sugar are manufactured from *Saguerus Rumphii* Roxb. (*S. saccharifer* Bl.), often known as the *sugar palm*, from other species of palms and various other plants; but these products are rarely if ever articles of commerce in this country.

The official sugar is thus described:

White, dry, hard, distinctly crystalline granules, odorless, and having a purely sweet taste. Permanent in the air.

Soluble, at 15° C. (59° F.), in 0.5 part of water and in 175 parts of alcohol; in 0.2 part of boiling water and in 28 parts of boiling alcohol; also soluble in 80 parts of boiling, absolute alcohol, but insoluble in ether, chloroform, or carbon disulphide.

The aqueous solution, saturated at 15° C. (59° F.), has the specific gravity 1.345, and is miscible with water in all proportions.

The aqueous or alcoholic solution of sugar is neutral to litmus paper.

Both the aqueous and the alcoholic solution of sugar should be clear and transparent. When kept in large, well-closed, and completely filled bottles, the solutions should not deposit a sediment on prolonged standing (absence of *insoluble salts, ultramarine; Prussian blue*, etc.).

If 1 gm. of sugar be dissolved in 10 c.c. of boiling water, the solution mixed with four or five drops of silver nitrate T.S., then about 2 c.c. of ammonia water added, and the liquid quickly brought to the boiling point, not more than a slight coloration, but no black precipitate, should appear in the liquid after standing at rest for five minutes (absence of *grape-sugar*, or of more than a slight amount of *inverted sugar*).

PREPARATION.—The essential features of the manufacture of sugar are the rapid expression of the juice, the separation of impurities by various methods, partly mechanical and partly by precipitation, the evaporation of the water by boiling, the separation of the mother liquor or molasses (described below) and the crude sugar, and the refining and crystallization of the latter. These several processes may be performed by various methods. Although such modifications are frequently very slight, from a theoretical standpoint some of those of modern introduction are of so great an economic importance that they have completely revolutionized the industry, and their introduction into certain countries and not into others has even resulted in the complete ruin of the industry in the latter places. One of the most important of these series of modifications consists in the better use of lime or other alkalies for the purpose of neutralizing the acids present, which, under the influence of the heat in boiling, were formerly responsible for heavy losses in the yield of sugar through its conversion into invert sugar.

The large number of commercial varieties of refined sugar, depending as they do chiefly upon the degree of purification, the form and size of the crystals and of the fragments, the processes of powdering, coloring, and so on, are merely incidental and without pharmaceutical or medicinal interest. There are, however, certain of the sugar products which differ enough from ordinary crystallized sugar to be worthy of mention.

Barley sugar (*Saccharum hordeatum*) is sugar brought into the condition of a transparent, non-crystalline, yellowish body, as a result of melting and cooling. In this condition its taste is markedly different from that of the crystalline substance.

Caramel is an empyreumatic product made by keeping sugar at a temperature of 180° to 200° C. (356° to 392° F.) until it turns brown and loses two molecules of water. Caramel possesses a peculiar odor and taste, as well as a brown color, and is chiefly used for coloring purposes. It can, however, be decolorized, this product having been named *caramelan*.

Invert sugar is produced from ordinary sugar by various methods, most readily through the action of dilute acids under the influence of heat. It can also take place as a result of the prolonged action of heat alone upon a mixture of sugar and water. Invert sugar is a mixture of the two products dextrose and levulose, the latter not being capable of crystallization.

Rock candy is a very pure form of sugar, made to form in very large crystals.

The behavior of sugar under the action of certain ferments will be found considered under alcohol. Other changes produced in it are considered under the subject of digestion.

ACTION AND USE.—Sugar has been known from a very remote period in India, where the cane has been used as food from prehistoric times. It found its way into Europe about the beginning of the Christian era, probably as a natural exudation, like manna, from the wounded canes. It was originally an expensive rarity in Europe and used only as a medicine or luxury. Its general use there as a food dates back only two or three hundred years. Even at the present time, its consumption as a food is continually increasing upon a vast scale, partly because of the extension of its uses for preserving purposes, but chiefly on account of the continued cheapening of its price. It has no medicinal importance except for its slight expectorant properties (see below, under *Molasses*). Certain morbid conditions induced by its excessive or improper use are very general. Undoubtedly the human race would be far better off, so far as health is concerned, if the use of pure glucose could be generally substituted for that of cane sugar.

In pharmacy, the uses of sugar are varied, extensive, and highly important. As a preserver of some unstable chemicals, like iodide and suboxide of iron, fruit juices, and other perishable vegetable and animal products, it is invaluable. Mixed with water, it becomes a preservative solvent for many drugs, though if its strength be too greatly reduced it becomes readily fermentable. Its consistence frequently gives required body to preparations, and its taste is of the greatest value in many of its uses as an adjuvant. Finally, it is of great use as a coating for pills.

The only official preparation of sugar itself is *Simple Syrup* (*Syrupus*, U. S. P.), made by dissolving 850 gm. of coarsely powdered sugar in enough distilled water to make 1,000 c.c. It may also be made by the percolation of distilled water through sugar. Other official and unofficial syrups are to be regarded rather as syrupy preparations of the drugs themselves than as preparations of sugar.

Other Sugars.—Other kinds of sugar, animal and vegetable, will be found described in this work under the titles *Glucose*, *Honey*, *Manna*, *Milk*, *Sugar of*, as well as in connection with the liver, diabetes, etc.

Molasses or *treacle* is the mother liquor remaining after the separation of all the sugar which can be caused to crystallize after the boiling down of the prepared juice of the plant. The varying color, odor, flavor, and consistence of different varieties and grades of molasses depend partly upon the amount of sugar left in it, the degree of refinement and cleanliness observed in its preparation, and more or less purification to which it may be subjected. The practice prevails very largely at the present time of making molasses out of glucose, the latter chiefly manufactured from Indian corn, or of adding such glucose to natural molasses. Syrup, sugar-house syrup, or crystal drips, is a product of the final draining to which refined sugar is subjected.

In the household, the different varieties of molasses are credited with important and varied medicinal properties. Doubtless molasses or syrup has quite an important action in relieving an irritable cough, and many of the popular proprietary cough syrups probably owe the most of whatever value they possess to the influence of the syrup which they contain. *Henry H. Rusby.*

SUGARINE, methyl-benzoyl-sulfimid, methyl saccharine, is a compound said to have five hundred times the sweetening power of sugar. *W. A. Bastedo.*

SUGGILLATION (more properly *sugillation*, from *sugillare*, to beat black and blue).—In the older literature this term is used to designate superficial areas of discoloration, as black and blue spots, ecchymoses, hyperæmic spots, livid marks or patches, or various spots occurring in the skin in different diseases. The patches of discoloration in the skin of the cadaver due to post-mortem hypostasis or incipient putrefaction were likewise termed suggillations (*sugillatio*). More recently, through the influence of the German school, the term has come to be applied to hemorrhages into or beneath the tissues, of a larger size than ecchymoses; and with this usage there is also conveyed the idea of a *suffusion* of the tissues with blood. The term is, therefore, used interchangeably with *bloody suffusion*, and is applied to more or less flattened, diffuse swellings of the skin due to hemorrhage into the subcutaneous tissues, or to similar hemorrhages occurring in other loose tissues. A suggillation is distinguished from a hæmatoma by the fact that in the former the tissues are infiltrated with blood but not torn apart so as to form a distinct cavity filled with blood. Suggillations are usually due to direct trauma, but occur in cases of both congenital and acquired hæmophilia. In the latter case they may result from the changes produced in the blood-vessel walls through intoxication or infection. Suggillations of the skin may take place in pernicious anæmia, leukæmia, sepsis, chronic icterus, and in the hemorrhagic forms of the acute infections. In typhoid fever suggillations of the abdominal recti may occur as the result of extensive parenchymatous changes (Zenker's necrosis) in the muscle. The sequelæ of suggillation are similar to those of hæmatoma—absorption, organization, or cyst formation. *Aldred Scott Warthin.*

SUICIDE.—The term suicide, to express the act of self-destruction, was probably first employed by Desfontains in the last century. It is derived from the Latin words *sui* (self) and *cædere* (to kill). (Synonyms: Fr., *Suicide;* Ger., *Selbstmord;* It., *Suicidio;* Legal, *Felo de se.* Other rarely employed terms are: Gr., *αὐτοχειρία*; and Lat., *Propriicidium.*)

Suicide is a voluntary human act of self-destruction, and it is claimed by some writers that the act is always due to some disorder of the mind at the moment of its accomplishment.

History.—From the earliest times of which we have record the custom of self-destruction has existed to a greater or less degree, and it would appear that the peoples of antiquity were so taught by their religion that they could look upon the act as logical, and perform it with stoicism.

The religion of Brahma justifies suicide, and looks upon it, under certain conditions, as an honorable and praiseworthy act, which is often solemnized in a public manner. Fanatics in India, who believe in the transmigration of souls, seek an improvement in their condition and a freedom from present ills by courting death. The Brahmins have in a great measure given up their terrible custom of prostrating themselves before the car of their gigantic idol Juggernaut, to be crushed to death. Still they occasionally do it, and the women throw themselves upon the funeral pyres of their husbands.

Although held in honor among the people of the Orient, it was always rare in Persia, and is an exceptional occurrence among the Turks. The teachings of the Koran are opposed to it. Mohammed forbade it, and inculcated a spirit of patience in adversity. Here, too, the belief in fatalism probably exercised a marked influence, and the people were not given to philosophic thought, as were those of Greece, where many great men have sought death at their own hands.

When circumstances warranted the act, it was considered, in ancient Greece, a virtue for men to destroy themselves, thus escaping human ills, and, as they supposed, ameliorating their condition.

According to Legoyt,[1] Strabo relates as an historical fact that the inhabitants of the Isle of Ceos, in the Grecian Archipelago, poisoned themselves after reaching the age of sixty, so that the younger could have greater abundance; and Montaigne says that the senate of Marseilles, which then belonged to Greece, placed poison at the disposition of those who wished to commit suicide, when their motives were approved of.

The Hebrews, it would appear, scarcely knew suicide, and few cases are recorded. The Bible gives accounts of the self-destruction of Samson, Eleazar, Saul, Judas, and others.

The Celts were taught the immortality of the soul and their divine origin; still, suicide for the old and infirm was encouraged.

At Rome we find many noted suicides recorded, including that of Junius Brutus, and under the reign of Tiberius they appear to have increased in frequency. From the fifth to the twelfth centuries suicide almost wholly disappeared, but in the next century revolutionary ideas prevailed, and the previous influence of the Christian religion was so far lost that all classes of society suffered from a revival of suicide. Jews now resorted to it freely as a means of escape from hardships and to avoid disloyalty to their faith.

A decided increase is noted from the beginning of the sixteenth century, due to a disregard for religion and a revival of customs of antiquity.

In China and Japan men of honor have long resorted to self-inflicted death.

In Africa it was not rare for individuals and whole bodies of men to commit suicide, and Carthaginian generals often destroyed themselves after defeat.

The increase of suicide in civilized countries during the present century is shown by carefully gathered statistics, and conceded by most writers.

Statistics of suicide began to be systematically collected and studied only in the last century, official statistics being published in several European countries during the first twenty years of the century.

In Captain Graunt's "Bills of Mortality," published in 1665, it appears that 222 persons "hanged or made away with themselves" in the twenty years 1629–38 and 1647–58. This number, however, does not probably represent all the suicides, since there were probably a considerable number among the 827 registered as drowned, 243 found dead in the streets, and 14 poisoned. He estimated the population of London at that time as about 460,000.[26]

The following figures from the registrar-general's report for 1900 show that the suicide rate in England is increasing with a comparative degree of regularity:[3]

Suicides per Million Living, England and Wales, in Five-Year Periods.

	Rate per million.		Rate per million.
1861–1865	65.2	1881–1885	74.8
1866–1870	66.4	1886–1890	79.4
1871–1875	66.0	1891–1895	88.6
1876–1880	73.6	1896–1900	89.2

The following table presents the death rates from suicide per million inhabitants in the principal countries of Europe, and a few other countries, and in the six New England States:

Death Rates from Suicide in Different Countries per Million Inhabitants, 1880–1886; 1887–1893; and for the Single Year 1894.

Countries.	Estimated population in 1894.	Deaths from Suicide per Million Inhabitants.		
		1880–1886.	1887–1893.	1894.
Italy	30,818,248	47	54	56
France	38,133,385	196	227	?
England and Wales	30,060,763	76	82	91
Scotland	4,063,959	54	57	62
Ireland	4,600,599	22	25	30
German Empire	48,681,503	248	206	217
Bavaria	5,740,059	134	130	136
Saxony	3,703,600	375	324	312
Austria	24,549,193	164	161	‡ 154
Switzerland	3,006,886	237	219	235
Belgium	6,341,958	106	125	132
Holland	4,764,279	52	59	69

DEATH RATES FROM SUICIDE.—*Continued.*

Countries.	Estimated population in 1894.	Deaths from Suicide per Million Inhabitants. 1880-1886.	1887-1893.	1894.
Sweden	4,873,183	98	125	158
Norway	2,030,000	67	64	70
Denmark	2,259,500	256	251	255
Russia (Europe)	91,248,465	31	31	31
Poland	9,152,830	23	24	24
Spain	17,247,738	29	21	?
Uruguay	776,314	43	64	?
Argentine Republic	4,750,000	13	19	?
Japan	41,810,202	159	162	?
New England States.				1894-1900.
Massachusetts	2,445,604	87	96	116
Rhode Island	378,726	72	68	105
Vermont	336,910	91	81	90
Connecticut	811,100	* 106	128	116
New Hampshire	390,555	* 88	98	101
Maine	674,450	....	† 88	§ 99

* 1883-1886, four years only. † 1892-1893, two years only.
‡ 1896. § 1894-1899.

By the foregoing table it appears that suicides have increased in the greater number of countries shown in the table, but the length of time cannot be deemed to be sufficient to make the figures conclusive.[4, 15]

F. L. Hoffmann, in a study of the subject, found that the rate had increased, in fifty cities of the United States, from 120 per 1,000,000 in 1890 to 166 in 1901.[5]

The rate differs in these cities from a maximum of 499 per 1,000,000 in San Francisco to 29 in Fall River.[6]

The following list presents the suicide rates per million inhabitants in the year 1900 for cities having a population of more than 200,000:

Cities.	Suicides per million in 1900.	Cities.	Suicides per million in 1900.
New York	221	Pittsburg	121
Chicago	210	New Orleans	139
Philadelphia	114	Detroit	119
St. Louis	226	Milwaukee	207
Boston	135	Washington, D. C.	104
Baltimore	122	Newark	191
Cleveland	149	Jersey City	165
Buffalo	113	Louisville	98
San Francisco	499	Minneapolis	99
Cincinnati	135		

The following table presents the suicides for London, Berlin, Paris, Vienna, and Budapest:

Cities.	1895.	1896.	1897.	1898.	1899.	Annual average per million population.
London [3]	483	425	451	436	485	102
Berlin [23]	446	494	495	462	457	268
Paris [24]	1,030	941	1,004	906	788	372
Vienna [25]	427	429	440	450	463	284
Budapest [26]	227	196	260	261	....	375

According to the London *Lancet*, the number of suicides in France during 1876 was 5,617. Of these, 4,435 were men.

Morselli believes in a law of continual increase, and shows by a table that the increase per cent., from 1827 to 1852, was from 100 to 238.[2]

It is shown by one of his tables that Saxony, which furnishes the largest number of suicides, has suffered an increase from 158 per 1,000,000 inhabitants in 1836-40, to 391 per 1,000,000 in 1877, but the rate had decreased to 312 per 1,000,000 in 1894.

Another table prepared from the statistics of Italy, from 1864 to 1877, shows an increase from 29.2 to 40.6 per 1,000,000, and these had also increased to 65 per 1,000,000 in 1898.

The suicides in Italy were as follows for the five years 1894-98:[22]

Year.	Number.	Per million inhabitants.
1894	1,732	55
1895	1,874	60
1896	2,000	63
1897	1,895	60
1898	2,059	64

The highest rate was that of Liguria, 126 per 1,000,000 in 1898; and the lowest was that of Calabria, 12 per 1,000,000 in 1897.

In the German empire the suicides in the four years 1896-99 were as follows: 1896, 10,484; 1897, 10,692; 1898, 10,559; 1899, 10,418. These were equivalent to an average annual rate of 201 per 1,000,000 inhabitants.[9]

From these and other data the following law is formulated:

"In the aggregate of the civilized states of Europe and America, the frequency of suicide shows a growing and uniform increase, so that generally voluntary death since the beginning of the century has increased, and goes on increasing more rapidly than the geometrical augmentation of the population and of the general mortality."

In the combined central and southwestern states and provinces belonging to Prussia the proportion of 150 suicides in the million is given. Morselli says:

"The synthetic and most certain law which springs out of these facts is that in the centre of Europe, from the northeast of France to the eastern borders of Germany, a *suicidigenous* area exists, where suicide reaches the maximum of its intensity, and around which it takes a decreasing ratio to the limits of the Northern and Southern States."

NATURE.—The question of the nature of the act of self-destruction is a difficult and a delicate one withal to decide, but its great importance calls for much careful attention. Morselli says suicide is a social fact, and its nature "may now be reckoned among the most certain and valuable discoveries of experimental psychology"; and, further on, characterizes it as "an effect of the struggling for existence and of human selection, which works according to the laws of evolution among civilized people." But the question arises, is a given suicide, at the moment the act is committed, in the full and free possession of his faculties, and should he be held responsible for his movements? If the act be always due to a morbid condition of mind (as claimed by Dr. Liebman, in a paper read before the Medical and Chirurgical Faculty of Maryland, April, 1881), it should not be punishable as a crime; nor would, in this event, the punishment carry with it the intended restraining influence upon other would-be suicides. The mind which could conceive and plan so foul a deed would not, in all likelihood, be influenced by the thought of legal punishment in case of an unsuccessful attempt.

Insanity is probably present in the vast majority of suicidal attempts, and the number of those who act calmly and in the possession of their faculties must be much smaller than is generally supposed. Many obscure cases are difficult to explain on any other theory. There is a want of motive. The surroundings and station in life of the suicide are the best, and so far as can be learned, the social, financial, domestic, and other relations are only such as would be conducive to life and happiness. Such cases are more common in so-called epidemics of suicide. If the attempt has not resulted in death, evidences of insanity often soon appear, and make it clear that mental irresponsibility existed at the time.

In other cases insanity may have been previously known or suspected from conditions present, either immediately preceding the act or at some more remote period, and still no decided symptoms may have shown themselves until after an attempt at suicide.

An hereditary mental defect may have been known to exist, the person regarded as eccentric, and the attempt not unlooked for.

Organic disease, excesses, venery, onanism, etc., may have been the cause of a mental aberration whose first outward sign has been the suicidal attempt.

Hammond says:[10] "Closely allied to emotional homicidal impulse is that form of mental derangement which consists in an *emotional impulse to the perpetration of suicide*. The conditions may coexist. In some cases the contemplation of the act is attended with feelings of pleasure. He is neither governed by delusions nor by logical reasons. He is actuated by a passion which it is pleasant for him to gratify. When the impulse has passed, he looks back upon it with horror, and, shuddering at the escape he has made, perhaps seeks medical advice."

Automatic suicide, or suicide by impulse, is closely allied to that of the insane, and, like it, occurs without apparent cause—the sight of a weapon, the finding of one's self upon a height or by the river's side, or favorably situated for the accomplishment of the act, being sufficient for the attempt. In non-success the circumstances of the act are more or less confused in the suicide's mind, and the only safety for those thus impelled is to hasten from the scene. Some persons, appearing to be conscious of this outward influence, avoid suggestive situations, and, feeling themselves powerless to resist, ask that precautions be taken to prevent the act.

Suicide by suggestion is well illustrated in a personal experience of Sir Charles Bell, when surgeon of the Middlesex Hospital, which is related by Wynter.[11] While being shaved, he told his barber of an operation he had just performed on a man who had made an unsuccessful attempt to cut his throat, and explained the anatomical reasons for the failure. The barber, excusing himself, went into an adjoining room, and was found a few moments later with his throat cut in the proper anatomical situation to assure success.

Epidemic suicide, due to a neuropathic state of the system of those living under the same influences, is well known to neurologists, and many instances have been observed. An epidemic among the women of Miletus is recorded, at a time when the men were away at war, which reached great proportions and was checked by a decree that the naked bodies of those who killed themselves should be exposed in public with a rope about the neck. In Mexico and Peru the inhabitants killed themselves in great numbers, it is said, after the invasion by Spain. Mansfeld had an epidemic in 1697, according to Sydenham. There was one at Versailles in 1793, and one occurred at Rouen in 1806, and at Stuttgart in 1811.

Some years ago five inmates of the Hôtel des Invalides, in Paris, hanged themselves upon the same crossbar within a fortnight.

Double and *multiple* suicides are occasionally recorded. The former usually consisting in the simultaneous death of man and wife, or two lovers or friends; the latter in the concordance of suicide of bodies of men, such as is said to have occurred in China among the philosophers of the Confucius school, when deprived of their books by the order of the emperor Chi-Koang-Ti.

Feigned Suicide.—Although the term is not a strictly proper one, it applies to those cases occasionally met with in which, to excite sympathy, secure desired ends, afflict friends, or for some other reason, a person makes it appear that he has made an attempt upon his own life.

Child suicide requires special notice, since young children, even as young as five years, have been known to commit suicide for trifling cause, following impulse and sentiment without having the restraining influence of mature judgment and the power of comparison and thought for anything beyond the present.

By nature children are sensitive to slights and injustice, easily depressed, fretful under restraint, and at times revengeful. They have vivid imaginations, are quick to imitate, but are defective in the power to reflect and form just conclusions. The sense of responsibility is wanting, so that no sooner is the act conceived than it is put into execution.

The belief of Durand Fardel,[12] that the act of self-destruction is usually accomplished with much self-possession and after reflection, cannot apply to suicides in childhood (see, also, under *Age*).

Suicide following homicide is not very uncommon, but the subject is almost always melancholic. Esquirol tells of a Belgian woman who threw her four children into a well and jumped in after them. Both sexes include their children in the death they give themselves, but women would appear more inclined to this than men. In rare cases both parents conspire to kill their children and then themselves; such a case is related by Esquirol, and one has recently occurred in Paris.

CAUSES OF SUICIDE.—In former times, and indeed at the present day in some countries, as we have seen, whole masses of people, as well as individuals, under the influence of their religious or philosophic beliefs, and following the customs of their forefathers for generations, have in great numbers become the subjects of self-destruction. No such custom is to be found to-day in any civilized country, but efforts to do away with it in India have failed, and we must put down fanaticism as one cause of many self inflicted deaths. No encouragement is given to the act in enlightened lands, but, on the contrary, laws, both human and divine, are strict in forbidding it. Still, suicides have been shown by careful students of the subject to be on the increase, and we naturally inquire what are the causes which contribute to this state of affairs, and why do men take their own lives at all.

The causes are twofold: A subjective condition may exist which predisposes the individual to the act, or his environment may be such as to produce an objective state favorable to suicide. The pathological or other subjective condition may coexist with the surroundings which furnish the determining cause, or the one or the other may be wanting.

Predisposing causes to suicide are quite numerous, but heredity is one of the most important. The transmission of a suicidal tendency is an established fact of which many instances are known to alienists, and which forms a familiar phase of the practice of the family physician.

This transmitted tendency may lie dormant, or make its presence suspected by the development of mental disease; or the suicide may have been looked upon for years as one about whom there was "something strange," without any actual disease or decided symptoms of nerve or mental trouble being apparent.

The offspring of a suicidal parent appears to inherit a system favorable to the development of nervous affections leading to self-destruction, and a decided tendency appears to exist to commit the act at about the same age at which the parent died, and to use the same means; showing that the hereditary disposition is attended with a certain uniformity of action.

Education would appear to predispose to suicide, for it has been conclusively shown that more attempts occur in centres of civilization, among the best educated classes, and in cities where, through the press, pulpit, and stage, as well as through educational institutions proper, the masses of the people are better informed than those in the country, and, as a rule, have more active minds; but in whom the conditions of life are more apt to favor a spirit of discontent. Among savages suicide is comparatively rare. Among the whites in the United States, according to the census of 1900, the suicides were 5,340 as compared with 149 among the negroes, the actual death rate from this cause being about five times as great among the whites as among the colored.[13]

Occupation appears to have a predisposing influence. Thus the trades in which the greatest number of suicides occur are shown to be those of tailors, seamstresses, laundresses, jewellers, carpenters, cooks, etc. The hardships of life attending many of these occupations may account for the number of deaths.

Wine merchants and innkeepers make large contributions to the number of suicides, because their occupation tends to induce excess in the use of alcohol.

The liberal professions furnish about one-fifth of the total number of suicides; physicians, chemists, and druggists give a high percentage, and their occupations may be said to predispose to it by bringing them into such constant and intimate relations with poisons.

The stringency of military discipline in Germany, France, and Austria has been advanced as a reason for the high death rate from suicide in these countries.

Morselli finds the greatest number of suicides among (1) literary and scientific men, or brain-workers generally, professors, teachers, etc.; (2) the military; (3) workers in the trades.

According to Legoyt (1856–60), the middle classes and outcasts furnish the greatest number in France, and the same is found by Block to hold true (p. 251).

The condition of life has its influence as well, and those living solitary lives, as widowers, bachelors, divorced women, etc., are more prone to the act. By the census of 1900 it appears that there were in that year 1,620 suicides among single persons, 2,832 among the married, 560 who were widowed, and 41 who had been divorced.[13]

Religious Belief.—From a large collection of cases in Germany and Austria it appears that the suicide rate among Catholics was 51.3 per 1,000,000 living, among Protestants it was 79.5 per 1,000,000, and among Jews only 20.7 per 1,000,000.[14]

Climate and temperature in many instances undoubtedly contribute their share, but the attempts to regard them as the main cause of a high percentage of suicides in some countries have not been eminently successful. The cold, rain, and fog of England have, by various writers, been regarded as conducive to self-destruction. Thus, Montesquieu said, "England is the classic land of suicide"; but in Wynter we read ("The Borderland of Insanity," 1875), "Paris is the headquarters of self-destruction."

Putting aside the compliments that may be passed between these two countries, we must remember that the Esquimaux and Falkland Islanders, whose climate is incomparably more severe than that of either of these countries, do not kill themselves.

The influence of climate is, on the whole, not marked, but excessive heat has been known to drive men to frenzy and self-destruction. Long since it was pointed out that the hot and dry wind of the African sirocco caused delirium, madness, and many suicides.

Seasons.—In most countries the maximum of suicides is reached in May and June, when nature would seem to be most conducive to life. In Saxony and Bavaria, however, July is the favorite month.

Authorities agree that insanity increases in the summer time, and this may explain, as Wagner thought, the greater number of suicides. Leffingwell presents a table in which he shows that for the ten years (1878–87) the suicides in the warm months (April–September) constituted sixty per cent. of the whole number, and those in the cold months were forty per cent. A similar table for Japan for the years 1882–85 gave the same result.[15]

Sex.—In a general way, the average of female suicides for the United States is given as from fifteen to thirty per cent. of the whole number. In 1900, according to the United States census, suicides of women constituted 21.5 per cent. of the whole number of suicides in the United States.[13] Liebman says three men kill themselves to every woman.

The proportion of women is given for Germany as under, and for England as over, twenty per cent. As accounting for this excess of male suicides it has been advanced that women have less energy, less resolution, are more governed by religious teachings, etc. The suicides of males in England were 101 per 1,000,000 in 1875 and had increased to 137 per 1,000,000 in 1899, while those of females were 34 per 1,000,000 in 1875 and had increased to 44 per 1,000,000 in 1899.[7]

Age.—Considerable regularity is shown, in each country, in the number of suicides at each age-period of life. From Ogle's table, as well as from those of Morselli, it is seen that, from the tenth year on, the number of cases rises steadily to between the ages of fifty five and sixty-five years; remains almost stationary to about seventy-five, and then decreases rapidly. It is rare before fifteen, but, excepting the very young, it is common to all periods of life.

The period from the twentieth to the fiftieth year has the most instances, for it is then that men pass through the most serious portion of their lives. It is then they are engaged in the battle for existence, require more comforts, and have most care and responsibility.

According to Ogle, 1 out of every 119 men who reach the age of twenty ultimately dies by his own hand, and 1 out of every 312 women who have reached the age of fifteen.

Attempts upon their own lives have been made by children at as early an age as five years. Durand Fardel found one under five, and two between eight and nine. Out of 25,760 suicides in France occurring from 1835 to 1844, he found 192 to be in persons under the age of sixteen.

According to the census of 1900 the suicides in the United States in that year occurred as follows:[13]

Ages.	Suicides.	Ages.	Suicides.
5 to 9	1	50 to 54	490
10 to 14	28	55 to 59	371
15 to 19	246	60 to 64	314
20 to 24	531	65 to 69	253
25 to 29	534	70 to 74	175
30 to 34	555	75 to 79	117
35 to 39	594	80 to 84	49
40 to 44	600	85 to 89	14
45 to 49	542	90 and over	5

The suicides in the German Empire by ages were as follows in 1892:[28] Under 15 years, 7 per 1,000,000 living at that age; from 15 to 60 years, 280 per 1,000,000; over 60 years, 510 per 1,000,000.

Collineau[16] relates the case of a boy ten years of age who, "to make his parents angry," hanged himself on being sent back to school.

Winslow[17] reports several cases at an early age, and quotes Casper to the effect that in Berlin, from 1812 to 1821, 31 children, twelve years of age and under, committed suicide for trifling causes. Many cases at this early age appear to be similar to the emotional susceptibility of adult life.

Suicide is an act which springs from a brain constantly influenced by conditions present within the body, as well as by those of the external world, many of which we have considered as predisposing causes.

Determining Causes.—Insanity with suicidal tendency is quite a common form of mental disease. It is not proposed to enter upon a consideration of the various forms of insanity in which this tendency is present. We may find it as a monomania, or associated with a homicidal mania.

It is often by suicide that the melancholic rids himself of his imaginary woes, and the maniac escapes from the imaginary foes with which his hallucinations surround him.

There are those who claim that the act of suicide is of itself an evidence of insanity. In the maniac there is no planning, and no precautions are taken; violence is characteristic of the act, and it is as a rule accomplished quickly. Should it fail, there is a knowledge and recollection of the details. Death may accidentally result from the attempts of the maniac to escape from hallucinations or in his efforts to free himself from restraint. This should not, properly speaking, be termed suicide, for although it is self-destruction, there is no intention or motive, and the term, as commonly used, implies a purpose.

In some insane persons there is an ever-present hallucination attended with a morbid sadness, and the act of suicide is deliberately planned and, with much precaution and calmness, carried into execution; or, if not at once successful, it will be persisted in until it is.

There is a form of anxious melancholy in which, without any cause, either real or imagined, there is, as it were an instinctive but violent desire to die; so strong, indeed, is it, that no will-power seems capable of overcoming it. The previous anxiety is lost when all preparations are made and the desired end appears near, and this sudden change to cheerfulness may give friends and attendants the cue to watch for the attempt.

As a rule, determined and deliberate attempts at suicide, with details carefully planned, indicate an unsound mind. When the attempt has failed to cause death, it is often found that insanity soon appears. In other cases the attempt itself relieves the condition which caused it, and death is no longer desired.

The flow of blood from a razor wound, Hammond says, may relieve the cerebral congestion present. In the same way, a plunge into the cold water may result in bringing the would-be suicide to a realizing sense of his desire for life rather than for death.

Others, to assure success, may tie their own hands and feet together before making the plunge, and may even attach weights to themselves, as in the recent case of a young actor who, before plunging into the Charles River, in Boston, put on a heavy coat of mail; and of a man who jumped from a Brooklyn ferryboat with lead-pipe wound round and round the body. The possible occurrence of such cases must be remembered in medicolegal and coroner's investigations, and not be mistaken for cases of murder. Financial ruin, famine, and pestilence following in the train of wars, etc., have often resulted in great numbers of suicides, the nervous system being over-excited.

Disease, as an inciting cause of the suicidal act, is not uncommon. The body, worn out with suffering, at last affects the mind, or the patient, believing his disease incurable, prefers to make an end of all his woes, and "fly to others which we know not of."

Statistics for Italy and France show that those affected with pellagra furnish a large percentage of suicides. Other diseases in which suicide appears to be common are those of the digestive organs, liver, etc., cancer, urinary diseases, phthisis, loss of sight, and chronic affections generally; after castration it appears also to be frequent. Suicides through physical suffering attain their maximum in the educated and cultivated classes.

Financial troubles cause the highest percentage among the working classes, though self-destruction is often seen after reverses of fortune, losses in gambling, and financial embarrassment in the wealthy.

Alcohol is a potent cause of self-inflicted death; drunkenness, poverty, and laziness going hand in hand. In the three years 1888–90, in Massachusetts, 93 suicides out of a total of 485, or 19 per cent., were due to intemperance.[18]

Passions.—Love, betrayed or disappointed, and jealousy are found to be a fruitful cause of suicide among students, soldiers, schoolmistresses, and servants. Explosions of rage and anger are apt to gradually increase and overcome the will power to resist, until trivial circumstances will occasion violent outbursts, and may lead to violent acts against one's self. Hate, pride, shame, and revenge may all lead to suicide.

Other determining causes often found are domestic troubles, remorse, dishonor (as in women pregnant out of marriage), poverty, misfortune, grief, pain, and disappointment.

Occasionally regret is experienced before the act has been fully accomplished.

METHOD.—The method of securing death, and the place or scene of its execution, are influenced by the surroundings of the individual and the natural facilities afforded; but the supposition advanced by Esquirol, that the occupation governed the choice of instrument, is not always borne out by statistics. Still, it is found that the choice of the soldier falls, as if in theory it naturally would, upon firearms. Butchers, barbers, and shoemakers resort mostly to the knife. The favorite method varies in different countries, and although in a given locality or city the prevailing custom may change from time to time, there is a pretty constant preference for one fixed form from year to year. De Guerry[19] was the first to show a regularity in the method employed.

The rope appears to be the most common choice, second comes the water, firearms third, cutting instruments fourth, then follow jumping from a height, taking of poisons, inhalation of deadly fumes, etc.

There are two factors which, as a rule, influence the choice of the means, viz., certainty and quickness of action. Women are not so apt as men to make choice of a painless method.

There is also a difference in the means employed by women from those resorted to by men. In Italy, for example, the men shoot themselves, and women resort to the water when weary of life; while in Prussia over half the suicides die by hanging, and women surpass the men in their tendency to kill themselves by the knife.

Out of 2,896 suicides which occurred in England in 1900, 102 were upon railways, 690 were by gunshot wounds, throat-cutting, etc.; 10 by burns and explosions, 454 by poisons, 695 by drowning, 792 by hanging, 68 by jumping from a height, and 84 by other methods.

The poisons preferred were in the following order: Carbolic acid, 134; preparations of opium, 69; oxalic acid, 47; hydrochloric acid, 42; prussic acid, 36; strychnine, 17; cyanide of potassium, 16; phosphorus, 8.[3]

In Massachusetts suicides by the use of arsenic had increased from 2 in 1878 to 35 in 1887, but had again fallen off to 9 in 1899 and 6 in 1900.[15]

Poison, as a choice, appears to be increasing in favor in this country, and to be on the decline in France; in fact, the favor it receives among Anglo-Saxon suicides is shown to reach 40.8 per cent., including this country. Out of 148 cases of suicide occurring in New York in the year 1876, poison was used in 31.7 per cent., firearms in 33.1; hanging gave 13.5; cutting wounds, 10.8; drowning, 6.8; falls from height, 3.4; and other means, 0.7; thus showing that poison and firearms were the choice, each in about one-third of the cases. This predilection on the part of the English and Irish for poisons is further shown by the following table, taken from Morselli, and giving the suicides among foreigners in New York for the year 1876:

Per 100.	English.	French.	Germans.	Irish.
Poisoning	46.1	25.0	28.9	52.4
Hanging	....	12.5	17.4	4.8
Asphyxia and drowning	....	....	5.7	9.6
Gunshot wounds	15.4	50.0	35.0	4.8
Cutting and stabbing	30.8	....	7.2	9.5
Falls from height	7.7	12.5	5.8	18.9
Total	100.0	100.0	100.0	100.0

The following were the methods employed by suicides in Paris for the five years 1895–99:[24]

Poison	192	Cutting instruments	69
Asphyxia	1,075	Jumping from a height	265
Strangulation (hanging)	1,310	Crushing, railroad	19
Drowning	988	Other modes	4
Firearms	747		

The following figures show the methods adopted in the United States in 1900 (United States Census):

	Males.	Females.
Shooting	1,190	103
Drowning	157	84
Poison	761	464
Other methods	2,205	534
Total	4,313	1,185

The methods employed at different ages present striking differences, according to the United States Census of 1900, where it appears that at ages 15–24, 168 females and only 95 males committed suicide by poison, while at ages 50–59, 184 males suicided by shooting, and only 7 females.[13]

Drowning as a means decreases as the north is approached; the colder the water, the fewer its attractions.

Devergie found that in Paris, from 1827 to 1836, drowning, together with asphyxia by charcoal fumes, held the second place, but in 1851 Trébuchet placed asphyxia at the head of the list. This latter mode of death has spread rapidly over Europe and increased in fashion in Paris. The reasons for this are that it affords the most painless and agreeable form of death, and, strange as it may appear, man's vanity extends beyond the gates of death, and the suicide desires the body to present a good appearance after the breath has left it, and knows that there is usually no disfigurement from charcoal fumes.

The introduction of a new and easy method of committing suicide affects the numbers by different methods. Previous to 1890 the extremely poisonous agent, water gas, was excluded from Massachusetts by law. After the repeal of this law in 1890, its use became free and unrestricted, and the suicides by gas poisoning increased from a total of 5 out of 915 by all methods in the five years 1886–90, or 0.55 per cent., to a total of 116 out of 1,575 by all methods, or 7.4 per cent., in the five years 1896–1900, an increase of nearly fifteenfold.[18]

Only the other day the papers contained an account of a "wholesale charcoaling," in which a father, mother, and two children sought death in this way, preferring this mode of death to starvation. When heredity is a factor in the case, the method of exit from the world is apt to be the same as that employed by the ancestor.

Winslow says that one manner of death having been conceived, the man bent on suicide will wait a long time until he can carry out his particular plans. We, however, often see a man who has failed in one way take the first opportunity to secure death in another. Maniacs are most apt to throw themselves from a height, and it is often difficult to say whether one who has fallen from a window did so in simply making an attempt to escape imaginary enemies, mistaking the window for a door, or possibly walked out without any knowledge of the act, or was conscious of the attempt. Some inflict wounds upon themselves, or severely injure the head by pounding it against the wall, impelled by their pains to seek this means of gaining relief. Melancholics often hear a voice urging them to take their lives, and this "voice" at times suggests the means.

Place.—Much ceremony attends the act in some individuals, and publicity is sought. This is often done when revenge is intended. Usually, however, suicides occur in privacy, and it is not uncommon for a man to retire to a concealed and unfrequented spot to carry out his object.

Particular places may become, as it were, fashionable for a time in the suicidal world. Thus, one year, in Paris, the Arc de Triomphe, another Nôtre Dame steeple, and another one of the bridges, will be the favorite leap. The Milan Cathedral, St. Peter's at Rome, and the Campanile at Florence have all in turn had their epidemics, so to speak. So also have the Brooklyn Bridge and Niagara Falls in America.

Esquirol[20] relates a very remarkable method which was employed in a case reported by Dr. Ruggieri,[21] an Italian, which shows what an amount of self-inflicted torture will be endured. A shoemaker in Naples, who had the year before castrated himself and thrown the genitals from the window, after making a good recovery, conceived the idea that God had commanded him to suffer on the cross. He passed two years in perfecting his plans, which were so well carried out that one morning he was found with hands and feet securely nailed to a cross, with a stab wound in the left side, hanging out of his bedroom window. He had constructed the cross and attached it by ropes in such a way that after crucifying himself he could, by motions of the body, cause it to slip from the window. When rescued he was delirious, and although he recovered from his wounds, he exhausted himself by fasting and died.

A novel method has just been introduced in this country, by an anarchist, of exploding a dynamite cartridge in the mouth, bearing out Esquirol's claim that the instrument chosen was apt to be the one which the suicide used professionally.

Time.—The time of day most favorable to acts of self destruction appears to be between the hours of six and twelve in the morning. This preference for the early part of the day extends to the other divisions of time, for it has been found that more suicides occur in the forepart of the week and the first half of the month than in the latter parts.

SYMPTOMS.—It is questionable whether we can say that there are any actual symptoms by which an act of suicide can be predicted. In insanity, and especially in melancholia, an attempt must always be watched for.

In some cases a man, who has been previously healthy, will complain of pain in the epigastrium, of heaviness in the head, will become quiet, listless, lose all ambition, refuse to work or attend to his usual vocations; the habits are changed, and intoxication may be indulged in. There may be scarcely any other symptoms until he tries to cut the thread of life. Weariness of life is often complained of, but Esquirol says he has never seen any attempt because of this *tædium vitæ* alone.

Some individuals predict that they will some day kill themselves and eventually do, but as a rule the one who threatens the act rarely commits it.

In some cases it may be discovered that preparations are being made for death, associated with a sadness of expression and an uneasiness of action. In melancholia the opposite condition may prevail just before the attempt, when all the plans are laid. The skin of suicides has been said to assume a yellow tinge and the features to become shrivelled, giving a changed appearance at the same time that a change is noticed in the actions.

Anæsthesia is a marked symptom at the actual moment of the attempt in many cases, and it is said that after the skin is cut the pain in cutting the throat is not at all severe. This accounts for the little complaint or appearance of pain in cases which, it would appear, must have been attended with torture.

DIAGNOSIS is important in a medico-legal sense, as we have seen that few signs or symptoms of value precede the act. A knowledge of previous attempts will aid us, and at times a hint may be given by some word of the individual or by an ante-mortem letter.

If the attempt has failed the fact may be acknowledged; if death has resulted, writings are to be looked for. The body is to be examined for lesions, especially in the vital regions. The direction of bullet and penetrating stab wounds is to be carefully noted, and the existence or absence of powder marks upon the skin, and wadding, pieces of clothing, etc., within the wound. If death has resulted from a sharp weapon, signs of violence must be looked for upon the body and in its surroundings. The employment of a razor, although favoring a theory of suicide, is not to be regarded as conclusive, because in this country it is quite a favorite weapon with the negro race. If the razor can be shown to belong to the individual, the suicide theory is strengthened.

If poison has been taken, a bottle or paper which has contained it may be discovered near the scene. Though most men found hanging are suicides, the possibilities of lynching and of hanging a dead body to hide a crime must be remembered. In the case of bodies found in the water, great care must be exercised in giving true significance to wounds, and determining whether they were inflicted before death. The fact that the limbs are tied has not great weight, for the suicide might have thought thus to assure success, and even have attached weights to the body.

Pathological lesions found on autopsy shed but little light on the subject of suicide.

PROPHYLAXIS.—Cannot something be done, we instinctively ask, to prevent so great a number of human beings from committing so heinous an act? Something at least to prevent the ever-constant increase? The solution of the problem must lie largely in the better care of the insane, and earlier and more scientific treatment of mental diseases. Hospitals properly equipped for the treatment, supervision, and restraint of the mentally weak and infirm, and the disappearance of the popular prejudice against insane asylums, will do much to decrease the number of suicides in this large class.

Legislation.—In epidemic suicide and in alarming increase of the act, it has been found necessary to enforce stringent laws against the bodies, property, and families of the suicide at various periods of the world's history, and at times with some apparent success.

Laws were established in regard to suicide at a very early day. Zeno's motto, which was such a favorite phrase of the Stoics, "*Mori licet cui vivere non placet,*" was found not to have an application to the individual whose act caused injury to others and loss to the state. It was opposed to the teaching of the Bible, which says, "Thou shalt not kill."

Esquirol thinks some threatening law against the individual should be enforced with reference to the social usages of the people of each particular country. He says comminatory laws have caused suicide to cease in Egypt and Miletus.

Legislation, though not powerful to accomplish much, should nevertheless exist. It will undoubtedly deter a few, and this alone will prove its usefulness.

The attempt at suicide is punishable in New York State by five years' imprisonment, according to existing laws recently enacted.

The confiscation of property and denial of the right of burial, formerly practised in France, have of late years been stricken from the Code.

Formerly, in England, the body of a suicide was treated with ignominy, buried in the highway, and transfixed by a stake. When this law was abolished, the body could still only be buried at night and without religious rites. The canons of the Roman Catholic Church still forbid the burial of a suicide in consecrated ground.

The laws of antiquity, severe as they were upon the family, name, and possessions of the individual, had but slight effect in repressing suicide, as would naturally be expected in the case of the insane, who contribute most largely. In some countries the bodies of all suicides are given for dissection.

The public press has it in its power to favor an increase in suicide by publishing, with minute details, descriptions of all suicides, thus exciting depraved tastes, pampering to the vicious, and putting ideas regarding the act into the minds of nervously weak and predisposed persons. Fortunately, this tendency is much less marked than at a former period, but the danger should be constantly pointed out and guarded against when suicides become at all frequent in a community.

Silence is the antidote for this form of nervous, imitative suicide, as Moreau has aptly and truly said.

TREATMENT.—When a tendency to self-destruction has been discovered, moral treatment may be of much benefit. Kindness, cheerful attention, and society, and the assurance of aid and support, may brighten hope. Argument and sympathy have never done good. When an individual threatens to kill himself, the best treatment is probably to tell him to go ahead and do it. This usually results in a cessation of the threats.

Those mentally afflicted should be placed in institutions, and it has been recommended that all having suicidal tendency be placed together, at least at night, and this plan is carried out in many of our institutions. Tonics and sedatives are usually called for, and remedies suited to the physical derangement, whatever that may be.

Charles W. Allen.

Revised by *Samuel W. Abbott.*

BIBLIOGRAPHY.

Bloch: Vom Selbstmord, Zurich, 1792.
Brierre de Boismont: Du suicide et de la folie suicide, Paris, 1856.
Brigham: Statistics of Suicide in the United States. American Journal of Insanity, 1844-45.
Buonafede: Histoire du suicide, 1761. Translation, Paris, 1843.
Casper: Beitrag zu Med., Berlin, 1825.
Engel: Zeitschrift des preuss. Statistischen Bureaus, 1871.
Engel: Der Philosoph. fur die Welt, Leipsic, 1787.
Encyclopaedia Britannica, Art. Suicide.
Kayser: Official Statistics of Suicide in Norway, Christiania 1852.
Mesnier: Du suicide dans l'armée, 1881.
Millar: Journal of the Statistical Society, London, June, 1874.
Montesquieu: Paris, 1721.
Moreau: Nouveau Dictionnaire, Art. Suicide.
Morel: Traité de médecine mentale, Paris, 1870.
Osiander: Ueber den Selbstmord, Hanover, 1813.
Praetorius: Der verdammliche Selbst- und Eigenmord, Dantzig, 1693.
Winslow: The Anatomy of Suicide, London, 1840.

[1] Le suicide ancien et moderne, Paris, 1881.
[2] Il suicidio, Milan, 1879. Translation, London, 1881; New York, 1882.
[3] Registrar-General's Reports, England, 1861-1900.
[4] Bulletin of International Statistical Society, Rome.
[5] Article by F. L. Hoffmann in the Spectator, August 14th, 1902.
[6] Medical Record, September 27th, 1902.
[7] Paper on Suicide, read before the American Medical Association, 1882.
[8] Suicides in New York City. Reprint from vol. vii., Public Health Papers of the American Public Health Association.
[9] For other statistics see Confronti Internationali (1865-1883), Rome, 1884, published by the Italian General Statistical Department.
[10] Treatise on Insanity, New York, 1883.
[11] The Borderland of Insanity, 1875.
[12] Étude sur le suicide chez les enfants. Annales Médico-physiologiques, January, 1855.
[13] United States Census, volumes relating to vital statistics, 1900.
[14] Eulenburg's Real-Encyclopedie, Art. Selbstmordstatistik.
[15] Albert Leffingwell, M.D.: The Influence of Seasons on Conduct, London, 1892.
[16] Du suicides chez les enfants. Journ. de méd. mentale, 1868.
[17] The Anatomy of Suicide, London, 1840.
[18] Massachusetts Registration Reports, 1886-1900.
[19] Statist. morale comparée de la France et de l'Angleterre, Paris, 1864.
[20] Maladies mentales, Paris, 1838. Translation, Philadelphia, 1845.
[21] Medical Library, September, 1811.
[22] Statistica delle cause di morte, Rome, Italy, 1894-1899.
[23] Statistisches Jahrbuch der Stadt Berlin, 1895-1899.
[24] Annuaire Statistique, Paris, 1895-1899.
[25] Municipal Reports of Vienna and Budapest, 1895-1899.
[26] Captain John Graunt's Bills of Mortality, London, 1665.
[27] Die Sterbefälle im Deutschen Reiche, 1896-1899.
[28] Rahts: Die Häufigkeit der Selbstmord in den grösseren Orten des Deutschen Reiches, Berlin, 1894.

SULFOSOT is a syrup containing about five per cent. each of guaiacol and cresol sulfonates of potassium. These are obtained by treating creosote with concentrated sulphuric acid and combining with potassium. The remedy is used for tuberculosis in dose of 4 c.c. (ʒ i.).

W. A. Bastedo.

SULPHAMINOL.—An antiseptic formed by the action of sulphur upon certain salts of the aromatic series. In the body it is supposed to decompose into carbolic acid and sulphur compounds. It was introduced for the purpose of replacing iodoform, on account of its active antiseptic action and freedom from odor. It is a pale yellow powder, without taste or odor, insoluble in water but dissolved by the addition of alkalies; it is soluble in alcohol. When subjected to heat it turns brown and melts at about 155° C. The dose for internal administration is four grains three times a day, but it does not appear to have been used to any extent.

Externally, it has been used in all cases in which iodoform is employed.

Beaumont Small.

SULPHIDES.—Sulphides of four metallic bases occur among medicines, namely, sulphides of *mercury, antimony, potassium*, and *calcium*. Of these, the sulphides of mercury and antimony are, medicinally, not specifically peculiar, and will be found discussed under the titles of the several metals. The sulphides of the other two bases exhibit marked properties, evidently due to the sulphur of their composition, and accordingly form a distinct group of medicines. The common characteristics are, physically, an alkaline reaction, a disagreeable smell, and an alkaline and offensive sulphureted taste; physiologically, quite intense, irritant properties, and a special obnoxiousness to animal and vegetable skin parasites; and, therapeutically, a local healing influence over many skin diseases in their chronic stage, and, given internally, an uncertain tendency to abate chronic glandular, or cutaneous, or arthritic disease, and to control or repress suppuration. In full dose too long continued, the compounds tend to impair general nutrition, leading to emaciation and muscular weakness. Following are in detail the pharmaceutical preparations containing the sulphides in question, with their special properties and uses:

POTASSA SULPHURATA: *Sulphurated Potassa.*—This is an official preparation of the United States Pharmacopœia, made by heating in a covered crucible, to melting, a mixture of dried potassium carbonate and sublimed sulphur. The product solidifies upon cooling, and is then broken into pieces and put up in well stoppered bottles of hard glass. Products obtained by the foregoing general process are commonly called, generically, *hepar sulphuris* (liver of sulphur), the name being expressive of the color. Such products are composite bodies, but the composition varies according to the degree of heat to which the mixture of potassium carbonate and sulphur has been subjected in the preparation. By the comparatively low heat directed in the United States pharmacopœial process, the product is probably a mixture of potassium hyposulphite and trisulphide ($K_2S_2O_3 + 2K_2S_3$). At a higher heat, such as is used in the British pharmacopœial process, the hyposulphite first formed splits into potassium sulphate and pentasulphide. When freshly made, sulphurated potassa appears in irregular, liver-colored lumps, which, on exposure to the air, gradually absorb oxygen, carbon dioxide, and water, and change color to a greenish-yellow. Finally they turn into a gray material containing potassium carbonate, sulphate, and hyposulphite. Liver of sulphur dissolves, all but a small residue, in two parts of cold water. Alcohol dissolves the potassium sulphide, but leaves undissolved the other component substances of the preparation. Sulphurated potassa should contain at least fifty-six per cent. of potassium sulphide. It is decomposed by mineral acids, and by most solutions of metallic salts.

Sulphurated potassa possesses the general properties detailed above; it is violently irritant, even to corrosiveness, and overdosage may easily kill by excessive gastrointestinal irritation. The medicine is used, locally, to kill parasites, and to favor the healing of skin disease or the abatement of rheumatic or gouty troubles, and, internally, to assist in the two latter-named operations. The parasiticide action is utilized mainly for the destruction of the itch insect, for which purpose this compound is exceedingly efficacious. The preparation is applied locally, in the form of ointment, lotion, or general bath. For an ointment of proper average strength, sulphurated potassa may be mixed with lard in the proportion of six per cent. of the former; for a lotion, an aqueous solution ranging from three to six per cent. in strength may be used; and, for a bath, about 125 gm. (four ounces) may be dissolved in about 120 litres of water (about 30 gallons). Concentrated applications never should be made, because of the sharp irritation which would result. Baths containing sulphurated potassa (commonly spoken of as *sulphur baths*), besides their foregoing use, are sometimes employed in the treatment of chronic lead-poisoning, because of the finding that patients suffering from lead contamination show upon their skins, after immersion in a sulphur bath, a dark discoloration, as from the forming there of lead sulphide. The inference is that the sulphur in some mysterious way coaxes the lead out of the system through the skin emunctories, in order to satisfy its chemical longing for a union with the metal. Sulphur baths are administered warm or hot, and of a duration from half an hour to two or three hours. They are apt, particularly when protracted, to produce a good deal of irritation of the skin, even to the development of a papular or vesicular eruption. These baths should be prepared in wooden tubs. For internal giving, the dose of sulphurated potassa ranges from 0.12 to 0.40 gm. (two to six grains), several times a day, given in pill or in some aromatized syrup.

CALX SULPHURATA: *Sulphurated Lime.*—The preparation thus named in the United States Pharmacopœia is what is commonly, but incorrectly, called *sulphide of calcium.* It is a mixture in varying proportions of calcium sulphide, calcium sulphate, and carbon, but should contain at least sixty per cent. of calcium sulphide—the salt which gives the substance its medicinal activity. Sulphurated lime is made, by the process directed in the United States Pharmacopœia, by heating to a bright red heat in a closed crucible a mixture of dried calcium sulphate, charcoal, and starch. The product, after cooling, is pulverized, and at once put up in small glass stoppered vials. It appears as a grayish-white or yellowish-white powder, which slowly decomposes on exposure to the air. It has a faint odor of hydrogen sulphide, and an offensive and alkaline taste. It is alkaline in reaction, is very slightly soluble in water, and insoluble in alcohol.

Sulphurated lime, like sulphurated potassa, has the general properties of the alkaline sulphides, as already detailed. It is powerfully irritant, even medicinal doses being apt to upset the stomach. And it is a disagreeable medicine for internal taking, also, because of its giving rise to eructations of sulphureted gases. The preparation has been used, locally, principally as a depilatory. For this purpose it is applied in powder, and, after fifteen minutes, the part is wiped with a wet sponge. Medicine and hairs then come away together. Internally, sulphurated lime has acquired a certain reputation as tending to control suppurations, the discharge lessening in quantity and offensive pus acquiring a better character under the medication. Given between times in recurring suppurations, as in recurring crops of boils, it is also held to abate the frequency and severity of the attacks. The dose of sulphurated lime ranges from 0.003 to 0.006 gm. (gr. $\frac{1}{20}$ to gr. $\frac{1}{10}$), several times a day, or even hourly, given most conveniently in trituration with sugar of milk. *Edward Curtis.*

SULPHITES AND "HYPOSULPHITES" (Thiosulphates).—I. GENERAL MEDICINAL PROPERTIES OF SULPHITES AND "HYPOSULPHITES."—A number of sulphites and "hyposulphites" are used in medicine because of a virtue which they are considered to derive, in common, from their acid radicals, and accordingly such salts form a distinct group of medicines, which it is convenient to discuss under a single heading. The class characteristics are as follows: The salts are soluble in water, have a combined saline and sulphurous flavor, and are, in physiological operation, locally bland and constitutionally innocuous. From a medicinal point of view, their most important reaction is that in the presence of stronger acids they are decomposed, with the evolution of sulphurous acid. Given medicinally, they are thought to undergo this change in the stomach through the agency of the free acid of the gastric juice. The decomposition is said to be slower with "hyposulphites" than with sulphites. As a secondary result of the chemical change, sulphates are formed, such being the combination in which the base reappears in the urine when a sulphite or "hyposulphite" is swallowed in ordinary dosage. Medicinally, these salts are employed with the single view of obtaining by their means the germicide and antiseptic action of sulphurous acid. But in this connection it must carefully be borne in mind that sulphites and "hyposulphites," while maintaining their chemical composition as such, have been proved experimentally to be practically devoid of either germicide or antiseptic power.[1] They can, therefore, even theoretically, be of avail in this line only under circumstances determining their decomposition and the evolution thereby of sulphurous acid. Such reaction may take place in the stomach, but is seemingly impossible in the blood, and with the inference naturally following from these premises clinical experience is in accord. For these salts have been vaunted in the treatment of pyrosis and sarcinæ, and their employment has proved fairly efficacious; but they have been even more strenuously advocated for the treatment of constitutional diseases assumed to be caused by infection of living organisms (Polli), and have, in the hands of the majority of the profession at least, signally failed. The salts have also been used, with variously reported success, as lotions for the cure of parasitic skin disease, or for the abatement of the pain of chilblains, sprains, etc.—applications in which it is certainly doubtful if they exert any specific influence.

II. THE SULPHITES AND "HYPOSULPHITES" USED IN MEDICINE.—The salts of this category are the normal and acid sulphite, respectively, of *sodium*, and the normal thiosulphate of *sodium* (commonly called *hyposulphite*).

Normal Sodium Sulphite, $Na_2SO_3.7H_2O$.—The salt is official in the United States Pharmacopœia as *Sodii Sulphis*, Sodium Sulphite. It occurs in colorless, transparent, monoclinic prisms, which effloresce in dry air. It is odorless, with a cooling, salty, and sulphurous taste. It dissolves in 4 parts of cold water and in 0.9 part of boiling water. It is sparingly soluble, only, in alcohol. The salt should be kept in well-stoppered bottles in a cool place.

Sodium sulphite may be used locally in twelve-per-cent. aqueous solution, and may be given internally in doses ranging from 1 to 4 gm. (gr. xv. to gr. lx.) three or four times a day.

Acid Sodium Sulphite, $NaHSO_3$.—The salt is official in the United States Pharmacopœia as *Sodii Bisulphis*, Sodium Bisulphite. It occurs in opaque, prismatic crystals, or a crystalline or granular powder, and on exposure to air slowly oxidizes and becomes the sulphate. The salt has an odor of sulphur dioxide and a disagreeable, sulphurous taste. It dissolves in 4 parts of cold water and in 2 parts of boiling water, in 72 parts of cold alcohol, and in 49 parts of boiling alcohol. It should be kept in small vials, well-stoppered and well-filled.

This sulphite is less stable than the normal sodium salt, and more disagreeable to taste. In other respects it is similar.

Normal Sodium Thiosulphate ("Hyposulphite"), $Na_2S_2O_3.5H_2O$.—The salt is official in the United States Pharmacopœia under its former chemical title of *Sodii Hyposulphis*, Sodium Hyposulphite. The present confusion in the use of the term *hyposulphite* arises from the fact that before the discovery by Schützenberger of what is now, and properly, called hyposulphurous acid—namely, the body H_2SO_2—the name in question was applied to thiosulphuric acid ($H_2S_2O_3$). Hence it comes about that though a true sodium hyposulphite is known, the salt that passes current by that name is not a hyposulphite, but a thiosulphate. The old title, however, is so firmly fixed by long and popular usage that it has been retained by the United States Pharmacopœia, and is the title by which the salt is universally known as a medicine. Sodium "hyposulphite" occurs as large, colorless, transparent, monoclinic prisms, or plates, which effloresce in dry air of a higher temperature than 33° C. (91.4° F.). It is odorless, with a cooling bitter, and somewhat sulphurous taste. It dissolves in 0.65 part of cold water and in about 0.5 part of water at temperature 20° C. (68° F.). In boiling water it decomposes rapidly. It is insoluble in alcohol. It should be kept in well stoppered bottles.

Sodium "hyposulphite" is more stable than the sulphites, undergoing decomposition by acids less easily. In properties, uses, and modes of administration it resembles sodium sulphite. The internal dose is generally from 1 to 1.30 gm. (gr. xv. to gr. xx.).

Besides the foregoing, potassium sulphite and magnesium sulphite have been used in medicine, but are out of vogue and not now official in the United States Pharmacopœia. They are, medicinally, duplicates of the sodium salts. *Edward Curtis.*

[1] Sternberg: American Journal of the Medical Sciences, April, 1883, p. 321.

SULPHOCARBOLATES—*Phenolsulphonates.*—Carbolic acid (*phenol*), added to strong sulphuric acid, dissolves with the formation of the acid body, $C_6H_4(OH).SO_3H$, termed *phenolsulphonic acid* by the chemist, but commonly known as *sulphocarbolic acid*. Sulphocarbolic acid unites with bases to the formation of salts, and in these salts it was hoped there might be found substances which would retain the therapeutic powers of carbolic acid while free from the poisonous properties of that body. So far as observation has gone, however, this hope does not seem to have been realized. A single salt of sulphocarbolic acid is official in the United States Pharmacopœia, as follows:

SODII SULPHOCARBOLAS, *Sodium Sulphocarbolate*, $NaSO_3C_6H_4(OH)$.—This salt occurs in colorless, transparent, rhombic prisms, which effloresce somewhat in dry air. It is odorless, with a cooling, saline, and bitterish taste. It dissolves in 4.8 parts of cold water, and readily in boiling water. It dissolves in 132 parts of cold alcohol and in 10 parts of boiling alcohol.

Sodium sulphocarbolate is a bland salt, producing but little constitutional disturbance in ordinary medicinal doses beyond some lightness of the head. It has been prescribed in doses ranging from 0.65 to 2 gm. (from gr. x. to xxx.) for the purpose of constitutional antisepsis in so called zymotic diseases, but without striking results. *Edward Curtis.*

SULPHOCYANIDES (*Rhodanides, Thiocyanates*).—The sulphocyanides, or salts of sulphocyanic acid (CNSH), are of interest in medical science chiefly from the fact of their occurrence in certain of the secretions and excretions of the animal body. Even before the discovery of sulphocyanic acid, Treviranus noted the red coloration which results when human saliva is mixed with a solution of ferric chloride; but Tiedemann and Gmelin first correctly attributed the reaction to the presence of a sulphocyanide. Their experiments further indicated the possibility of finding sulphocyanide in the urine, in which its normal occurrence was subsequently investigated by Gscheidlen, Külz, I. Munk, and Bruylants.

The observations of F. Krüger have demonstrated, in contrast to those of some earlier investigators, that sulphocyanides are almost constantly present in the saliva of man, although the quantity involved is subject to considerable variation. With this the experience of Schneider and of the writer fully agrees. The latter found an average sulphocyanide content of 0.007 per cent. (as KSCN) in mixed human saliva. Notable is the fact that the content of sulphocyanide is decidedly higher in the case of smokers, contrasted with non-smokers, while it is independent of age, sex, or the state of preservation of the teeth. Claude Bernard was the first to call attention to the pronounced difference just referred to, but he failed to appreciate the true cause in attributing it to the presence of nicotin from the tobacco. A post-secretory formation of sulphocyanide in saliva has also failed of proof. The following data, collected under the writer's direction from observations on two hundred and twenty-nine individuals, give an indication of the average difference between the saliva of smokers and that of non-smokers:

SULPHOCYANIDE REACTION IN HUMAN SALIVA (Schneider).

	Smokers, per cent.	Non-smokers, per cent.
Traces (less than 0.0016 per cent.) in....	1	23
Weak reaction (0.0016-0.008 per cent.) in	23	72
Strong reaction (more than 0.008 per cent.) in..............................	76	5

Our observations completely confirm those of Krüger, who found 0.0117 per cent. of KSCN in the combined saliva of a number of smokers, and only 0.0041 per cent. in the secretion of an equal number of non-smokers. No quantitative variations from these results were obtained with saliva from women and children. The excretion of sulphocyanide may be considerably diminished by prolonged stimulation of the salivary glands. For example, in one case when the flow of saliva was continuously provoked by chewing a piece of soft paraffin for three hours, it diminished as follows: At 8:15 o'clock the saliva contained approximately 0.004 per cent. (KSCN); at 10 o'clock, approximately 0.003 per cent. (KSCN); at 11 o'clock, approximately 0.002 per cent. (KSCN); at 12 o'clock, approximately 0.002 per cent. (KSCN). No constant relationship between the content of sulphocyanide and the composition of the saliva has been ascertained.

The parotid saliva of man has uniformly been found to be richer in sulphocyanide than the submaxillary saliva collected from the same individual at the same time. The two corresponding glands (right and left) usually afford reactions of like intensity. The difference between smokers and non-smokers is found to hold good for the individual glands also, as the following data from Schneider indicate:

Comparison of the Sulphocyanide Reaction of the Parotid and Submaxillary Salivas.

HSCN reaction.	Smokers.		Non-smokers.	
	Parotid saliva.	Submaxillary saliva.	Parotid saliva.	Submaxillary saliva.
Trace	None.	4	2	19
Weak	4	13	22	5
Strong	24	11	None.	None.

Regarding the origin of sulphocyanides in the organism little is known. Since they contain Nitrogen and Sulphur, they have been assumed to arise from the metabolism of proteids. Various attempts have been made to establish some clinical significance for the variations in the sulphocyanide output (Fenwick, Grober, Muck). Thus Grober states that of one hundred patients in the Jena medical clinic, sixty who yielded weaker sulphocyanide reactions in their saliva were more ill in general than the remaining forty with whom stronger reactions were obtained. He concluded from these observations that the excretion of KSCN is presumably dependent upon the extent to which proteid utilization and katabolism proceed in the organism; that, since these processes are diminished in cachectic patients with severe chronic illness, the excretion of sulphocyanide which is derived ultimately from proteids must be slight or wanting. An exhaustive systematic study of this subject is necessary before any deductions of importance can be made.

According to Ellenberger and Hofmeister, sulphocyanides are missing in the saliva of the horse, ox, sheep, goat, and pig. Whether they occur in the saliva of the dog is doubtful (Munk). Nencki has succeeded in isolating sulphocyanic acid from the gastric juice (obtained free from contamination with saliva) from the dog and cat. The quantity was estimated at 5 mgm. per litre. In the pancreatic juice, muscle, and liver of the dog none could be detected. With blood positive results have been obtained (Nencki, Gscheidlen, Bruylants). Wróblewski has shown that sulphocyanic acid retards the action of pepsin and rennin in artificial digestions.

Sulphocyanides have been detected in the urine of the dog, cat, rabbit, horse, and cow. The quantity found in human urine is given by various investigators at 0.003–0.035 gm. per litre, thus yielding about one-third of the so-called "neutral" sulphur of the urine. According to Bruylants, sulphocyanide occurs only in the urine of those species which excrete their Nitrogen in the form of urea; in birds and reptiles it is wanting.

In cow's milk Musso has estimated a minimum of 0.0021 and a maximum of 0.0046 sulphocyanide (as NaSCN) per litre. Whether the compound arises within the cells of the mammary gland, or is merely secreted directly from the blood as a preformed product, is left undecided.

Muck has demonstrated the presence of sulphocyanide in the fluid which bathes the conjunctiva, as well as in the secretion from the nasal mucosa. He obtained the reaction in individuals with catarrhal as well as healthy membranes, and observed that its intensity varied with that of the saliva.

The antiseptic value attributed to the sulphocyanide in the saliva has no experimental justification. Even relatively strong solutions possess little bactericidal power (Nicolas and Dubief, Treupel and Edinger). Sodium sulphocyanide has been administered to rabbits for months without producing unfavorable symptoms, thus contrasting with the corresponding toxic cyanide. Cyanogen compounds may be transformed in the body into sulphocyanides, the latter being a synthetic product formed from the ingested cyanogen radical and the SH group of decomposed proteid (Lang). The reaction is a purely chemical one, apparently not dependent on the living tissue (Pascheles). Administration of a thiosulphate (or sulphide) may greatly diminish the toxicity of a cyanide, owing to the formation of the comparatively harmless sulphocyanide, thus:

$$NaCN + SO_2\begin{smallmatrix}\diagup SNa \\ \diagdown ONa\end{smallmatrix} + O = NaSCN + Na_2SO_4.$$

On the basis of this theory the intravenous injection of sodium sulphide has been advised in poisoning with prussic acid and cyanides; and animals seem to survive an otherwise lethal dose when this is done.

Sulphocyanides introduced directly into the organism are excreted again unchanged. The path of excretion lies through the kidneys, and several days usually intervene until the salt is completely eliminated. This is well shown in the experiments of Pollak, from which the following table is constructed:

Excretion of Sulphocyanides.

Animal.	Substance introduced.	Quantity eliminated in urine.	Duration of elimination.
Dog, 6,350 gm.	1.268 gm. NaCNS subcutan.	1.189 gm.	Four days.
Dog, 6,350 gm.	1.440 gm. NaCNS subcutan.	1.482 gm.	Four days.
Dog, 8,970 gm.	.907 gm. NaCNS subcutan.	.904 gm.	Five days.
Dog, 8,970 gm.	1.012 gm. NaCNS per os....	1.038 gm.	Five days.
Dog, 7,800 gm.	.510 gm. $(NH_4)CNS$ subcutan.	.49 gm.	Five days.
Rabbit 1,420 gm.	.220 gm. NaCNS subcutan.	.206 gm.	Nine days.
Man	2.200 gm. NaCNS per os....	2.167 gm.	Six days.

Of the various tests which have been proposed for the detection of sulphocyanides in animal fluids, the *ferric chloride reaction* is most commonly used. Thus if a few cubic centimetres of saliva are slightly acidified with hydrochloric acid and then treated with a very dilute solution of ferric chloride, a red color develops in the presence of the sulphocyanide. Occasionally it is necessary to concentrate the saliva before trying the reaction. Gscheidlen recommended the use of filter paper which has been dipped in a very dilute acidified solution of ferric chloride and allowed to dry. The amber-colored test paper takes on a reddish stain when a drop of saliva is applied to it. Solera suggested the use of *iodic acid* in the presence of starch paste. Iodine is liberated by the sulphocyanide and reacts with the starch to form the characteristic blue compound. This reaction is exceedingly delicate. Krüger has introduced the use of test papers prepared as follows: Filter paper of good quality is saturated with a half-per-cent. starch paste containing a little pure iodic acid in solution, and is then dried in the air. When carefully prepared, this test paper responds readily to very small quantities of sulphocyanide by giving a blue coloration due to the liberation of iodine; and with proper precautions the reagent papers can be preserved without decomposition for a considerable time.

In testing for, or estimating sulphocyanides in the urine, special precautions are necessary; and these must be ascertained from appropriate handbooks, such as Huppert's "Analyse des Harns." The quantitative determination of sulphocyanic acid in the saliva may be carried out by Munk's method:

A known weight of saliva is evaporated to dryness, and an alcoholic solution of the dry residue is made; this is evaporated to dryness, dissolved in water, and the clear solution is precipitated by means of silver nitrate and nitric acid; the precipitate is washed, collected on a filter, and dried at 100° C.; it is then ignited in a silver dish, with pure sodium hydrate and potassium nitrate. The fusion products are dissolved in water, and the solution is treated with hydrochloric acid and barium chloride, to precipitate the sulphuric acid formed by the oxidation of the sulphocyanic acid. From the weight of the barium sulphate precipitate the amount of sulphur originally present in the sulphocyanide is then calculated.

Lafayette B. Mendel.

LITERATURE.

Bernard: Liquides de l'organisme, 1859, ii., 241. (Saliva of smokers.)
Bruylants: Jahresbericht f. Thierchemie, 1888, xviii., 134. (Sulphocyanide in the urine, saliva, and blood.)
Ellenberger und Hofmeister: Vergleichende Physiologie der Hausthiere, 1890, 495. (Sulphocyanides in various animals.)
Fenwick: The Saliva as a Test for Functional Disorders of the Liver, London, 1889.
Grober: Deutsches Archiv f. klin. Medicin, 1901, lxix., 243. (Saliva in disease; smoking.)
Gscheidlen: Pflüger's Archiv f. Physiologie, 1876, xiv., 401. (Urine.)
Huppert: Neubauer und Vogel's Analyse des Harns, 1898, 219. (Analytical methods for urine.)
Külz: Sitzungsber. der Gesell. f. Beförderung der gesam. Naturwissen. zu Marburg, 1875, 76. (Urine.)
Krüger: Zeitschrift f. Biologie, 1899, xxxvii., 6. (Literature, saliva.)
Lang: Archiv f. exper. Pathol. u. Pharmakol., 1894, xxxiv., 247; 1895, xxxvi., 75. (Transformation of cyanides into sulphocyanides.)
Longet: Traité de physiologie, 1868, i., 183. (Saliva; older literature).
Mendel and Schneider: American Journal of Physiology, 1900, iv., p. vii. (Saliva of man.)
Musso: Jahresbericht f. Thierchemie, 1877, vii., 168. (Milk.)
Muck: Münchener med. Wochenschr., 1900, No. 34, 1168; No. 50, 1732. (Sulphocyanide in nasal and conjunctival secretion; saliva and disease.)
Munk, I.: Virchow's Archiv, 1877, lxix., 350, 354; Pflüger's Archiv f. Physiologie, 1895, lxi., 620. (Saliva and urine of man; Saliva of dog.)
Nencki: Berichte d. deutschen chemischen Gesell., 1895, xxviii., 1318. (Gastric juice.)
Nicolas et Dubief: Journal de Physiologie, 1899, i., 979. (Bactericidal significance of saliva.)
Pascheles: Archiv f. exper. Pathol. u. Pharmakol., 1894, xxxiv., 281. (Transformation of cyanides.)
Pollak: Hofmeister's Beiträge zur chemischen Physiologie, 1902, ii., 430. (Fate of sulphocyanides in body.)
Schneider: American Journal of Physiology, 1901, v., 274. (Human saliva, effect of smoking.)
Solera: Jahresbericht f. Thierchemie, 1877, vii., 256; 1878, viii., 235. (Iodic acid reaction.)
Tiedemann und Gmelin: Die Verdauung nach Versuchen, Heidelberg, 1831, i., 9. (Discovery of sulphocyanide in saliva.)
Treupel und Edinger: Munchener med. Wochenschr., 1900, Nos. 21 and 22; 1901, No. 39. (Toxicity; bactericidal action.)
Treviranus: Biologie, 1814, iv., 330. (Discovery of ferric chloride reaction with saliva.)
Wróblewski: Berichte d. deutschen chemischen Gesell., 1895, xxviii., 1719. (HSCN and digestion.)

SULPHONAL.—(*Dimethyl-methane-diethyl-sulphone*) $(CH_3)_2C(SO_2C_2H_5)_2$. Sulphonal was not placed in the Pharmacopœia on account of its being a proprietary article. It is official in the British Pharmacopœia as "a product of the oxidation of mercaptol, obtained by the oxidation of acetone and mercaptan." It forms in colorless, odorless, and nearly tasteless prismatic crystals; soluble in 450 parts of cold water and 15 parts of boiling water. It is soluble in 50 parts of alcohol.

Professor Kast introduced it in 1888 as an hypnotic, and it has proved so efficacious that it is now recognized as one of the best drugs we possess for that purpose. It is purely a soporific, and is rarely employed for any other purpose than to procure sleep. It does not influence the body temperature, it has no antiseptic qualities, and as an analgesic is of no practical value. Unlike other narcotics, it has no period of excitement, does not check or alter the secretions or derange the digestive organs, and is almost without any influence upon the heart or circulation. Devoid of these many disadvantages, its success as an hypnotic is readily understood.

The action of sulphonal is directed to the central nervous system as a sedative, inducing a quiet and calm sleep from which the patient awakens refreshed. In the case of animals, when excessive doses are given the sleep deepens into coma, convulsions, and paralysis. Its sedative action extends to the spinal cord, lessening reflex action. In animals the loss of power in the hind limbs may be an early symptom. After absorption sulphonal is decomposed in the system and excreted in the urine in the form of sulphur compounds. Some observers have reported the presence of pure sulphonal in the urine after its free administration. At times sulphonal proves irritating to the kidney, causing lessened secretion and pain. It may also give rise to a peculiar reddish-brown discoloration due to the presence of *hæmatoporphyrine*, which may terminate in death (*British Medical Journal*, 1901, i., p. 1473).

Sulphonal has proved of greatest service where the insomnia is of purely nervous origin, as in neurasthenia, mental depression, overwork, and worry, and has found a field of great usefulness in the various forms of mental disease. When pain is the cause of the sleeplessness, its good effects are greatly modified, but in many forms of neuralgia and pain of a reflex character it may be used with success. Where pain is due to organic disease it has no influence whatever. In the insomnia of acute and chronic disease, and during convalescence from disease, it is of much benefit, but requires to be given with some caution, particularly when there is much debility or prostration, and in the aged. In the sleeplessness of cardiac disease and of other forms of organic or mechanical derangement, it is not of much use. In delirium tremens it has been much used, in many instances with benefit, but in these cases the effect is uncertain, and the dose required is excessive and approaching the limit of its physiological action.

As an hypnotic, the dose is from fifteen to thirty grains. It is usual to commence with fifteen grains and increase the quantity until the proper effect is produced. Ten grains will often be sufficient in the aged and debilitated, or where the insomnia is of a mild degree. Under ordinary conditions thirty grains is a perfectly safe dose, and this quantity is usually required to produce its full hypnotic action. On account of its insolubility the action is slow, and the dose should be administered at least one hour before bedtime in hot solution. Six or eight ounces of boiling water are recommended to dissolve thirty grains. Hot milk and broth may also be made use of; tea and coffee are frequently used, but they undoubtedly, to a certain extent, counteract its effect. It may also be administered in alcohol or any spirituous liquor.

The sedative action of sulphonal on the spinal cord and nerve centres has led to its use in some nervous troubles. In chorea it has been given to children in doses of from two to five grains, and has been followed by a fair percentage of successes. In old-standing cases it has little or no influence.

It is now fully recognized that sulphonal is not without its toxic action, and numerous fatal cases have followed its employment. The simplest symptoms that may arise include drowsiness and stupor, giddiness, vertigo, ataxia of the tongue and muscles of the throat and face, and of the extremities. These symptoms gradually disappear after an interval of from ten to twelve hours, without leaving any ill effects. The more severe symptoms are profound coma, muscular twitchings, paralysis of sphincters, hallucinations, delirium, anuria, great prostration.

An erythematous patch is often produced, accompanied by itchiness and pain. The symptoms of toxic action generally appear after large doses, or after repeating an ordinary dose of thirty grains several times. In some instances, when the patient is debilitated and the subject of some wasting disease, very small doses may be followed by toxic symptoms. It has been remarked that poisonous symptoms are much more frequent in females.

The fatal cases that have been reported were due to overdoses or to the prolonged use of the drug.

In one case (*British Med. Journal*, October 25th, 1890) the patient was supposed to have taken about an ounce of sulphonal. The stupor which followed deepened into insensibility and anæsthesia, the pupils remaining normal and acting to light, while the conjunctiva was insensitive. Breathing was natural, pulse very slightly disturbed, but the temperature ranged between 100 and 103° F. A profuse perspiration bathed the body, and there was total suppression of urine after the first day. On the third day the breathing suddenly became short and jerky and ceased altogether. Another case is reported (*Medical News*, August 10th, 1890) in which two doses of fifteen grains, given within an hour and a quarter of each other, caused death. The patient was a young insane woman who had formerly been given large quantities of chloral and other hypnotics. No medicine had been given on the day she took the sulphonal. She slept quietly all night, and on the following day was drowsy, but could be roused and made to talk rationally; sleep at once came on when she was left alone. The pulse and respiration were slightly accelerated and the pupils normal. Eighteen hours after taking the medicine the pupils began to contract and her temperature rose to 102° F.; in forty hours cyanosis began, and she died from failure of respiration.

Lépine (*La Semaine médicale*, January 20th, 1893) has collected a series of thirteen cases terminating in death. These patients had taken the drug for periods varying from sixty to over a hundred days in ordinary doses. Severe symptoms suddenly supervened, which would indicate a cumulative action, and death followed within a few days, although the medicine was stopped at once. In some instances very large doses have been taken without causing death; in one case four hundred and sixty-three grains were recovered from after one hundred and fourteen hours' sleep (London *Lancet*, 1889, i., 915). See also *Synthetic Products, Poisoning by*.

Beaumont Small.

SULPHO-PARALDEHYDE, tri-thialdehyde $(C_2H_4S_2)_3$, occurs in crystals, is soluble in alcohol and insoluble in water, and is used in dose of 1–4 gm. (gr. xv.–ʒ i.) as a hypnotic.

W. A. Bastedo.

SULPHO-SALINE SPRING.—Hamilton County, Ohio.
POST-OFFICE.—Cincinnati.

ACCESS.—By Elm Street cars to Henry Street, thence one block west.

This well is 2,408 feet in depth and flows in an abundant and continuous stream at a temperature of 62° F. An analysis by Professor Wayne, of Cincinnati, shows the following ingredients: One United States gallon contains (solids): Magnesium carbonate, gr. 9.13; calcium carbonate, gr. 19.34; calcium sulphate, gr. 29.20; potassium sulphate, gr. 2.30; sodium phosphate, gr. 1.34; sodium chloride, gr. 534.77; magnesium chloride, gr. 17.27; calcium chloride, gr. 22.19; potassium chloride, gr. 3.95; magnesium bromide, gr. 0.39; magnesium iodide, gr. 0.30; iron oxide, gr. 0.43; silica, gr. 0.79; loss, gr. 0.76. Total, 642.16 grains. This analysis shows the presence in considerable amounts of valuable ingredients. The water is well adapted for the treatment of portal congestion, hemorrhoids, metallic poisoning, etc. In the form of baths it is useful in many of the chronic skin affections and in advanced syphilis. A very elegant and elaborate bath-house has been fitted up and supplied with all the modern appurtenances of such an establishment.

James K. Crook.

SULPHUR.—Sulphur is used in medicine in the condition of fine powder, three styles of which are official in the United States Pharmacopœia, as follows:

SULPHUR SUBLIMATUM, *Sublimed Sulphur*.—This preparation, commonly called *flowers of sulphur*, is crude sulphur purified by distillation in an apparatus so arranged that the vaporized sulphur shall condense in the form of a powder upon the walls of the receiving chamber. Sublimed sulphur is a fine, citron-yellow powder, of a slight, characteristic odor, and generally of a faintly acid taste and an acid reaction. It is insoluble in water or alcohol. When ignited, it burns with a blue flame, forming sulphur dioxide gas. Sublimed sulphur always contains a little sulphuric acid, whereby it is unfitted for internal medicinal use.

Sulphur Lotum, Washed Sulphur.—This preparation is simply sublimed sulphur freed from contaminating sulphuric acid. The sulphur is digested for three days with diluted ammonia water, by which process the sulphuric acid is fixed as ammonium sulphate, and the mass is then thoroughly washed with water upon a muslin strainer. The ammonium sulphate is thus washed away, and the purified sulphur is finally dried at a gentle heat, and passed through a No. 30 sieve. Washed sulphur is a fine, citron-yellow powder, odorless and almost tasteless, insoluble in water or alcohol. When derived from a sulphur originally obtained from metallic sulphides, washed sulphur may contain the very dangerously contaminating substance, arsenic, in the form of the trioxide or trisulphide of that element. Proof of absence of arsenic is afforded by digesting a sample of washed sulphur with two parts of ammonia, filtering, and finding the filtrate unaffected by supersaturation with hydrochloric acid, and not precipitated by passing through it a stream of hydrogen sulphide.

SULPHUR PRECIPITATUM, *Precipitated Sulphur*.—This preparation, formerly known as *milk of sulphur*, is an exceedingly fine powder of sulphur, gotten by precipitating with diluted hydrochloric acid a solution of sulphur salts of calcium, obtained by mixing sublimed sulphur and slaked lime with water. The sulphur, after precipitation, is collected upon a strainer, thoroughly washed with water, and dried at a gentle heat. Precipitated sulphur is a very fine, yellowish-white, amorphous powder, odorless and almost tasteless, insoluble in water or in alcohol. Precipitated sulphur should stand the same tests for absence of free acid and of contaminating arsenic as washed sulphur (see above). This variety of sulphur powder differs from the foregoing in being lighter in color and of finer particles. From the latter fact it derives the advantages of greater smoothness and readiness of mixing with fluids; but, to offset, it has the disadvantage of tending to develop an acid upon keeping.

Sulphur is insoluble in water and practically so in alcohol, but dissolves in varying proportions in solutions of the alkalies and in oils, fixed and volatile. Because of its insolubility in aqueous fluids, sulphur is practically devoid of physiological activity while under its own form, but, when rubbed in ointment upon the skin or when taken internally, a feebly irritant action appears, presumably due to a sulphide formed in small quantity by the chemicals present in the secretions of the part. What little of an internally taken dose of sulphur is absorbed is also probably in the condition of a sulphide, and the constitutional effects that follow are a feeble reflex of those of the alkaline sulphides (see *Sulphides*). In single, considerable dose the local irritation displayed by sulphur determines increased intestinal activity, showing itself by relaxation of the bowels, but this with but little increase of secretion. The stools are therefore generally composed of solid or semisolid fecal matter, and the operation of the medicine is mild and slow, the call to stool rarely occurring until from six to eight hours after the taking of the sulphur. If habitually used as a laxative, sulphur may induce a low catarrh of the alimentary tract. A disagreeable feature of its internal taking for any purpose is the tendency to the generation of flatus, offensive from the presence of sulphureted gases.

The therapeutic applications of sulphur are as follows: By some it is given internally as a means of getting the constitutional effects of the sulphides in constitutional diseases, but by the majority of practitioners the internal use is in laxative dose only, for a laxative effect. Such dose is from 4 to 12 gm. (ʒ i.–iij.), the washed or precipitated preparations being selected, and the powder mixed with molasses or diffused in milk for the taking. Externally, ointments containing sulphur are a good deal used as mildly irritant applications in skin diseases generally, and, specifically, as efficient parasiticidal dressings in itch. The following ointment is official in the United States Pharmacopœia:

Unguentum Sulphuris, Sulphur Ointment.—This preparation is compounded of thirty parts of sublimed sulphur and seventy of benzoinated lard, thoroughly incorporated. It may be applied without dilution, and is a very commonly used ointment for the treatment of the itch. It has a disagreeable sulphuretted smell, which may to a certain degree be masked by the addition of a little of some odoriferous volatile oil. *Edward Curtis.*

SULPHUR DIOXIDE (formula SO_2).—This compound, commonly miscalled *sulphurous acid gas*, is the product of the combustion of sulphur in air. It is a colorless gas, of a well-known characteristic "sulphurous" odor, and is both offensive to the nostrils and intensely irritant to the larynx. Even the fumes of a single burning sulphur match-head easily excite coughing, and air highly charged with the gas is fatal to life. Sulphur dioxide dissolves freely in water—in one-fiftieth of its volume at ordinary temperatures—forming in the process of solution an acid body, *sulphurous acid* proper (H_2SO_3) (see *Sulphurous Acid*).

The medicinally valuable property of sulphur dioxide is its peculiar noxiousness to the vitality of disease germs—a germicidal potency in which this compound, among gases, is rivalled only by formaldehyde, chlorine, and the vapors, respectively, of bromine and of iodine. Yet in its application to disinfect apartments the inherent uncertainties in the general method of aërial disinfection must never be forgotten. Could we be certain that every disease germ present in a chamber would be fully exposed to the action of the disinfectant gas, then we might rely with corresponding fulness upon the disinfection thus attained; but when we bethink us how easily these germs, microscopic in size, may safely be fortified against assaults of a gas by lodgment in cracks and crannies of furniture and fabrics, then we cannot but realize the important truth that even the most thorough aërial disinfection is at best but an unreliable procedure. In this connection the strong and offensive smell of sulphur dioxide is a distinct advantage, since, after fumigation by the gas, a chamber and all articles therein must be thoroughly aired, and thus additionally disinfected before the human nose will permit of their resumed use.

For the determination of the exact germicidal power of sulphur dioxide, very careful experiments were made by Sternberg,[1] by submitting vaccine virus, moistened with glycerin on the one hand, and dried upon ivory points upon the other, to the action, in a closed chamber, of air charged with varying percentages of sulphur dioxide, the exposure ranging from six to twelve hours. After exposure the virus, or the charged ivory points, were used for vaccination side by side with some of the same sample of virus which had not been exposed to the germicide. The general results were that in the case of moist lymph, destruction of infective power followed a twelve-hour exposure to air charged with a proportion of sulphur dioxide such as would be produced by burning three-quarters of a grain of sulphur for each cubic foot of air; and, in the case of the dried virus, similar results followed with an impregnation equivalent to the combustion, per cubic foot of air, of three grains of sulphur. These results accord with common experience, and teach that at least a one-per-cent. impregnation of air with sulphur dioxide will ordinarily be required to sterilize floating germs.

For the practical application of sulphur dioxide as an aërial disinfectant, the gas is most easily and cheaply obtained by burning sulphur, and in calculating the quantity of sulphur required it is obviously wisest to err very far on the safe side. A good rule, therefore, is to allow from two to three pounds for each one thousand cubic feet of chamber to be disinfected. The strength of fumes thus generated being vastly in excess of what is respirable, the procedure is possible only in vacated rooms. In a chamber to be operated upon, therefore, all living creatures must be removed, and every possible outlet for the gas, such as doorways, windows, and chimneys, must be closed, and even cracks and keyholes should be stopped with cotton or pasted over with paper. Then all articles needing disinfection must be thoroughly exposed on all sides to free access of the gas—bureau-drawers being opened, carpets, curtains, and blankets hung over lines across the room, and mattresses ripped open and the hair loosely strewn on the floor. The proper quantity of sulphur, in the form of sublimed sulphur, is then best mixed with one-fortieth of its weight of powdered charcoal, to secure readier combustion, and put into an iron pot, or upon a metal plate resting upon the legs of a half-open pair of tongs set across a wash-tub half full of water. By these precautions all danger of accidental setting of the floor on fire is avoided. A single door being left unsealed, the operator fires the sulphur by a live coal or a teaspoonful of flaming alcohol, and immediately retires, closing and sealing the door behind him. The sulphur is left to burn itself out, and next day the chamber is cautiously entered, the windows are thrown open, and all articles thoroughly aired. It is possible also to generate sulphur dioxide by burning carbon disulphide in a specially constructed lamp, but from the great inflammability of that compound the procedure is not altogether safe, and presents no advantages over the simple method by the combustion of sulphur. A convenient way of burning the sulphur is by use of sulphur candles, so called, in which a wick is incorporated in a moulded mass of sulphur. By lighting the wick sulphur dioxide is generated.

The use of sulphur dioxide as an aërial disinfectant is now largely superseded by the similar use of formaldehyde. *Edward Curtis.*

[1] American Journal of the Medical Sciences, April, 1883.

SULPHUR IODIDE.—Under the title *Sulphuris Iodidum*, Sulphur Iodide, the United States Pharmacopœia recognizes a preparation made by fusing by heat a mixture of one part of washed sulphur and four parts of iodine. The fused mass, after cooling, is broken into pieces and kept in glass-stoppered bottles. These lumps are grayish-black in color and have a metallic lustre. They have the odor of iodine and an acrid taste. The substance is practically insoluble in water, but dissolves in about sixty parts of glycerin. Alcohol and ether dissolve out the iodine and leave the sulphur. On exposure to the air, also, iodine is gradually lost.

This substance is differently regarded by chemists, some considering it a definite compound, corresponding to the formula I_2S_2, and others thinking it more probably a mere physical mixture. If a true chemical compound, it is one of exceptional instability, as the foregoing narration of its properties makes evident. To the therapeutist it presents itself practically as a joint representative of free sulphur and free iodine. It has occasionally been given internally for the purposes for which iodine is so administered, but the commoner employment is external as a gently irritant, iodized application in various skin diseases. It is best applied in the form of ointment made with lard, containing the sulphur iodide in the proportion of about eight per cent.

Edward Curtis.

SULPHURIC ACID.—Oil of Vitriol, H_2SO_4. This well-known acid is official in the United States Pharmacopœia under the title *Acidum Sulphuricum*, Sulphuric Acid, and is defined to be "a liquid, composed of not less than 92.5 per cent. of absolute sulphuric acid, and not more than 7.5 per cent. of water" (U. S. P.). Sulphuric acid is a heavy liquid of an oily appearance, colorless when newly made, but apt to acquire a smoky hue upon keeping. The specific gravity varies in different samples, but a gravity of 1.835 is recognized as standard by the United States Pharmacopœia. The acid has an intense affinity for water. Mixed with that fluid, it unites therewith with the evolution of considerable heat and with a contraction of volume, forming a clear solution. By reason of the same affinity, many organic bodies are decomposed upon treatment with sulphuric acid, the acid abstracting from their molecule the elements of water. Thus, by dehydration, oxalic acid is chemically broken up, alcohol is converted into ethylene gas (C_2H_4), wood and sugar are blackened, and textile fabrics and animal tissues are destroyed. Sulphuric acid, if diluted, also attacks most of the common metals, the prominent exceptions being gold, platinum, and iridium. Certain of the metals, such as copper, mercury, antimony, bismuth, tin, lead, and silver, are also acted upon by the concentrated acid, if the same be heated.

Upon the living animal system strong sulphuric acid acts purely as a powerful caustic. Its action is a spreading one, and the sloughs have a dusky or blackish hue, quite different in color from the yellow sloughs produced by nitric or hydrochloric acid. Swallowed in any quantity, the strong acid is an intense corrosive poison.

Therapeutically, strong sulphuric acid is occasionally used as a caustic, but the very intensity of its action is in its disfavor, so that nitric acid is generally preferred. The acid must be kept in glass-stoppered bottles.

Diluted, so as not to be corrosive, sulphuric acid, like all sour acids, tends to check acid, and to increase alkaline secretions, to inhibit fermentations, and, of course, to neutralize alkalinity. Dilute preparations of sulphuric acid are, therefore, available to repress morbid sweatings, both applied locally as lotions, and given internally to allay thirst and quicken appetite; to prevent fermentation of food in the *primæ viæ*, and so to cure diarrhœas due to the irritation of the products of such fermentations, and to neutralize the alkali of alkaline pyrosis. For these various purposes the following official preparations of the United States Pharmacopœia are available:

Acidum Sulphuricum Dilutum, *Diluted Sulphuric Acid.*—This preparation is a simple aqueous dilution of sulphuric acid, of ten-per-cent. strength. It is a colorless fluid, intensely sour of taste, and of about the specific gravity 1.070. It should be kept in glass-stoppered bottles. This grade of acid, although not corrosive, is quite irritant, and, for medical use, requires considerable further dilution. The dose is from ten to thirty drops, diluted thirty- or fortyfold, and to be taken through a tube, with the mouth well rinsed after the swallowing.

Acidum Sulphuricum Aromaticum, *Aromatic Sulphuric Acid, Elixir of Vitriol.*—This preparation consists of alcohol charged with sulphuric acid and tincture of ginger, and flavored, in addition, with a trace of oil of cinnamon. It contains about twenty per cent., by weight, of sulphuric acid. The preparation is a limpid, yellow fluid of an aromatic, ethereal, and strongly sour taste, and of specific gravity about 0.939. As its odor suggests, it probably contains some ethereal product of a reaction between the acid and alcohol of its composition. The United States Pharmacopœia considers, thus, that there is a certain amount of ethyl-sulphuric acid present. Aromatic sulphuric acid should be kept in glass-stoppered bottles.

This preparation is the favorite one for the internal administration of sulphuric acid. It is to be given in the same manner as the dilute acid (see above), and in the same or somewhat lesser doses. *Edward Curtis.*

SULPHURIC ACID, POISONING BY. See *Acids, Mineral, Toxicology of.*

SULPHUROUS ACID.—H_2SO_3. Sulphur dioxide gas (SO_2) is readily absorbed by water, and in so dissolving is to be regarded as uniting with water, molecule for molecule, with the formation of the acid body, H_2SO_3. The United States Pharmacopœia recognizes under the official title *Acidum Sulphurosum*, Sulphurous Acid, an acid representing not less than 6.4 per cent., by weight, of sulphur dioxide, and of specific gravity not less than 1.035. Sulphurous acid is a colorless fluid, smelling pungently of sulphur dioxide, and tasting both sulphurous and sour. It has a strong acid reaction, and first reddens and then bleaches litmus paper. It is wholly volatilized by heat, and tends constantly to undergo conversion into sulphuric acid by the absorptions of oxygen. This change is hastened by the action of light, hence the Pharmacopœia directs that sulphurous acid be put up in glass-stoppered, dark amber-colored bottles, and be kept in a cool and dark place. The pharmacopœial process for making the acid is to generate sulphur dioxide by heating a mixture of sulphuric acid and charcoal, and to conduct the mixed sulphur and carbon dioxides into distilled water. The sulphur dioxide dissolves in the water with the formation of sulphurous acid, and the carbon dioxide mostly escapes.

In its medicinal properties sulphurous acid resembles sulphur dioxide (see *Sulphur Dioxide*), and may practically be regarded, indeed, as a simple aqueous solution of that compound. It is a pretty potent germicide, and upon tender surfaces of the animal body is decidedly irritant. It bleaches vegetable colors. The acid is used, externally, as a wash in parasitic skin diseases, generally diluted two- or threefold, and, internally, is occasionally prescribed in cases of pyrosis and sarcinæ. It is, however, an exceedingly disagreeable medicine to take. The dose is 4 gm. (about one fluidrachm) of the official acid, taken in a wineglassful of water. *Edward Curtis.*

SUMACH or **SUMAC.**—Smooth Sumac. (*Rhus glabra*, U. S. P.) The dried ripe fruit of *Rhus glabra* L. (fam. *Anacardiaceæ*). This very handsome shrub or small tree grows abundantly in dry places throughout the greater part of North America. It is well distinguished by its smooth young branches from the stag-horn sumac (*R. typhina* L.) upon which they are velvety, and it bears little resemblance to other species. R. copallina has the leaf rachis winged between the leaflets. The poison sumac (*R. vernix* L.; see *Poisonous Plants*) has smooth green or yellowish-green fruits, in very loose open panicles, while that of *R. glabra* occurs in very large and very dense pyramidal masses. The commercial fruits are about a sixth of an inch long and broad, and somewhat flattened, ovoid, obtuse, truncate at the base. The epicarp is of a deep crimson color and glandular-tomentose, and contains a single smooth yellowish stone. The hairy covering is strongly acid and astringent. The hairs are rather short and matted, those of the stag-horn sumac being shaggy. The drug contains two different classes of constituents, imparting distinct medicinal properties, besides the fatty oil of the seeds. About two per cent. or three per cent. of tannic acid and a very little gallic acid make it a mild and useful astringent, while its malic acid renders it distinctly refrigerant. For the latter purpose it is now scarcely employed, although it was largely so during earlier periods, when lemons and similar refrigerant fruits were less readily obtainable in country districts. As an astringent, sumac berries are usually employed for gargling, in various forms of sore throat, and are frequently combined with chlorate of potash. The acid taste renders this more grateful than other throat astringents. The drug is also often used as an intestinal astringent. The official preparation is the fluid extract, which contains ten per cent. of glycerin, and the internal dose of which is 2 to 4 c.c. (fl. ʒ ss.–i.). This is commonly diluted with from one to three parts of water, to be used as a gargle, though the decoction and infusion are more commonly employed for that purpose.

Henry H. Rusby.

SUMBUL.—U. S. P. (*Sumbul Radix*, B. P., *Muskroot*.) The dried root of *Ferula Sumbul* Hook., f. (fam. *Umbelliferæ*). This large perennial herb, belonging to the asafœtida-, galbanum-, and ammoniacum-yielding group of the family, and inhabiting the same general region, has a large, rather short cylindrical root, attaining a diameter of four or five inches, and a length of say a foot, when it divides into several stout branches. The root itself as a perfume, and afterward as a medicine, appeared in Europe about 1840.

Sumbul occurs in transverse segments, varying in diameter from about 2 to 7 cm., and in length from 15 to 30 mm.; light, spongy, annulate or longitudinally wrinkled; bark thin, brown, more or less bristly fibrous; the interior whitish, with numerous brownish-yellow resin dots and irregular, easily separated fibres; odor strong, musk-like; taste bitter and balsamic.

CONSTITUENTS.—The most important constituent is the *resin*, of which there is nine per cent. (Flückiger); it has a musky smell, more developed in contact with water, and a bitter, aromatic taste. The root contains also a small quantity of dull-bluish-colored oil.

ACTION AND USE.—Sumbul has not any important medicinal value; like asafœtida, and its namesake, musk, it is gently stimulant and slightly antispasmodic, and may be given for the same nervous conditions as they; but its principal employment is in the preparation of some perfumes, where it takes the place of musk. A tincture (*Tinctura Sumbul*, strength one-tenth) is official.

W. P. Bolles.

SUMMERVILLE, SOUTH CAROLINA.—This popular winter resort, among the pines, is situated in the southeastern portion of the State, twenty two miles northwest from Charleston. Its favorable features as a health resort are its dry sandy soil, pine forests, equable mild temperature, and freedom from the enervating heat peculiar to points farther south. The pines are an especial feature of the place, and abound not only about the town but are thickly scattered throughout it "in the middle of the streets, on the sidewalks, in the gardens, and in fact everywhere." There are local laws prohibiting the cutting down of these trees. The atmosphere is permeated with their balsamic odor, and if there is any virtue in such a naturally medicated air it must surely be found here.

The population of the town is about 5,000 souls, and there are various churches, schools, shops, good markets, etc.

The sanitary condition is carefully supervised by an efficient board of health, of which Dr. A. H. Hayden is president, to whom the writer is indebted for climatic and other information contained in this article. Tuberculosis is included in the list of contagious or infectious diseases required to be reported to the board, and whenever in a hotel or any other building a case of consumption has "lived, resided or died," it must be reported in writing to the secretary of the board of health; and "immediately upon receipt of each report, the health officer shall, at the expense of the occupant or owner of the premises, cause said premises to be at once fumigated and properly disinfected." [Extract from the Rules and Regulations of the Board of Health.]

The natural drainage is excellent, and this is supplemented by an open canal, on one side of the town, some miles in length, and into this accessory canals or ditches empty. Soil carts are also employed by the town.

The water supply is very generally derived from open wells, although the Pine Forest Inn and Pinehurst (Tea Farm) have artesian wells.

The accommodations are good, there being several first-class hotels and many boarding-houses.

The outdoor attractions and amusements are walks and drives among the pines, golf, many excursions in the vicinity to various historic and ancient landmarks,—old churches, plantations, and the like,—the Pinehurst Garden Park, with its large variety of ornamental trees and shrubs, and the Pinehurst Tea Gardens where the tea plant is successfully grown. Twenty-two miles distant is Charleston, with all its attractions in and about the city. There are also opportunities for shooting and fishing.

The subjoined meteorological table affords an index of the various climatic features. It will be seen that the winter temperature is comparatively mild, the mean maximum and minimum temperatures not extreme, and a large majority of the days are sunny, so that one can be out of doors the most of the time. The mean average annual rainfall for nineteen years was 56.76 inches, and for the four years of the chart, 59.16 inches. On account of the character of the soil the ground is quickly dry after the heaviest rainfall. The average relative humidity appears high, but it is said that there is no sensation of dampness in the atmosphere. According to Dr. W. H. Prioleau, of Summerville (*Therapeutic Gazette*, September, 1897), the climate is most beneficial to invalids from October to May, "for during that time there is bright sunny weather, and the atmosphere changes are seldom so sudden as to cause any serious anxiety or discomfort." "The town is near enough to the sea coast," says the same authority, "to cause the atmosphere to lose the aridity of a sandy plain; at the same time sufficiently distant to be free from all dampness."

* CLIMATE OF SUMMERVILLE, S. C.—PERIOD OF OBSERVATION FROM JANUARY, 1899, TO JANUARY, 1903.

	November.	December.	January.	February.	March.	April.	July.	September.	Year.
Temperature—Degrees Fahr.									
Average mean	59.3°	47.5°	46.8°	46.6°	54.4°	59.2°	80.1°	72.5°	
Average maximum	79.5	74.7	74.8	76.2	81.2	83.7	96.2	91.0	
Average minimum	29.5	19.0	21.4	16.7	27.6	34.7	65.2	53.5	
Mean maximum	66.5	58.7	58.4	56.3	67.7	68.1	88.3	82.7	
Mean minimum	51.2	46.2	36.8	37.1	44.9	50.2	71.2	65.2	
Average daily range	15.3	12.5	21.6	19.2	22.8	17.9	17.1	17.5	
Average monthly range	51.2	55.0	53.4	57.4	53.6	49.0	31.0	37.5	
Humidity—									
(The humidity was recorded only a portion of the period.)									
Average relative	77.4%	76.8%	70.8%	70.9%	72.5%	73.0%	83.5%	79.5%	
Precipitation									
Average in inches	2.77	3.73	3.49	4.67	3.01	4.08	5.25	3.56	59.16
Wind									
Prevailing direction	N. E.	S.W.-N.E.	S. W.	S., N. W.	S. W.	S. E.	S. W.	N. E.	N.E., S.W.
Weather—									
Average number of clear days	18.2	15.0	13.0	10.4	13.4	15.7	15.2	19.7	
Average number fair days	6.7	7.5	9.2	10.0	11.2	9.2	12.5	5.2	
Average number clear and fair days	24.9	22.5	22.2	20.4	24.6	24.9	27.7	24.9	
Average number cloudy days	5.0	8.2	8.8	7.6	6.4	5.0	3.2	5.0	

Frost occurs from November to April, with ice and occasional snow in the coldest months of the year.

* These data were obtained through the kindness of Dr. A. H. Hayden, of Summerville, S. C.

The diseases and conditions for which this climate is suitable are pulmonary tuberculosis in the early stage, laryngitis, bronchitis, asthma, influenza, neurasthenia, and insomnia. Further, it is a favorable place for a winter residence for the many who, for one reason or another, desire to escape the cold of the North or West. "I must admit," says Elizabeth Stuart Phelps, writing in *McClure's Magazine*, "that Summerville is a land of lovely dreams, with more conveniences and fewer discomforts, more tonic and less enervation than any other Southern health or pleasure resort I have seen. Roses run riot over it; its homes are gardens, and gardens are its homes. There the winds are laid. . . . There it is always dreamland, and there the knotted Northern nerves may relax and rest."

One can reach Summerville by various railroad routes or by water from New York to Charleston and from thence by rail. The time from New York by rail is twenty-four hours. *Edward O. Otis.*

SUMMIT SODA SPRINGS.—Placer County, California.

Post-Office.—Summit Soda Springs. Hotel and cottages.

Access.—Viâ Central Pacific Railroad to Summit station, thence by stage or carriage, twelve miles to the springs. The location is near the summit of the Sierra Nevada Mountains, at an altitude of 16,000 feet above the sea-level. The region is one of picturesque grandeur, and the magnificent view from the neighborhood of the springs is unobstructed for miles around. The air is pure, dry, and invigorating, being cool and pleasant all the summer. The springs are situated in an expansion at the head of a deep canyon, along which winds one of the forks of the American River. The hotels and cottages are pleasantly located, and good bathing facilities are at hand. Two analyses have been made. They are as follows:

One United States Gallon Contains:

Solids.	Dr. Winslow Anderson, 1888. Grains.	J. T. Randolph, 1878. Grains.
Sodium chloride	26.18	26.22
Sodium bicarbonate	4.11	....
Sodium carbonate	5.75	9.50
Potassium carbonate	.82	Trace.
Magnesium carbonate	4.05	4.20
Calcium bicarbonate	38.93	43.20
Calcium carbonate	6.55	....
Ferrous oxide	....	1.55
Ferrous carbonate	2.70	....
Borates	Trace.	....
Alumina	1.13	1.75
Silica	1.94	2.06
Organic matter	Trace.	....
Total solids	92.16	88.68

Free carbonic acid gas, 187.25 cubic inches (saturated).

The water has antacid, diuretic, aperient, and tonic properties, and is useful in the treatment of dyspepsia, torpidity of the liver and bowels, Bright's disease, stone in the bladder, etc. *James K. Crook.*

SUNDEW. See *Droseraceæ.*

SUPERFŒTATION.—Ordinary multiple pregnancy is generally the result of the simultaneous fertilization of more than one ovule. Should such fecundation be *successive* instead of *simultaneous*, it is called *superimpregnation*. Of this, there are two varieties: (1) *Superfecundation*, which occurs when two (or more) ovules belonging to the *same* period of ovulation are impregnated by successive acts of coitus. (2) *Superfœtation*, which occurs when two or more ovules belonging to *successive* periods of ovulation are impregnated, so that a woman who is already pregnant becomes again pregnant a month or more later, and carries simultaneously in the uterus both these products of conception. Thus a second ovum is fertilized after the first has been developing for a month or more, and the two fœtuses continue to develop simultaneously and independently.

The term *superimpregnation* has been used in two senses: (1) as a generic term including both superfecundation and superfœtation; and (2) as synonymous with superfœtation or superfecundation. We believe the former to be the more correct usage, though the term might well be abolished.

Superfecundation is now well recognized, and needs no discussion. There have been reports of too many well-authenticated cases to allow of any doubt on this point. The most conclusive proofs are furnished by those cases in which a black woman has at the same time given birth to twins, of different colors, the one a mulatto and the other black, and whose features have unmistakably indicated their paternity. In many of these instances the mother has explained that both a white man and a black man had had intercourse with her within a short interval of each other. Similar, but not so frequent, are the reported cases in which a white woman has had intercourse successively with a white man and a black man, and has given birth to twins of different colors and races. Illustrative cases in abundance may be found in the pages of works on medical jurisprudence, notably those of Tidy and Beck.

But *superfœtation* has not been so readily admitted. Like other theories which have subsequently crystallized into facts and been accepted, the possibility of superfœtation has been alternately asserted and denied. Thus, according to Beck, Brassavolus, who lived between 1500 and 1555, said that he had known *superfœtation to be epidemic!!!* By later physicians, the possibility of superfœtation was generally accepted, and many cases were brought forward to support the claim; but it is doubtful how many of these cases would stand the test of a thorough investigation at the present day; and some of them are certainly capable of much simpler explanation. The next stage was that of vigorous denial. This view has been taken by Lusk, who says: "That impregnation can take place at two periods distant from one another—must be regarded as an inadmissible hypothesis, until physiologists shall succeed in demonstrating in a single instance, by the presence of corpora lutea of different ages, that ovulation ever occurs during pregnancy" ("Midwifery," 1896). No doubt ovulation does ordinarily cease during pregnancy; and this may be one of the reasons why there are so few cases of superfœtation. But that ovulation can occur during pregnancy has been demonstrated by Christopher (*Am. Jour. of Obstet.*, 1886), who also cites Slavjansky's case, as follows: "Professor Slavjansky, of St. Petersburg, in a laboriously exact paper in the *Annales de Gynécologie*, vol. ix., furnishes a report of a very interesting and instructive case. A woman, twenty-four years of age, had menstruated since her seventeenth year, and had been delivered of a child three years previous to her present pregnancy. Her last menstruation occurred November 5th, 1876, but conception is supposed to have taken place early in December. Death occurred March 23d, 1877, from a rupture of the left Fallopian tube, due to tubal pregnancy. The legal autopsy was made thirty hours after death, and the generative organs afterward given to Slavjansky for examination. He found on the left ovary a tumefaction which presented a cavity 1 to 3 cm. in diameter, and on microscopic examination presented all the characters of a Graafian follicle. The contents, which had been coagulated by alcohol, were carefully separated by a needle, and on examination under the microscope were found to be the cells of the discus proligerus, and within them was found the ovule with its eccentrically situated germinal vesicle and germinal spot clearly marked. In the cortical substance of this ovary were found numerous Graafian follicles in all degrees of development, from the primordial follicle up to the follicles of 0.3 cm. in diameter. A corpus luteum of 0.4 cm. in diameter was found immediately under the principal cavity. In the cortical substance of the right ovary were numerous follicles of varying degrees of development, one being 0.3 cm. in diameter. A recent corpus luteum 1 cm. in diameter was clearly outlined in the surrounding tissues." Of even more value, and apparently unassailable, is Cosentino's case: "A woman in the sixth month of pregnancy died of heart disease. The ovaries were subjected to a careful microscopic examination, and in them were found follicles in all stages of development; also one ruptured follicle of a diameter of 15 mm. with ragged margins and a rich arterial and venous network surrounding the theca folliculi. Between the granular layer and a lot of detritus a perfectly mature ovum with all of its elements was found" (quoted by Herzog, in Chicago *Medical Record*, July, 1898). Even more emphatic in his rejection of superfœtation is Kleinwächter; he says: "The whole claim as to superfœtation, however, collapses, because the base on which this alleged occurrence rests does not exist. As soon as pregnancy has occurred, ovulation ceases. Superfœtation, therefore, is a physiological impossibility. However, even if ovulation did take place, superfœtation nevertheless could not occur, since the sperma, in consequence of the plug of mucus in the cervix, cannot reach the ovum. This plug of mucus which forms in the cervix, the proliferation of the mucosa of the uterus, the fusion of the decidua reflexa with the decidua vera, which takes place in the twelfth week, make it impossible, even if an ovum should be discharged from the uterus, that it could come into contact with the sperma deposited in the vagina" (Herzog, *ut supra*). But these objections are more fanciful than real, for it has now been proved that: (1) Ovulation can occur during pregnancy (*vide supra*). (2) The plug of mucus which is found in the cervix of the pregnant uterus is also found in the cervix of the non-pregnant uterus, and, therefore, if it were a bar to superfœtation, it would also prevent pregnancy! Indeed, it has been asserted that, so far from this plug of mucus preventing the entrance of the spermatozoa, it, by absorption, rather assists them into the uterus. (3) The fusion of the decidua vera and the decidua reflexa occurs "at the fourth month" (J. Whitridge Williams, "Obstetrics"), and until this fusion occurs there is abundant opportunity for the spermatozoa to pass upward toward the Fallopian tube.

At the present day, both the possibility and the probability of superfœtation are fully admitted; that it is of frequent occurrence, or that the majority of the cases formerly reported under this heading are correctly designated, is not conceded. It must be remembered that superfœtation is neither normal nor physiological; it is a pathological condition. In an ordinary normal pregnancy we note the following (among other) characteristics: (1) It is single; (2) it is intra-uterine; (3) menstruation and ovulation both cease; (4) the uterus is neither bifid nor septate, but single. Now, variation in any of these conditions may produce pathological or abnormal results; and superfœtation is one such pathological variation. The possible results of superfœtation are two: *either* two children equally well developed, but born at different times; *or* the birth of twins, one of which is developed and the other not. Those who deny the possibility of superfœtation have explained these conditions as being due *either* (1) to an ordinary twin pregnancy, or a superfecundation, in which one fœtus was "crowded," or for some other reason did not obtain adequate nutrition during gestation, and was therefore not properly developed; *or* (2) to an ordinary twin pregnancy or superfecundation in which one ovum became blighted, and possibly suffered compression and partial mummification (= *fœtus papyraceus*); *or* (3) to a bifid uterus, in which one ovum was developed in each half.

There can be no doubt that many of the earlier reported cases of superfœtation can be explained as above; but there still remain some that are intelligible only on the ground of superfœtation. Thus, where viable children are born at an interval of *four months*, and the uterus is not double, there is at present no explanation to be offered beyond the one that forms the subject of this article. Tidy, in his "Legal Medicine," quotes one such case from Naphey: "Mary Anne Bigaud, at thirty-seven, gave birth, on April 30th, 1748, to a full-term mature boy, which survived its birth two and one-half months, and to a second mature child (girl) on September 16th, 1748, which lived for one year. The mother was proved after her death not to have had a double uterus. (This case is vouched for by Professor Eisenman, and by Leriche, surgeon-major of the Strasbourg Military Hospital)." And several such cases are given by Bonnar (*Edin. Med. Jour.*, January, 1865), "cases that prove, as far as anything of the sort can prove, that superfœtation is a positive fact."

R. J. E. Scott.

SUPRARENAL BODIES, PATHOLOGY OF.—Inasmuch as this subject has already been discussed to some extent in the article on *Addison's Disease*, only those conditions will be mentioned here which were not considered under that head.

Anomalies and Malformations.—Total absence of the adrenals has been reported, but in some of the cases it is impossible to state positively that the absence was congenital and not the result of an extreme atrophy. Congenital absence and hypoplasia have, however, been observed in cases of hemicephalus and anencephalus and in certain forms of malformations of the genito-urinary organs. According to Zander, the adrenal hypoplasia is associated only with defects of the frontal lobes. Aplasia of the medullary portion of the suprarenals has been seen in cases of chronic hydrocephalus, but the connection between these conditions is not clear. Fusion into one organ, abnormality of shape and form, displacement, separation into several bodies, and hypertrophy have been described. As a rule, the malformations of the suprarenals bear no relation to those of the kidneys, though in one case reported of horseshoe kidney there were four adrenals. Malformations of these organs appear to stand in a closer relationship with those of the sexual glands. Marchand has reported a case of marked hyperplasia of the suprarenals and of the accessory suprarenal structures in the broad ligament, in a case of rudimentary development of the ovaries and external hermaphrodism.

Accessory Suprarenals (Adrenal Rests).—Small isolated portions of adrenal tissue, varying in size from a pinhead to a cherry, are of very frequent occurrence in the immediate neighborhood of the main organ, lying in the peri-adrenal connective tissue, in the solar plexus, in or under the kidney capsule, in the kidney substance, or even in the liver. Small bodies consisting of tissue resembling that of the adrenal cortex are also found in the broad ligament, along the spermatic vessels, in the inguinal canal, on the spermatic cord, and in the retroperitoneal connective tissue. By a number of authors the adrenal tissue found in the last-named regions is regarded as analogous to the suprarenal organs of the lower vertebrates, the main adrenal organs of man representing the interrenal bodies of these animals. Marchand having been the first to observe their presence in the broad ligament, they have been designated the "adrenals of Marchand" ("Marchand'sche Nebennieren"). By other writers they are regarded as misplaced adrenal tissue referable to some disturbance of development. The chief pathological importance of these bodies is the possibility of the development in them of the same form of new growths as arise in the adrenals themselves, or in the adrenal "rests" of the kidney, liver, etc. Adrenal tissue has been found in a cystic tumor of the broad ligament. The small masses of adrenal tissue found in the inguinal canal or upon the spermatic cord have been mistaken for lipomata. It is also possible that these accessory bodies may undergo a compensatory hypertrophy in the case of destruction of the main organs in early life. Accessory adrenals or "adrenal rests" are of a yellowish color, and have a fatty shine. From their close resemblance to fat tissue they have frequently been mistaken for lipomata. In the great majority of cases the microscopical structure resembles that of the fascicular zone of the adrenal cortex; and very rarely do these bodies contain cells resembling those of the medullary portion of the organ.

Circulatory Disturbances.—Chronic passive congestion of the systemic veins gives rise to a *passive congestion* of the adrenals, which in consequence are enlarged and of a deep brownish-red color. *Hemorrhage* into the adrenals may occur in congenital or acquired hæmophilia, in pernicious anæmia, in leukæmia, after thrombosis of the veins, and as a result of trauma or of general passive congestion. Severe injuries, such as fracture of the spine, are frequently associated with hemorrhage into or about the adrenals. Hemorrhage into the suprarenals appears to be of frequent occurrence in the new-born. According to Mattei and Spencer, some degree of congestion of the suprarenals is always present in the new-born. As the border line between slight hemorrhage and congestion is not well defined, it is very probable that some cases of congestion have been regarded as hemorrhage. If not confirmed by microscopical examination, no diagnosis of adrenal hemorrhage should be made unless distinct hemorrhagic spots or bands are seen in the tissue of the organ, or unless the hemorrhage is so extensive as to convert the organ into a cyst filled with fluid or coagulated blood.

Hamill has collected ninety cases of adrenal hemorrhage occurring in the new-born. Various causes are given, but it is probable that the most common etiological factor in still-born children is prolonged and difficult labor requiring manipulation, especially in the case of breech delivery. In some of the infants dying within a few days after birth, the hemorrhage may be the result of injuries received during labor, but in the great majority of such cases some form of infection is to be regarded as the cause; in practically all cases dying after the tenth day some form of infection produces the condition. Of the ninety cases collected by Hamill, twenty-eight were seen in still-born children, twenty-seven between birth and the separation of the cord, and eleven after the latter event. The hemorrhage may be unilateral or bilateral, the lesion apparently being more common upon the right side, this being due probably to anatomical reasons. The hemorrhage is usually into the medullary portion, and the appearances vary with the amount of extravasation. The gland may be greatly enlarged and the blood may break through into the peritoneal cavity when the extravasation is large. When not immediately fatal the hemorrhage may lead to cystic or fibrous change in the gland, and it has been suggested that possibly some of the cases of Addison's disease in which a marked fibrosis of the gland was found may have been the result of a hemorrhage occurring at an earlier period. Old hemorrhages may become calcified.

Hemorrhagic infarction of the suprarenal due to thrombosis of the central vein has been reported as occurring in a child of eleven months. The etiology of the thrombus was not clear, but it was thought to be marantic in origin. A similar condition may follow thrombosis of the renal vein.

RETROGRADE CHANGES.—Simple *atrophy* of the adrenals occurs in old age and in cachectic conditions. A marked atrophy has been observed in cases of Addison's disease. The atrophic organs may be no larger than peas. Associated with the atrophy of old age there is frequently seen a marked pigmentation of the medulla.

Necrosis of the adrenals occurs in tuberculosis, eclampsia, in certain infections and intoxications, in extreme passive congestion, and following hemorrhage and thrombosis of the central vein. Focal necrosis has been observed in malaria. Inasmuch as the medulla of the adrenals very quickly undergoes a post-mortem disintegration, such change occurring even within from half an hour to one hour after death, the presence of a soft brownish substance in a cyst-like cavity representing the medulla should not be mistaken for a pathological condition. The post-mortem change may be recognized by the absence of hemorrhage or of changes in the cortex. The cyst-like cavities formed by post-mortem change gave rise to the designation "suprarenal capsule."

Cloudy swelling of the cells of the adrenals occurs in severe general intoxications.

Fat in the form of small droplets is almost constantly present in the cortical cells of the adult adrenal, particularly in those of the fascicular zone. Large droplets are often present. Excessive fatty change has been described as occurring in marasmic infants and in cases of congenital syphilis, and has also been regarded as a cause of Addison's disease.

Amyloid change is of frequent occurrence in the adrenals in cases of general amyloidosis. The amyloid is deposited in the walls of the blood-vessels and in the connective tissue. The parenchymatous cells become atrophic and may entirely disappear, the organ becoming larger, hard, waxy, and bluish-gray in color. The cortex usually shows the greatest change, but the medulla is not infrequently affected alone or coincidently. Amyloid change of the adrenals has also been regarded as a cause of Addison's disease.

Calcification of the adrenals may follow caseous necrosis or hemorrhage, and is not infrequently present without any signs of other pathological changes.

Pigmentation of the cells of the medulla is increased in old age and in conditions of excessive blood destruction.

Inflammation.—Simple inflammation of the adrenals is very rare. Metastatic abscesses occur in pyæmia and may lead to total destruction of the organ; they may rupture into the intestine or into the retroperitoneal connective tissue. Fibrosis of the adrenals due to chronic interstitial inflammation has been reported, but the nature of these cases is obscure. Such changes have also been reported as occurring in Addison's disease.

TUBERCULOSIS.—Miliary tubercles may be found in the adrenals, but tuberculosis of these organs is usually of the fibro-caseous type. The glands in the latter condition become enlarged, hard, and often nodular. The capsule is thickened, the parenchyma either wholly or in part replaced by a firm, dry, cheesy, yellowish or a soft pus-like material. About the capsule there may be present a large amount of scar tissue involving the semilunar ganglia. Tubercle bacilli are found in the caseous areas. Calcification or liquefaction may follow the caseation. In many cases only one organ is affected. The condition is rarely primary, but is in the great majority of cases secondary to a chronic pulmonary tuberculosis. When primary it may form the starting-point for a tuberculosis of the peritoneum. (See *Addison's Disease*.)

SYPHILIS.—Gummata have been found in the adrenals, and in both congenital and acquired syphilis thickening of the blood-vessels may occur. Total fatty degeneration has also been described as occurring in cases of congenital syphilis.

ACTINOMYCOSIS of the adrenals has been reported as extending from actinomycotic processes in the liver.

PROGRESSIVE CHANGES.—*Hypertrophy* and *hyperplasia* of adrenal tissue may occur in young individuals after loss of the main organ or organs. In the latter case the adrenals of Marchand or other accessory adrenal tissue may undergo a compensatory hypertrophy. The diffuse hyperplasias are very rare, but localized nodular hyperplasias are frequent.

TUMORS.—The most common form of tumor is that arising from adrenal rests (see *Hypernephroma*). These growths may reach a very large size, and occasionally present the appearance of a large cyst filled with a brownish pultaceous material produced by the extensive fatty degeneration characteristic of these growths. The smaller growths appear as yellowish nodules resembling fat tissue. The microscopical picture is usually that of the fascicular zone of the cortex, but growths consisting of medullary tissue have also been described. Though frequently benign except for size, the hypernephromas of the adrenals may through continued atypical growth take on the characteristics of a carcinoma. It is probable that the majority of the malignant tumors arising primarily in the adrenals, which have been reported as carcinomata, in reality belonged to the hypernephromata, though it is also possible that tumors of the type of carcinoma may be primary in this organ. The term *adenoma* or *malignant adenoma* is frequently applied to these growths (*struma suprarenalis*); at present they are classed with the hypernephromata.

Sarcoma.—Melanotic and non-pigmented sarcomata have been reported as primary in the adrenals. Lym phosarcoma is of rare occurrence. There exist in the literature numerous accounts of sarcoma of the adrenal, but it is very probable that these tumors belonged to the hypernephromata and not to the true sarcomata. This is especially true of the cases reported as "malignant tumor," "adenosarcoma," "alveolar sarcoma," "carcinoma," etc. Through the occurrence of hemorrhages the growths may become very large, and occasionally break into the veins and set up metastases. The latter are found chiefly in the lungs.

Gliomata and *neuromata* of the adrenals have been described, but the true nature of the cases is uncertain. They arise from the medulla or from the sympathetic system.

Connective-tissue growths are very rare. Cystic lymphangiomata have been very rarely observed. Ganglionic fibromyoangioma has also been described.

Secondary tumors (sarcoma and carcinoma) are of not infrequent occurrence. Metastasis takes place usually through the lymphatics. Secondary carcinoma may be associated with Addison's disease.

Parasites.—In very rare cases *echinococcus* has been found in the adrenals. *Aldred Scott Warthin.*

SUPRARENAL BODIES, PHYSIOLOGY OF. See *Secretion, Physiology of.*

SUPRARENAL CAPSULE, EXTRACT OF. See *Adrenalin*, and *Organotherapy.*

SUSPENSORY BANDAGES are employed for prophylactic purposes when the scrotum and its contents are normal, but exposed to injury or disease. Thus they are recommended to men whose occupation compels them to stand for hours in the upright position, to lift heavy weights, to take severe physical exercise, or to ride a horse or a bicycle for hours at a time. Athletes usually wear bandages technically called "jock-straps" in place of suspensories. These "jock-straps," however, while immobilizing the external genitals, drag them upward, and, in fixing them upon the pubes, may produce abnormal pressure of the scrotal contents, and expose them to the injuries which they are intended to prevent. Among the prophylactic uses of suspensory bandages, they are recommended in gonorrhœa to prevent epididymitis and orchitis. Experience, however, has proven that they are not always effective in this regard. The therapeutic uses of suspensory bandages are as varied as are the diseases which affect the scrotum and its contents. In general depressed states, where relaxation of the scrotum causes it to hang down below its normal level, a well-fitting and properly adjusted suspensory bandage gives the organs within it the needed support. In local conditions, such as scrotal dermatoses, it serves to immobilize the sac and thus compels any medicaments which may be applied to the skin to remain in direct contact therewith. In varicocele of a minor degree it oftentimes renders operation unnecessary. In funiculitis, epididymitis, orchitis, and orcho-epididymitis, when the swelling is not too great to be controlled by a suspensory bandage, it serves its purpose admirably. When the swellings in these diseases are very great, they require modifications of suspensory bandages, called compressors, such as the Miliano, Zeissl, Langlebert, Casper, and other scrotal compressors. These modifications not only support the scrotum firmly against the ascending rami of the pubis, but, having a firm, strong bag with lace-strings, they render it possible to subject the scrotum and its contents to uniform compression. It is essential to suspensories and compressors that traction should be exerted in a posterior direction upon the lower (posterior) apex of the bag. This traction is made by means of counter-straps. If these straps are omitted, as they sometimes are, especially in the cheaper forms of suspensories, these contrivances then become useless and even at times injurious. Firm support and compression are not possible without these counter-straps. When they are absent the scrotum is dragged upward and forward by the waist-band, and the posterior margin of the bag is likely to cut into the posterior surface of the scrotum. Many forms of excellent suspensory bandages are made, but no one form can be recommended for all prophylactic or therapeutic uses. The individual conformation of the external genitals varies as much as does that of the hand or foot. Suspensory bandages must therefore be "fitted" to the genitals, with consideration for the individual peculiarities as well as for the object to be attained. The inflexible rules regarding the effective use of suspensory bandages are, first, that they must not produce the slightest discomfort, and next, that they must instantaneously give at least marked, if not entire, relief from pain. If these ends are not attained, the bandage employed is not applicable to the case or has been defectively applied. In epididymitis, when the cord is not much involved, strapping the testicle by Fricke's method often enhances to a marked degree the value of a suspensory bandage. It must be remembered, however, that the application of strips of adhesive plaster for the accomplishment of the desired end is painful, unless it be done by an operator of great experience in the use of this form of dressing. When it is properly applied this dressing promptly reduces swelling and pain, and renders the patient entirely willing to have the operation repeated as often as may seem desirable. Gerson, of Berlin (*Berliner klinische Wochenschrift*, No. 3, 1897), devised "scrotal elevating strips" as a substitute for suspensory bandages. These strips (*Suspensionsbinden*) are elastic, adhesive bandages, with the upper margin softly fringed. Before applying them it is desirable to empty the lower part of the scrotum as much as possible by crowding the testicle firmly up against the external ring. In a certain number of cases these strips prove successful, and as it is an easy matter to apply them they may well be recommended for trial.

Ferd. C. Valentine.

SUTHERLAND SPRINGS.—Wilson County, Texas.

Post-Office.—Sutherland Springs. Hotel and boarding-houses.

Access.—From San Antonio viâ the San Antonio and Gulf Railroad, thirty miles distant.

The resort is pleasantly located on the Rio Cibolo, at an elevation of about 400 feet above the sea-level. The surrounding country is of a gently undulating character and presents much pleasing scenery of a mild and tranquil character. This part of the State is celebrated for its genial climate and its freedom from malarial and miasmatic disorders. At the date of our correspondent's letter (December 27th), the flowers were in full bloom out of doors and the gardens were as green as in summer. There is no ice at any time, and the frosts are seldom sufficiently severe to cause the trees to shed their leaves. Many persons who begin the baths during the summer continue them during the winter months, as it is seldom cold enough to interfere with this pastime. No analysis of the water has been made, but the numerous springs are said to offer a variety of therapeutic properties—tonic, alterative, astringent, laxative, diuretic, etc. This combination of valuable spring waters with a mild, dry, equable climate makes the location a very attractive one for a large class of sufferers from various ailments. It is said that a fine modern hotel will soon be built. *James K. Crook.*

SUTURES.—Suture Materials.—The materials used for sutures are very varied. The ones most employed are silk, catgut, silkworm gut, silver wire, horse-hair, and kangaroo tendon.

Silk, not being absorbable, is not good, except in the smaller sizes, for deep sutures or ligatures, and finds its use chiefly in uniting the skin and in intestinal work. It is also used for tying off pedicles where great strength is requisite. It is best sterilized by boiling it on spools in alcohol or in a one-per-cent. solution of carbonate of sodium. The small sizes are usually dyed black for easier detection. When the suture is small it may be cheapsulated and thus remain in the tissues indefinitely; but, on the other hand, it may give rise at any time to inflammation and the formation of a fistula.

Catgut is used largely for deep sutures, *i.e.*, those which are buried in the deeper parts. They are absorbed

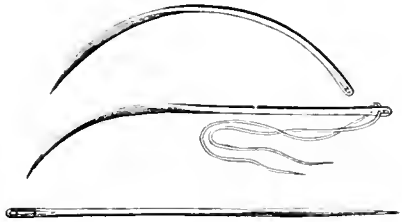


FIG. 4564.—Surgical Needles.

and thus produce no subsequent irritation, which is possible in non-absorbable materials. In order to prevent too rapid absorption the catgut may be "chromicized." Chromicized catgut may remain unabsorbed for as long a period as from two to six weeks. The gut is soaked in ether for twenty-four hours and placed for twenty-four hours more in a four-per-cent. solution of chromic acid in water. The gut is now dried in a hot-air sterilizer and disinfected by one of the usual methods. The most serious objection to catgut as a suture material is the difficulty of sterilizing it completely. This difficulty has given rise to a great number of methods of disinfection. Boiling in ninety-five-per-cent. alcohol for an hour with the use of a still is a very satisfactory method. For other methods, see under *Dressings (Surgical)*. Catgut is not so satisfactory as silk for suturing the skin.

FIG. 4565.—Interrupted suture.

Silkworm gut is an excellent material for tension sutures, but should not be used for buried sutures, as it has sharp ends and is non-absorbable. It is used extensively in perineum and cervix operations. It is prepared by boiling it in alcohol or water. It may be dyed black for easier detection. When boiled too often it breaks easily if drawn tight.

Silver wire is used in holding bone fragments together and also as a tension suture for the skin. The suture is twisted on itself and then it holds the parts in contact. It can be satisfactorily sterilized by boiling it in water.

Horse-hair is occasionally used for the skin when there is not great tension on the edges of the wound. It is sterilized by boiling it in water or alcohol.

Kangaroo tendon is obtained from the kangaroo's tail or leg. It is very strong and pliable. It can be satisfactorily used for buried sutures, and has found its chief employment in hernia operations. It should be chromicized. It is finally absorbed, but only after several weeks.

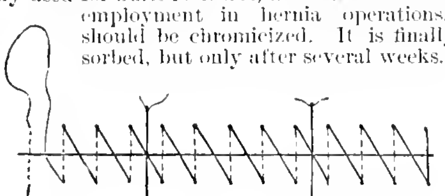


FIG. 4566.—Continuous Suture.

Surgical Needles.—These are of different sizes and shapes (Fig. 4564). They may be straight or curved, round or flat. Hagedorn needles which are flat and have a sharp cutting edge are in very general use. In intestinal work round needles are preferable, as they do not cut the thin tissues, causing the suture to pull out. For suturing deeper parts, as in pelvic operations, a needle-holder is useful, and there are many forms. Needles are sterilized by boiling or by placing them in carbolic acid, 1 to 20, for fifteen or twenty minutes.

THE DIFFERENT KINDS OF SUTURES.—Wounds can be united by a variety of forms of suture.

Interrupted Suture (Fig. 4565).—This is the usual form of suture for uniting the edges of the skin. The needle

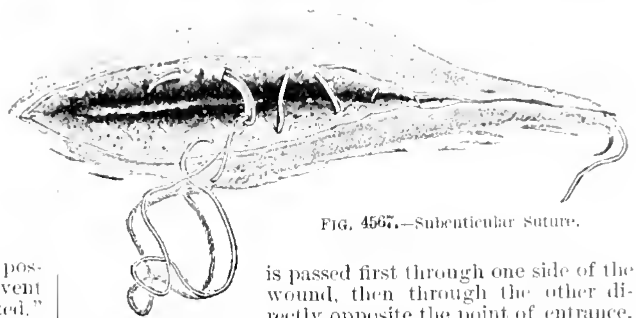


FIG. 4567.—Subcuticular Suture.

is passed first through one side of the wound, then through the other directly opposite the point of entrance. The two ends are tied with a reef-knot and cut short. The knot should be on one side of the line of the wound. When there is tension of the wound the so-called tension sutures are used, which are inserted at a further distance from the edges of the wound than ordinary coaptation sutures. The interrupted sutures should be placed near enough together to insure good approximation of the edges of the wound. The suture is removed by cutting the thread close to the skin and pulling on the knot. Medium-sized silk is generally employed for the skin.

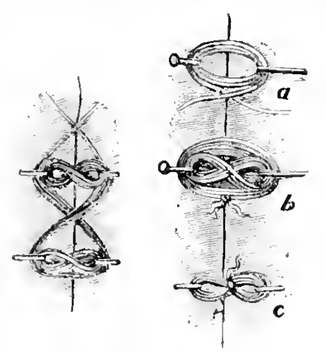


FIG. 4568.—Figure-of-Eight Sutures.

Continuous Suture (Fig. 4566).—This is begun at one end of the wound. Instead of cutting the thread after the first suture, the latter is continued throughout the whole length of the wound. The needle is inserted at points directly opposite each other. In this way the visible part of the thread forms a row of parallel oblique lines and the invisible part a row of transverse lines. The suture is tied by tying the double thread on one side to the single portion on the opposite. This suture can be inserted more rapidly than the interrupted, and is well adapted for long wounds.

Subcuticular Suture (Fig. 4567).—This is a catgut suture in which the curved needle is passed in and out below and parallel to the skin and then drawn up tight so as to bring the skin surfaces in contact. The advantages of it are that it leaves only a small scar and minimizes the danger of stitch hole abscesses from penetration of the skin with its bacteria.

FIG. 4569.—Mattress or Quilt Suture.

The Figure-of-Eight Suture (Fig. 4568) is made by transfixing both edges of the incision with a short pin and twisting a thread about the two ends. This is sometimes used in harelip operations.

Mattress or Quilt Suture (Fig. 4569).—In this variety the needle is passed through each side twice, and in this

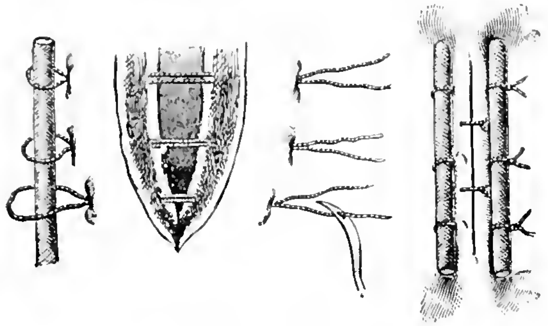


Fig. 4570.—The Quilled Suture.

way a firmer hold is obtained. It can be either interrupted or continuous.

Quilled Suture (Fig. 4570).—This is used in case of tension on the edges. A double thread is passed through both edges at a good distance from the same. Into the loop on one side a piece of catheter, gauze, or drainage tube is inserted and the free ends on the opposite side are tied about the same material. The edges may be brought into closer apposition by another row of sutures inserted close to the edges.

Secondary Suture.—If it is desirable to bring together a wound which is granulating, we employ secondary sut-

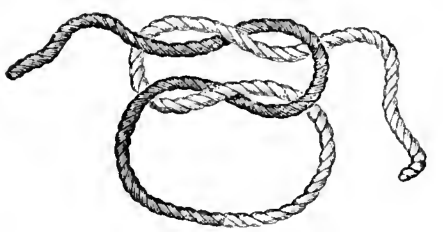


Fig. 4571.—The "Reef" Knot.

ure. This is also employed for wounds which, on account of their depth or of hemorrhage, were first packed. Any of the above forms of suture can be employed for this purpose.

Knots.—The knot used for tying sutures is usually the reef-knot (Fig. 4571). This is preferable to the granny knot (Fig. 4572), which is more likely to slip and become untied. The square knot can be combined with the so-

Fig. 4572.—The "Granny" Knot.

called surgeon's knot (Fig. 4573), in which the ends of the thread are twisted about each other twice instead of once.

Intestinal Sutures.—For intestinal work the small sizes of silk are employed and either the straight or the curved needle. An ordinary strong needle answers the purpose. The main object is to bring peritoneal surfaces in contact,

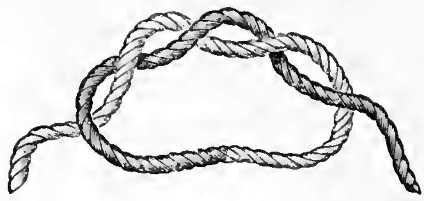


Fig. 4573.—Surgeon's Knot.

which then adhere promptly and prevent the escape of intestinal contents. The sutures may be interrupted or continuous.

Lembert Suture (Fig. 4574).—The needle penetrates a fold of the intestinal coat consisting of the peritoneal, muscular, and submucous layers without entering the

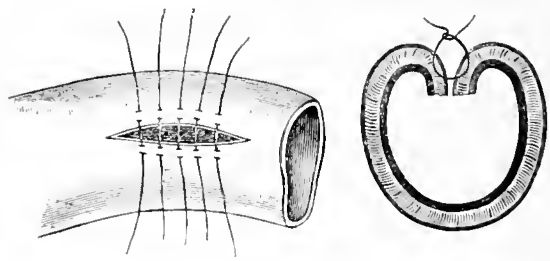


Fig. 4574.—Lembert Suture.

mucosa. The fold is about one tenth of an inch wide, and is situated about one-eighth of an inch from the edge. A similar edge is picked up on the opposite side and the suture is drawn tight, thus inverting the edges and bringing serous surfaces in contact. This is the usual form of intestinal suture and answers the purpose admirably. A second row outside the first may be added and in this way the edges inverted still more.

The Czerny-Lembert Suture (Fig. 4575) is merely a Lembert suture reinforced by a deep row bringing together the edges of the mucous membrane. These latter sutures are knotted inside or outside the bowel.

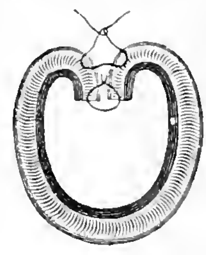


Fig. 4575.—The Czerny-Lembert Suture.

Halsted Suture.—This is supposed to have the advantage of not tearing so readily as most sutures do when subjected to tension. It is a Lembert suture which passes through the wall of the intestine parallel with the line of incision instead of at right angles to it.

Benjamin T. Tilton.

SUWANEE SULPHUR SPRINGS.—Suwanee County, Florida.

Post-Office.—Suwanee. Hotel, Suwanee Springs Hotel.

Access from all points viâ Savannah, Florida, and Western Railroad to Suwanee, thence one mile to springs.

The famous Suwanee River is now open as a regular tourist route, and the traveller for health or pleasure can with ease and comfort visit this romantic stream of legend and song and the attractive resorts located along its banks. The Suwanee Springs Hotel property consists of a beautiful park of massive live oaks and tall pines to the extent of one hundred acres situated along the river banks and on the picturesque bluffs. In the park the company has built a handsome hotel and eighteen comfortably furnished and conveniently appointed cottages. The visitor need therefore have no fear of being subjected to the usual discomforts of a newly settled country. The buildings are well equipped with an excellent system of water works, and the sanitary appointments are of the first class. The water from the springs is supplied, either hot or cold, by pipes directly from the fountains to the rooms. The springs are located about two hundred yards from the hotel, and immediately on the banks of the river. They boil up from the ground at a rate of forty-five thousand gallons per hour, and the water exhales a strong sulphurous odor. Bathhouses are conveniently located along the margins of the springs. An unvarying temperature of the water, of 74° F., enables the visitor to bathe in the springs at any season without ill effects. An analysis of the water by Professors Chandler and Pellew, of New York, in 1893, resulted as follows: One United States gallon contains (solids): Sodium chloride, gr. 0.62; potassium sulphate, gr. 0.60; calcium sulphate, gr. 1.78; sodium bicarbonate, gr. 0.96; calcium bicarbonate, gr. 11.02; magnesium bicarbonate, gr. 3.48; oxide of iron and alumina, gr. 0.15; silica, gr. 0.81; organic and volatile matter, gr. 2.19. Total solids, 21.61 grains. The waters are quite heavily charged with sulphureted hydrogen gas, to which they owe much of their virtue. Rheumatism, nervous disorders, dyspepsia, and diseases of the liver, kidneys, and blood are benefited by the waters and baths. The neighborhood holds forth many attractions to the tourist, not the least being the poetic old Suwanee, which is said to possess more elbows, curves, and angles in a shorter space than any other river in the world. Its banks are carpeted with ferns and mosses, and its dark but clear waters are overarched by a luxuriant tangle of umbrageous foliage. "A trip through the tortuous windings of this stream is indeed one of the most romantic that can be imagined, and when seated in a rowboat on a clear moonlight evening, floating over the placid surface of the dear old river, one can well imagine the sentiment that inspired the poet who has made the name of Suwanee so famous."

James K. Crook.

SWEAT. See *Skin, Functions of.*

SWEET CHALYBEATE SPRINGS.—Alleghany County, Virginia.

Post-Office.—Sweet Chalybeate Springs.

Access.—Viâ Chesapeake and Ohio Railroad to Alleghany Station, thence a drive of nine miles to the springs.

These well-known springs are ensconced in a lovely valley on the backbone of the Alleghany Mountains, at an elevation of 3,000 feet above the sea. The location is in the midst of the "Springs Region," and whatever may be said regarding the salubrity of climate, the charm of scenery, and the general attractiveness of the Old Dominion mountain resorts, may be fittingly applied to these springs and their environments. Among the more immediate desirable features may be mentioned a comfortable and tidy hotel, a commodious bathing establishment with facilities for hot and cold mineral-water baths, enclosed pools for plunge-bathing, etc. The section round about abounds in deer and other mountain game, while the streams afford excellent fishing. The springs, formerly known as the Red Sweet Springs, are situated in one of the most beautiful valleys of Virginia. So far as chemical composition is concerned, their waters do not show any very marked differences. The combined flow of the four is about forty-eight thousand gallons per hour. The following analysis was made by Prof. W. B. Rogers: One United States gallon contains (solids): Magnesium carbonate, gr. 2.70; sodium sulphate, gr. 3.23; calcium sulphate, gr. 32.88; magnesium sulphate, gr. 7.18; sodium chloride, gr. 0.09; magnesium chloride, gr. 1.57; calcium chloride, gr. 0.02; iron sesquioxide, gr. 0.73. Total, 48.40 grains. Gases: Carbonic acid, cub. in. 106.49; sulphureted hydrogen, a trace; oxygen, cub. in. 0.46; nitrogen, cub. in. 0.59.

A second analysis, by Professor Rowelle, shows four grains of iron (in combination) to the gallon. This is a very good calcic-chalybeate water. Its taste is somewhat sweet, but ferruginous. Its temperature at the fountain is about 75° F. The water is beneficially employed in anæmia, chlorosis, leucorrhœa, and other conditions indicating an impoverished state of the blood. It has also proved efficacious in neuralgia and gastralgia.

James K. Crook.

SWEET SPRINGS.—Saline County, Missouri.

Post-Office.—Brownsville. Hotel.

Access.—Viâ Sedalia and Lexington branch of the Missouri Pacific Railroad to Brownsville, thence one mile to springs.

The location is fifteen miles from the Missouri Blue Lick Springs.

These springs are five in number and have a flow of 224,000 gallons hourly. The temperature of the water is 54° F. Analyses of two of the springs have been made by Prof. Charles P. Williams:

One United States Gallon Contains:

Solids.	Akesion Spring. Grains.	Sweet Springs. Grains.
Calcium carbonate	40.25	9.56
Iron carbonate	.27	.57
Manganese carbonate	.20	Trace.
Sodium sulphate	2.61	....
Calcium sulphate	57.93	9.46
Barium sulphate	8.15	....
Calcium phosphate	.24	....
Magnesium nitrate	.18	....
Ammonium nitrate	1.17	....
Sodium chloride	756.11	86.92
Calcium chloride	74.79	14.72
Potassium chloride	28.56	3.40
Magnesium chloride	87.32	22.29
Lithium chloride	.30	.05
Magnesium bromide	.13	.12
Aluminum oxide	.17	.09
Silica	.51	1.08
Organic matter	3.05	4.01
Total	1,061.94	152.27

It will be observed that there is a great difference in the strength of these waters, the Akesion Spring being much more potent. The spring also contains a considerable amount of sulphureted hydrogen. It is especially recommended for diseases of the liver. The water of the Sweet Springs is recommended for diseases of the kidneys and bladder. An excellent bathing establishment is maintained at the springs, baths being supplied by water from the salt-sulphur spring, five miles distant. There are also white and black sulphur springs in the neighborhood.

James K. Crook.

SYCOSIS.—(Synonyms: Folliculitis et perifolliculitis barbæ; sycosis non-parasitica.) Sycosis is a disease of the skin that primarily affects the hair follicles. Most of the cases occur on the bearded portion of the face, but it may occur anywhere where there are coarse hairs, as on the scalp, eyebrows, axillæ, pubes, and even on the limbs of coarse-haired individuals. It has been called barber's itch, which is wrong, as that is ringworm of the beard. The term "non-parasitic sycosis" is also erroneous, as we now know that the disease is parasitic, though not due to the trichophyton fungus.

Symptoms.—*First, as it occurs on the face.* The disease begins by the eruption of a number of red, inflammatory, conical papules or nodules scattered over the whole or part of the bearded portion of the face. The lesions are discrete, and it will be noticed that each one is pierced in its centre by a hair. The skin between the lesions is unaffected. If the onset is very violent, so that a very large number of hairs are affected, the individual zones of redness will meet and then the whole of the affected area will be reddened and somewhat swollen. The lesions vary in size from that of a millet seed to that of a pea. Unless the disease is promptly relieved by treatment the papules give place to pustules, which likewise are pierced by hairs. The pustules show no tendency to run together and form patches as do those of eczema. After a time the pustules dry up and small crusts from about the hairs. If the disease is very intense infiltrated patches will form, and, instead of pustules, there may be abscesses. New papules continue to form and undergo their evolution into pustules, so that we find both forms of lesions present at the same time. The hairs in the pustules early lose their lustre. While at first firmly seated in their follicles so that attempts at depilation are painful, when the pustules are fully formed the hairs come out easily and without much if any pain. When the hairs are extracted early their root sheaths appear as glassy cylinders. After the pustules form the root sheaths will be yellowish and swollen with pus. While usually the hair is not permanently damaged, in chronic cases the hair papillæ are destroyed, the beard is thinned, and small cicatrices are seen.

The course of the disease is chronic, marked by relapses, the disease being at one time apparently cured, and then breaking out again with renewed violence.

Any part of the bearded portion of the face may be attacked. The disease is specially common on the upper lip. Usually there will be found at the same time a catarrhal or purulent discharge from the nose. The cheeks are the parts next most frequently affected, either one or both. The disease may occur symmetrically. It may be limited to a single area. As a rule it does not occur below the angle of the jaw. If it does occur there it is usually by extension from the cheeks. With it there is no eruption upon the non hairy parts of the face. Not uncommonly the eyebrows and the eye-lashes are affected at the same time as the cheeks.

There is little if any itching, the patient complaining rather of a feeling of soreness, distention, or burning.

Secondly, as it occurs on other parts. On the eyebrows and pubes and in the axillæ the appearances are similar to what obtains on the face, and the course of the disease is the same. On the scalp we meet with the characteristic papules and pustules pierced by hairs. When the disease occurs on the limbs (and it is mostly on the legs that it occurs), we find the same lesions; but, as the hair is more sparse, there is not the same tendency to form diffuse patches, the lesions remaining discrete throughout.

ETIOLOGY.—There is no doubt that the disease is parasitic. The majority of investigators ascribe its origin to the invasion of the hair follicles by the staphylococcus aureus et albus. Sabouraud states that it is due to the staphylococcus aureus alone. Unna teaches that there are two varieties of the disease, one of which he names the coccogenic, being due to the staphylococcus aureus et albus; and the other bacilligenic, being due to an organism which he calls *bacillus sycosiferus fœtidus.*

The disease is contagious, and barber shops are, without doubt, a frequent source of contagion. Like many other diseases due to micro-organisms, there are two factors at work—one the predisposing cause, the character of the soil; and the other the exciting cause, the micro-organism. Eczema is sometimes the forerunner of sycosis. Other predisposing agencies are irritant applications to the skin, such as mustard or other poultices, intense heat, cosmetics, and the like. A nasal discharge is the predisposing cause of sycosis of the upper lip. Shaving with a dull razor is supposed to be the cause in some cases, but those who do not shave are by no means exempt from the disease. Most patients with sycosis are in poor general condition. Men naturally are the most frequent sufferers from the disease.

PATHOLOGY.—Sycosis is primarily a perifolliculitis, the hair follicle and the sebaceous glands being affected secondarily.

DIAGNOSIS.—The two diseases from which sycosis must especially be differentiated are eczema and ringworm of the beard.

Eczema may be limited to the bearded portion of the face, but it is prone to pass over to the non-hairy parts; sycosis is confined to the hairy parts. Eczema is very pruritic and the skin is scratched; sycosis is not pruritic and the skin is not scratched. The lesions of eczema bear no special relation to the hairs; it is a catarrhal disease of the skin, and the hairs are affected as it were accidentally and superficially. No matter how bad an eczema may be, it never destroys the hair. Sycosis is primarily a disease of the hair, the skin between the individual hairs is unaffected except in very bad cases, and the hair may be destroyed. In eczema crusting is a feature of the disease, and when the crusts are removed a raw and oozing surface is exposed. In sycosis the crusts are usually confined to the hair follicles. If diffused crusts are formed, when they are removed it will be found that the hairs stand in little inflammatory areas while the intervening skin does not present a moist surface as is the case in eczema. In some cases it is impossible to make a diagnosis at first, but it is arrived at by studying the effect of treatment, sycosis being more intractable than eczema, and the follicular character becoming more pronounced as the disease approaches recovery.

Ringworm of the beard usually occurs on the chin and neck below the angle of the jaw; sycosis occurs most often on the upper lip and cheeks. Ringworm occurs either as a superficial scaly ring or as large-sized nodules arranged in circles and segments of circles; sycosis occurs as an eruption of papules and pustules pierced by hairs and without any grouping. In ringworm the hairs are broken and split and can be pulled out readily though the root is often left behind; in sycosis the hairs lose their lustre, but otherwise are unaffected, and in the early stages attempts at removing them are very painful. Ringworm once cured does not tend to relapse; sycosis does. Under the microscope the hairs from a case of ringworm will be found loaded with spores and mycelia; in sycosis micro-organisms are found not in the hair but in cultivations from the follicle contents.

Acne should offer no difficulty in diagnosis, as it occurs all over the face and comedones are always present.

PROGNOSIS.—While the disease is essentially chronic, it is curable. Permanent loss of hair is exceptional.

TREATMENT.—When the upper lip is affected it is necessary first to seek out and cure any disease of the mucous membrane of the nose that may be present. In all cases attention to the general health should be given, so as to improve the character of the soil and enable it to resist the invasion of the fungus. The skin must be protected from irritation. The congestion of the skin that is often present in acute cases should be relieved by the administration of laxatives. There is no specific for the disease. Locally, the treatment will vary with the stage of the disease. At the beginning the inflammation may be treated by bathing the affected parts with hot water and following this with an alkaline lotion, such as black wash, lead and opium wash, or a zinc lotion containing two per cent. of salicylic acid. In some cases the application of six drachms of the ointment of the ammoniate of mercury and two drachms of cold cream will abort the disease. When pustules have formed the hairs should be plucked from the diseased follicles,—a conservative process, as it tends to prevent the destruction of the hair papillæ. If there are a large number of pustules a rapidly favorable effect may be produced by going over the face with a dermal curette, after which the parts should be bathed with a 1 to 1,000 solution of bichloride of mercury. If crusts are present they should be removed by soaking them at night with a two-per-cent. solution of salicylic acid in sweet oil, and washing them off on the next day with soap and water. The applications advised above may be used. Diachylon ointment, made according to Hebra's formula and spread on cloths and bound down on the face, is an excellent remedy.

In more chronic conditions sulphur ointment is often a sovereign remedy. The employment of tumenol is at times followed by brilliant results. Tar ointment may be used. In very obstinate cases we may have to resort to stimulation by means of scrubbing with green soap and then binding on zinc-oxide ointment. It is best to keep the beard clipped short during treatment. Epilation is advised by many authorities. Many cases have been cured by both radio- and phototherapy. As the disease is a most obstinate one, we shall have to make many changes in our treatment before we succeed in curing it. It is well to continue some protective applications for several weeks after the disease seems to have been cured.

George Thomas Jackson.

SYMPATHETIC NERVOUS SYSTEM.—An orderly presentation of the facts and theories relating to the sympathetic nervous system calls for the adoption of the following three heads: Anatomy, Histology, and Physiology.

GENERAL SURVEY OF ANATOMY.

The sympathetic nervous system is composed of the following anatomical elements:

1. The great gangliated cords. 2. The intermediate or central nerve plexuses. 3. The peripheral plexuses. 4. The terminal or monocellular ganglia. The general structure and topographical relations of each of these will first be considered, and afterward the general relations of these divisions to each other and to the central nervous system.

I. *The Great Gangliated Cords.*—The great gangliated cords (sympathetic cords, sympathetic nerves; trunci sympathici; Grenzstrang des Sympathicus; nerf grand sympathique) consist of a series of ganglia (sympathetic ganglia, ganglia trunci sympathici) united to each other by longitudinal cords, the so-called *rami internodiales.* These two gangliated cords are placed symmetrically, partly in front and partly to the side of the vertebral column, and extend from the base of the skull to the coccyx. The internal carotid nerve which emanates from the uppermost cervical sympathetic ganglion must be considered the upward continuation of the sympathetic cord into the region of the head. Some of the cephalic ganglia, viz., the ciliary, the sphenopalatine, the otic, the submaxillary, likewise the cervical ganglion of the pneumogastric, and probably also the ganglion petrosum glossopharyngei, must be regarded as homologues of the ganglia of the great sympathetic cords.

The two great gangliated cords and their homologues in the cranial division of the sympathetic have the following connections:

1. *The Interfunicular Cords or Rami* (*Rami Interfuniculares*). These serve to unite the two great gangliated cords and are developed to the greatest extent in the lumbar and sacral portions of the sympathetic nerves.

2. *The Communicating Rami* (*Rami Communicantes*) establish a connection between the sympathetic ganglia and the cerebro-spinal nerves. By these rami communicantes the ganglia of the sympathetic chain are united with the anterior primary divisions of the spinal nerves of their immediate vicinity. There are white and gray rami communicantes, the former consisting mainly of medullated fibres, the latter of pale fibres (Gaskell). The two kinds form either separate branches or are in other instances blended into one cord, composed of a white and a gray part. Having arrived in the spinal nerves, the fibres of the rami communicantes, according to Gaskell, take opposite directions; part of the fibres, contained mainly if not all in the white rami, pass into the spinal cord; the other part, contained chiefly, perhaps exclusively, in the gray rami, assume a centrifugal course, passing with the other fibres of the spinal nerve to the periphery. (See Fig. 4576 and page 581.)

The rami communicantes are represented in the cranial division of the sympathetic system by the so-called roots of the cranial sympathetic ganglia (the sphenopalatine, ciliary, etc.).

3. *The Peripheral Rami* (Hoffman and Rauber) or *Rami Efferentes seu Afferentes.* These are branches proceeding from the gangliated cord to the prevertebral plexuses or vice versa.

We now pass to

II. *The Intermediate or Central Nerve Plexuses of the Sympathetic.*—Here it will be convenient to distinguish, as Thane (Quain's "Anatomy") proposes:

1. *The Large Prevertebral Plexuses.* These are three

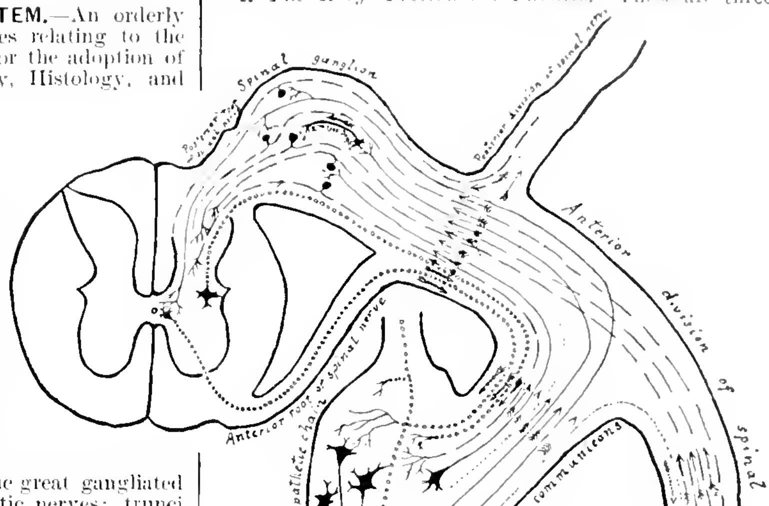


FIG. 4576.—Diagram of the Structural Interrelation between the Cerebro-spinal and Sympathetic Systems.

= Cerebro-spinal neurones of centrifugal functions.

= Cerebro-spinal neurones of centripetal functions.

= Sympathetic neurones of centrifugal functions.

= Sympathetic neurones of centripetal functions.

Marked "2nd type Dogiel" in the figure = the spinal ganglion cell of the second type of Dogiel.

in number, the *cardiac*, the *solar*, and the *hypogastric.* They are not bilateral but single, and lie all in front of the vertebral column, occupying the thorax, abdomen, and pelvis respectively. They are connected on the one hand with its cerebrospinal nerves and with the sympathetic cord, and on the other hand they form centres for the innervation of the viscera.

2. *The Smaller Plexuses of the Sympathetic.* Most of these are in intimate connection with the great prevertebral plexuses, and are in part directly continuous with them, forming, so to say, subdivisions of these. The remainder are united to the prevertebral plexuses by the nerve filaments or cords. These smaller plexuses are also in intimate connection with each other, and probably receive likewise a supply of cerebro spinal fibres. Among these plexuses we may class the *coronary*, the *mesenteric*, the *vesical*, etc.

III. *The Peripheral Plexuses.*—Such plexuses as these are found in the walls of the intestines (Auerbach's and Meissner's), the œsophagus, the bladder, and other hollow viscera. They receive their supply of nerve fibres from the plexuses mentioned under division number two.

IV. *The Terminal Monocellular Ganglia.*—These are the ganglia which Ramon y Cajal has found scattered in the interstices of glandular tissues, within the villi of the intestines, among the interstitial cells of the glands of Lieberkühn, in the substance of the pancreas, in the salivary glands, etc.

THEORIES OF THE GENERAL STRUCTURE OF THE SYMPATHETIC AND ITS CONNECTION WITH THE CEREBRO-SPINAL SYSTEM.—Before passing to a detailed description of the various parts of the sympathetic system, I deem it necessary to give a few general remarks anent the theories of the general structure of the sympathetic and the interrelation of its parts to the central nervous system by fibre tracts. The sympathetic nervous system contains fibres of centripetal, *i.e.*, sensory, and of centrifugal function. The centrifugal function may be motor (viscero-motor or vaso-motor), secretory, trophic, or it may be inhibitory (viscero-inhibitory, vaso-inhibitory, secreto-inhibitory). This division of the centrifugal fibres into centrifugo-exciting and centrifugo inhibiting fibres may hold true also of the centripetal fibres; these are probably also centripeto exciting and centripeto-inhibitory fibres. The centrifugal fibres must further be divided into at least two varieties, which distinguish themselves by their mode of origin.

1. *Cerebro-spinal motor* (or, more correctly, centrifugal) fibres, called also *motor fibres of the first order* by Kölliker, and *preganglionic fibres* by Langley (see Fig. 4576). These fibres have their cells of origin in the spinal cord or cerebral axis, being, in fact, the axis-cylinders of such cells. These fibres condition the dependence of the cells of the sympathetic upon the cerebro-spinal system.

2. *Sympathetic motor* (or in general centrifugal) *fibres*, called also *motor fibres of the second order* (Kölliker) and *post-ganglionic fibres* (Langley) (see Fig. 4576). These have their cells of origin in the ganglia of the sympathetic system, some in the ganglia of the two great gangliated cords, others in the prevertebral or peripheral plexuses. The fibres of the first named order terminate in end-arborizations or pericellular nests around those nerve cells of the sympathetic ganglia or plexuses which give origin to fibres of the second order; in this manner the conduction of a motor impulse to the periphery is possible.

The existence of a third or fourth set of fibres is denied by Langley and Kölliker, but claimed by Jendrassik. The former two deny that the connection of the primary motor centre of the spinal cord or cerebral axis with the periphery is ever established by more than two sets of neurones, which the latter claims.

Jendrassik's ingenious theory of the general structure of the sympathetic cannot be discussed nor quoted in detail here, but must be read in the original (see literary references at the end of this article).

The views of the mode of origin of the sensory fibres of the sympathetic system and of the manner of their connection with the cerebro-spinal system are still divided. Kölliker claims that all sensory fibres of the sympathetic originate from cells of the spinal ganglia in exactly the same manner as do the sensory fibres of the cerebro-spinal system. Dogiel, on the other hand, is inclined to assume the existence of specific sympathetic fibres derived from cells of sympathetic ganglia or plexuses (see Fig. 4576, second type Dogiel). Researches by J. Collins and the writer confirm Dogiel's view.

The two kinds of motor fibres, the cerebro-spinal and the sympathetic, are represented in nearly all subdivisions of the sympathetic system. Both kinds are met with in the rami communicantes, the white rami of which are for the most part composed of cerebro-spinal, the gray ones chiefly of sympathetic fibres (Gaskell). Many efferent rami contain predominantly sympathetic fibres; on the other hand, those efferent rami which proceed from the ganglia of the thoracic part of the sympathetic cord and unite to form the splanchnic nerves are said by Langley to be for the most part cerebro-spinal fibres, showing that they pass through the sympathetic ganglia of the thoracic portion without being interrupted by the cells of the latter. Cerebro spinal fibres are found also in the more peripheral plexuses, intermingled with sympathetic fibres

A word should be said here regarding inhibitory nerves. These may be of the efferent (analogous to motor nerves) or afferent order (analogous to sensory nerves), inasmuch as they can display their inhibitory influence on a given nerve cell in both a descending (toward the centrifugally terminal cells) and an ascending (toward the same cell centripetally) direction. Such inhibitory nerves are of frequent occurrence. Indeed, wherever in the vegetative system one finds nerves performing motor, vaso-motor, or secretory functions, one also finds usually the antagonists, that is, nerves inhibiting such functions. The inhibitory nerves have been encountered again and again by physiologists, and for a long time their rôle was not understood. Gaskell, however, has given a very ingenious and plausible interpretation of their significance. In defining anabolism and catabolism he expresses himself as follows

"There is, then, to my mind, no greater mystery involved in the conception of a nerve of *inhibition* than of a nerve of contraction. In the former case the cessation of function, the relaxation of tissue, is the symptom of constructive chemical changes going on in the tissue, *i.e.*, the anabolism or assimilation or trophic action, in precisely the same way as the activity of function, namely, the contraction of tissue, is a symptom of destructive changes, *i.e.*, catabolism or dissolution." Or, by transcribing this, we may say that the purpose of *inhibition* is the installation of restorative or constructive or anabolic changes in the tissue, while function is the expression of opposite changes, *i.e.*, destructive or catabolic changes. It is evident, however, that the installation of restorative changes after function (or perhaps even during function) is indispensable for the resumption of function. The rôle of inhibition seen in this light clearly gains great importance for the muscular, glandular, and other activities.

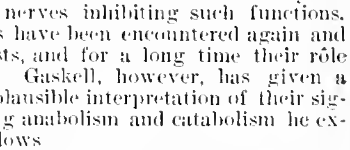


FIG. 4577.—Shows the Neurone *A* under the Exciting Influence of Neurones *B* and *C*. (The direction of the nerve current is indicated thus →.)

The writer (Onuf, "A Tentative Explanation of Some of the Phenomena of Inhibition on a Histophysiological Basis, Including a Hypothesis Regarding the Function of the Pyramidal Tracts," *State Hospitals Bulletin*, 1897) has attempted to give an explanation of inhibition on a histophysiological basis, and has called attention to the regulative rôle that inhibition may have on certain functions. The theory may be expressed in word and diagram (Figs. 4577 and 4578) as follows.

For the excitation of a nerve cell, the nerve current has to pass in the direction from the cell body or its protoplasmatic processes toward the nervous process; for the inhibition of the cell, the nerve current has to pass in the opposite direction, that is, from the nerve process or its collaterals, back to the cell body. In other words, to produce excitation of a given cell, the nerve current must enter this cell from the surface of its cell body or of its dendrites; but in order to inhibit or moderate the action of the cell, the nerve current has to enter the cell from its nerve process or collaterals thereof.

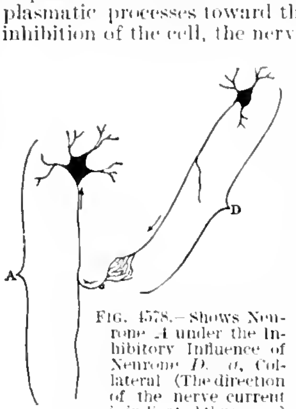


FIG. 4578.—Shows Neurone *A* under the Inhibitory Influence of Neurone *D*. *a*, Collateral. (The direction of the nerve current is indicated thus ⟶.)

These two modes of action are best illustrated by the diagrams (Figs. 4577 and 4578). For both figures the same neurone *A* has been chosen. Fig. 4577 shows this neurone *A* under the influence of excitation from the neurones *B* and *C*. Fig. 4578 represents neurone *A* under the influence of inhibitory action from the neurone *D*.

ANATOMY OF THE GANGLIATED CORDS.

We shall begin the detailed anatomical account with a description of *the two great gangliated cords*.

It is customary to distinguish four parts or portions of the great gangliated cords, the cervical, the thoracic, the lumbar, and the sacral. We shall describe these in this order, basing our description on that given by Thane (Quain's "Anatomy").

I. CERVICAL PART OF THE GANGLIATED CORD.—This is situated behind the great blood-vessels of the neck, resting on the muscles which cover the anterior surface of the vertebral column. The cervical part of the gangliated cord consists of three ganglia, as described below.

1. *Upper or Superior Cervical Ganglion.*—This, the largest ganglion in the great sympathetic cord, lies on the rectus anticus major muscle, opposite the second and third cervical vertebræ, behind the internal carotid artery, and to the inner side of the pneumogastric nerve. Usually fusiform in shape, it continues above into an ascending branch and tapers below into the connective cord. The following are the connections of this ganglion:

(*a*) *Connection with Spinal Nerves.* At its outer side the superior cervical ganglion is connected with the first four spinal nerves by means of gray rami communicantes. The branches to the third and fourth cervical nerves often pierce the rectus anticus major muscle. They may be given off from the upper part of the cord instead of directly from the ganglion. It probably consists primarily of several ganglia which have coalesced. Gaskell considers it to be a distal or collateral ganglion. It receives its cerebro-spinal fibres, which constitute the "cervical splanchnic nerve" of Gaskell, from the upper dorsal nerves to the cervical part of the sympathetic cord.

(*b*) *Connection with Cranial Nerves.* The ganglion or its cranial continuation is connected by small branches with the lower ganglion of the pneumogastric (ganglion cervicale vagi, plexus nodosus), and with the twelfth cranial nerve near the base of the skull. Another branch (N. jugularis), which is ascending, divides at the base of the skull into filaments, one of which ends in the petrosal ganglion of the glosso-pharyngeal nerve, while the others enter the jugular foramen to join the ganglion of the root of the pneumogastric.

Besides the branches connecting it with the cranial and spinal nerves, the first cervical ganglion gives off other ascending branches, viz., pharyngeal branches, the upper carotid nerve, and branches to the blood vessels, as well as two or three filaments which pierce the prevertebral muscles to supply the upper cervical vertebræ and their ligaments.

(*c*) *Ascending Branch and Cranial Plexuses.* The ascending or carotid branch of the first ganglion (N. caroticus internus) is in some degree a prolongation of the ganglion itself. Ascending behind the internal carotid artery, it enters the carotid canal, dividing here into an external and internal division.

The *external division*, lying on the outer side of the internal carotid artery, distributes filaments to the latter, receives one or two carotico-tympanic twigs from the tympanic branch of the glosso-pharyngeal, and after communicating by means of other filaments with the internal division of the cord forms the carotid plexus.

The *internal division*, rather the smaller of the two and situated on the inner side of the internal carotid, supplies filaments to the carotid artery and goes to form the cavernous plexus. The terminal parts of these divisions of the cranial cord are prolonged on the trunk of the internal carotid and extend to the cerebral and ophthalmic arteries, around which they form secondary plexuses, those on the cerebral arteries ascending on the pia mater. One minute plexus enters the eyeball, accompanying the central artery of the retina.

The *carotid plexus* (plexus caroticus internus) is situated on the outer side of the internal carotid artery at its sec-

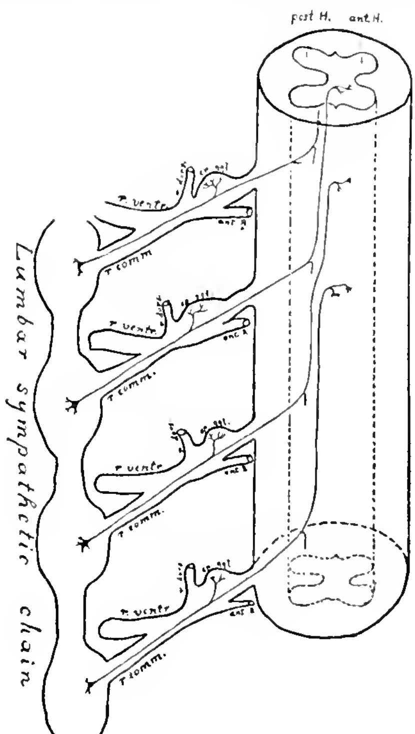


FIG. 4579.—Diagram to show the Ascent in the Spinal Cord of the Afferent (and probable Descent of the Efferent) Fibres derived from the Lumbar Sympathetic Chain, as resulting from the degenerations following removal of lumbar sympathetic ganglia. *post. H.*, Posterior horn; *ant. H.*, anterior horn; *r. ventr.*, ramus ventralis (anterior division) of lumbar nerve; *r. dors.*, ramus dorsalis (posterior division) of lumbar nerve; *sp. ggl.*, spinal ganglion; *ant. R.*, anterior root; *r. comm.*, ramus communicans.

For further details see p. 590.

ond bend (reckoning from below) or between the second and third bends. It forms connection with the sixth nerve and with the Gasserian ganglion (the latter, however, occasionally receiving its supply from the cavernous plexus) gives off the large deep petrosal nerve, which together with the large superficial petrosal from the facial forms the Vidian nerve, and so joins the sphenopalatine ganglion. It further gives off the small deep petrosal nerve to the tympanic plexus, and supplies filaments to the internal carotid artery.

Cavernous Plexus.—This plexus, taking its name from its position in the cavernous sinus, is placed below and slightly to the inner side of the highest turn of the internal carotid artery. Besides giving branches to the artery and all its branches, *i.e.*, the ophthalmic, the anterior cerebral, the median cerebral, and the posterior communicating arteries, and to the walls of the sinus, it communicates with the third, fourth, and the ophthalmic divisions of the fifth cranial nerve. The latter connection supplies filaments to the ophthalmic trunk (inner side) of the fifth nerve, and the sympathetic root to the ciliary ganglion. The cavernous plexus also furnishes minute filaments to the pituitary body.

(*d*) *Pharyngeal Nerves and Plexus.* The pharyngeal nerves, originating from the forepart of the first cervical ganglion, pass to the side of the pharynx. They unite with branches of the pneumogastric and glossopharyngeal nerves, forming the pharyngeal plexus. The latter supplies the muscles and mucous membrane of the pharynx, and connects with the superior and external laryngeal nerves.

(*e*) *Laryngeal Branches.* These branches anastomose with twigs from the inferior laryngeal to form the so-called laryngeal plexus.

(*f*) *Branches to Blood-Vessels.* The superior cervical ganglion gives off the external carotid nerves, which, twining around the external carotid artery, form the plexus caroticus externus. This plexus is continued on the branches of the said artery. The fine plexuses then formed are named after the respective arteries. The plexus on the facial artery supplies a filament forming the sympathetic root of the submaxillary ganglion. The plexus on the middle meningeal artery connects with the otic ganglion and with the geniculate ganglion of the facial (external superficial petrosal nerve). One branch is given off to the parotid gland. Besides microscopical ganglia found in the vascular plexuses, several larger ones are more constantly met with, for instance, the temporal ganglion.

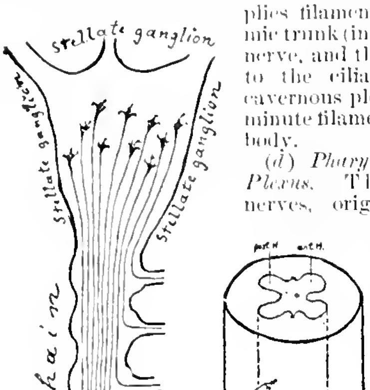


FIG. 4580.—Diagram showing the Afferent Fibres Derived from the Stellate Ganglion and Lower Thoracic Sympathetic Chain in their Course to the Spinal Cord. The course is suggested by the degenerations following removal of the stellate ganglion and also the lower thoracic sympathetic chain. The efferent fibres very likely have a similar course in opposite direction. *post.H.*, Posterior horn; *ant.H.*, anterior horn; *r. ventr.*, ramus ventralis (anterior division) of dorsal nerve; *r. dors.*, ramus dorsalis (posterior division) of dorsal nerve; *ant.R.*, anterior root; *r. comm.*, ramus communicans.

For further details see p. 590.

(*g*) *Upper* (*or Superficial*) *Cardiac Nerve.* This nerve, together with the middle and inferior cardiac nerves, goes to form the cardiac plexus. The left and the right nerves differ somewhat in their disposition, but in its course on the neck the right upper cardiac nerve has relatively the same position and relations as the left one, being placed in the back of the carotid sheath.

2. *Middle Cervical Ganglion.*—This ganglion is situated about opposite the sixth or seventh cervical vertebra. It is the smallest of the cervical ganglia. Gray branches unite it with the fifth and sixth cervical spinal nerves and with the superior and inferior cervical ganglia. It gives off thyroid branches, which form the inferior thyroid plexus and the middle cardiac nerve. The latter, in its course to the cardiac plexus, gives off filaments to the recurrent branch of the pneumogastric, to the upper cardiac nerve, and to the thyroid branches of the middle cervical ganglion.

3. *Lower or Inferior Cervical Ganglion.*—This ganglion is frequently united to the first thoracic ganglion, and the common mass is then designated as the first thoracic ganglion. Its shape is irregular, flattened. The ganglion is placed over the first costo-vertebral articulation in the lateral angle between the subclavian and vertebral arteries. Its union with the middle cervical ganglion is usually formed by a cord passing behind the vertebral artery, sometimes, however, especially on the left side, by a ring around the vessel. The two ganglia are also united by the ansa subclavia (ansa Vieussenii). The latter either passes as a single cord between the middle cervical and the lower cervical or first dorsal ganglion in front of the subclavian artery, or it forms a loop around that vessel, supplying it with small offshoots (plexus subclavius), which give off filaments to the internal mammary artery, communicating in some cases with the phrenic nerve.

The inferior cervical ganglion sends gray communicating branches to the lowest two cervical nerves, gives off the lower cardiac nerve (which passes behind the brachiocephalic artery on the right and behind the transverse aorta on the left side), and supplies twigs to the blood-vessels. The latter ascend along the vertebral artery, forming the vertebral plexus, the ultimate ramifications of which are continued on the intracranial branches of the vertebral and basilar arteries.

II. THORACIC PART OF THE GANGLIATED CORD.—The ganglia of the thoracic sympathetic are usually eleven in number, seldom twelve. The two thoracic sympathetic cords lie on either side of the spinal column over the costovertebral articulation, covered by the pleura, the third to the eleventh ganglia being generally placed over the heads of the ribs, the first one in the first intercostal space and the last one a little in front of the head of the twelfth rib. The first ganglion is often amalgamated with the lower cervical ganglion.

1. *Rami Communicantes.*—The branches connecting the thoracic sympathetic ganglia with the anterior divisions (rami ventrales) of the dorsal nerves are usually two in number for each ganglion, one of these being white and the other gray.

2. *Interfunicular Rami.*—Branches establishing a connection of the two thoracic sympathetic cords between each other are often found, but their occurrence is not constant.

3. *Peripheral Branches of the Ganglia.*—The upper four or five ganglia send small branches to the vertebræ and ligaments and to the descending thoracic aorta, on which latter, by union of the branches from the ganglion with filaments from the great splanchnic nerve, they form the plexus aorticus thoracalis. The second, third, and fourth ganglia also supply branches to the posterior pulmonary plexus, formed otherwise chiefly by ramifications of the pneumogastric nerve.

The rami proceeding from the lower six or seven ganglia join to form three cords on either side, known as the great, the small, and the smallest splanchnic nerves (abdominal splanchnics of Gaskell), which pass into the plexuses of the abdomen.

4. *The Great Splanchnic Nerve.*—The roots uniting to form this nerve are those furnished by the fifth or sixth thoracic ganglion and all the succeeding ganglia to the

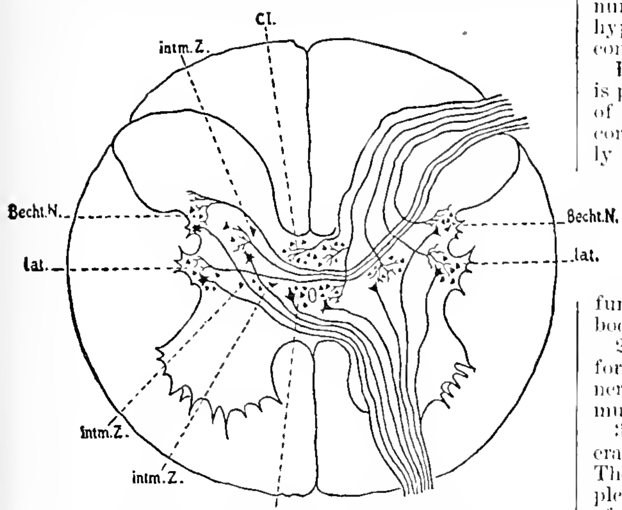


FIG. 4581.—Diagram Illustrating the Spinal Representation or Localization of the Sympathetic Nerve as made very probable from the Degenerations following lesions of the sympathetic chain. *Cl*, Clarke's column; *intm.Z.*, intermediate zone; *Becht.N.*, Bechterew's nucleus; *lat.*, lateral horn group; *parc.*, paracentral group.
See also p. 590.

ninth or tenth (inclusive). The nerve descends over the bodies of the dorsal vertebræ, passing mesiad of the gangliated cord, and, after perforating the crest of the diaphragm, terminates in the upper part of the semilunar ganglion, and sometimes, with a few fibres, in the suprarenal body and the renal plexus. The nerve contains a large part of medullated cerebro-spinal fibres, which give it a white color. They may be traced upward from the highest root along the sympathetic cord as far as the third thoracic ganglion or nerve, or even higher. The great splanchnic nerve often forms a plexus with the small splanchnic nerve, having in many cases a small ganglion (splanchnic ganglion) in its course. The greater splanchnic nerve and the splanchnic ganglion supply the vertebræ and the aorta with filaments.

5. *The Small Splanchnic Nerve.*—The thoracic ganglia giving origin to this nerve are the ninth and tenth, or sometimes the tenth and eleventh. It perforates the diaphragm with or somewhat behind and to the right of the great splanchnic, terminating in the lower part of the semilunar or occasionally in the aortico-renal ganglion. In the thorax anastomoses with the smallest splanchnic are often present.

6. *The Smallest Splanchnic Nerve* (N. renalis posterior of Walter) takes its origin from the last thoracic ganglion and communicates sometimes with the small splanchnic. It pierces the diaphragm with the cord of the sympathetic, and ends in the renal plexus. It is frequently absent as a separate individual nerve, being in this case represented by a branch of the small splanchnic.

The three splanchnic nerves are composed for the most part of cerebro-spinal fibres.

III. Lumbar Part of the Gangliated Cord.—The two lumbar sympathetic cords lie in rather close proximity to each other on the bodies of the lumbar vertebræ, along the inner border of the psoas muscle. Their position is extraperitoneal, the right one being partly covered by the vena cava, the left one by the aorta. Each lumbar cord contains usually four ganglia, but sometimes only three or even only two.

1. *Rami Communicantes.*—As a rule, each of the ganglia of the lumbar sympathetic has two rami communicantes, which, however, are not always connected with the same spinal nerves.

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2. *Rami Interfuniculares.*—These are also inconstant in their occurrence, although more constant than in the thoracic part of the gangliated cords.

3. *Peripheral Branches.*—These branches, varying in number, are distributed to the plexus on the aorta, to the hypogastric plexus, and to the vertebræ and ligaments connecting the latter.

IV. Sacral Part of the Gangliated Cord.—This is placed in front of the sacral bone along the inner side of the foramina sacralia, the two sacral cords converging correspondingly toward the coccyx. Each cord has usually four ganglia, but quite frequently less. Only few branches are given off to the viscera.

1. *Rami Interfuniculares.*—Fine branches uniting the two cords are of constant occurrence here, especially at the lower end, where they form a loop in which a single median ganglion, ganglion impar, or coccygeal ganglion, is often found. The interfunicular rami send off fine filaments into the vertebral bodies, to the coccyx and the coccygeal gland.

2. *Rami Communicantes.*—These are short, often two for one ganglion, frequently united to different sacral nerves. The last or coccygeal ganglion sends a communicating branch to the coccygeal nerve.

3. *Peripheral Branches.*—Only small and few peripheral branches are given off from the sacral ganglia. They are distributed to the sacral bone, to the pelvic plexus, and to the middle sacral artery, on which some of them form a plexus.

The Anatomy of the Plexuses.

I. Cardiac Plexus.—This plexus lies against the transverse aorta and pulmonary artery where these vessels are in contact. It is supplied by the cardiac branches from the cervical ganglia and by those of the pneumogastric nerves. It gives origin to nerves distributed to the heart and to others participating in the inner-

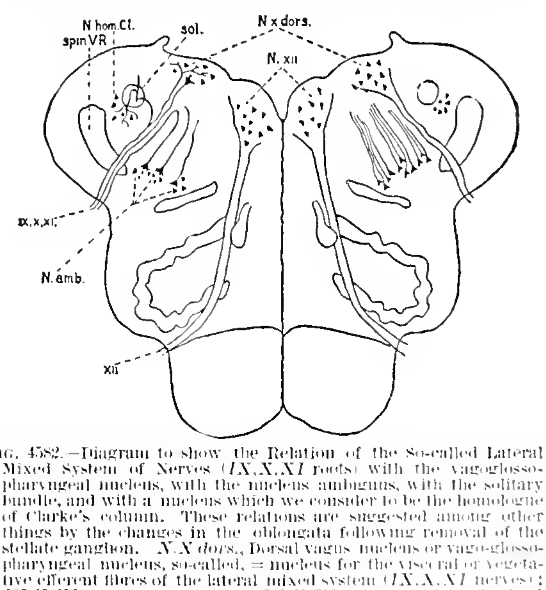

FIG. 4582.—Diagram to show the Relation of the So-called Lateral Mixed System of Nerves (*IX,X,XI* roots) with the vagoglossopharyngeal nucleus, with the nucleus ambiguus, with the solitary bundle, and with a nucleus which we consider to be the homologue of Clarke's column. These relations are suggested among other things by the changes in the oblongata following removal of the stellate ganglion. *N.X dors.*, Dorsal vagus nucleus or vago-glossopharyngeal nucleus, so-called, = nucleus for the visceral or vegetative efferent fibres of the lateral mixed system (*IX,X,XI* nerves); *IX,X,XI* common root of the *IX,X,XI* nerves (= lateral mixed system); *N.amb.*, nucleus ambiguus = nucleus for the somatic efferent fibres of the lateral mixed system (*IX,X,XI* nerves); *sol*, solitary bundle, called also trineural fascicle or descending root of the lateral mixed system; *N.hom.Cl.*, nucleus homologue of Clarke's column; *N.XII*, hypoglossal nucleus; *XII*, hypoglossal nerve; *spin.V.R.*, spinal trigeminal root.
See also p. 590.

vation of the lungs. That part of the cardiac plexus which is situated chiefly behind the vessels is called the deep cardiac plexus, while the one that lies more in front bears the name of superficial cardiac plexus. They are closely connected with each other and give off:

1. The right or posterior coronary plexus, accompanying the right coronary artery.

2. The left or anterior coronary plexus, accompanying the left coronary artery.

Filaments of these latter plexuses ramify under the pericardium.

Microscopical ganglia, which might perhaps be classed among the peripheral plexuses (homologues of Auerbach's and Meissner's plexuses in the wall of the intestine) (see the second foot-note on p. 581), occur in the nerves of the auricles and in the course of the coronary plexuses. The ramifications of the latter give rise also to the terminal plexuses which Gerlach has described as the "Grundplexus," and which, according to the recent investigations of von Openchowski, give off terminal fibres to the muscular fibres. Van Gehuchten has observed, by employment of the method of Golgi in the nerves of the heart of new-born white mice, a very abundant interlacing network between the nerve fibres of the muscle cells of the ventricle walls, but he has not been able to follow fibres of the peripheral ganglia. This same richness of fibres in every portion of the myocardium has been observed by Hymann and Demoor. The myocardial nerve filaments have also been beautifully demonstrated in the frog's heart by Strong.

II. Solar or Epigastric Plexus.—This plexus lies in front of the aorta and of the pillars of the diaphragm, between the right and left suprarenal bodies, and surrounding the origin of the cœliac and superior mesenteric arteries. It is the largest one of the three prevertebral plexuses, being supplied by the large and small splanchnic nerves and some branches of the pneumogastric. From the solar plexus smaller plexuses branch off, accompanying the principal visceral arteries of the abdomen, and thus forming the diaphragmatic, cœliac, mesenteric, and other plexuses.

1. *Semilunar Ganglia* (*Solar Ganglia, Cœliac Ganglia, Abdominal Brain*).—The two principal ganglionic masses of the solar plexus are the left and right semilunar ganglia, which are situated in the interstice between the suprarenal bodies, being connected with each other by a ganglionic and fibre lacework twining around the origin of the cœliac and superior mesenteric arteries.

The lower part of these ganglia, usually detached from the remainder, is known as the aortico-renal ganglion, in which the small splanchnic nerve terminates, and which supplies the greater part of the renal plexus. Another part, lying below and to the right of the origin of the superior mesenteric artery, is named the *superior mesenteric ganglion*. The formation of the following plexuses is contributed to by the solar and other plexuses and by branches of the cerebro-spinal nerves.

2. *Diaphragmatic or Phrenic Plexus.*—This is situated along the arteries at the lower surface of the diaphragm and is derived from the upper part of the semilunar ganglion. It is also supplied by the phrenic nerves. On the right side this plexus contains a ganglion which marks the junction of the phrenic (cerebro-spinal) and the sympathetic fibres. It gives filaments to the diaphragm, to the vena cava, to the suprarenal body, and to the hepatic plexus.

3. *Suprarenal Plexus.*—The nerves to this plexus emanate from the solar plexus, chiefly from the outer part of the semilunar ganglion, but the plexus also receives some filaments from the diaphragmatic plexus and from one of the splanchnic nerves. It is beset with minute ganglia.

4. *Renal Plexus.*—The chief supply of this plexus is from the aortico-renal ganglion, but the solar and aortic plexuses, the smallest splanchnic nerve, and sometimes the small splanchnic nerve, as well as the first lumbar ganglion, furnish also filaments. Ganglia of different sizes (renal ganglia) are met here. The plexuses of both sides give off twigs to the spermatic plexus and a filament to the urethra. The plexus of the right side supplies some filaments to the vena cava.

5. *Spermatic Plexus.*—This is derived for the most part from the renal plexus, and receives in addition some filaments from the aortic plexus. In the male it follows the spermatic artery and supplies the testis, a small spermatic ganglion being frequently found in its course. In the female it accompanies the ovarian artery and is distributed to the ovary and uterus.

6. *Cœliac Plexus.*—This large plexus, derived from the solar and situated in a kind of fenestrated sheath, surrounds the cœliac artery. It subdivides with the artery into stomachic, hepatic, and splenic plexuses, which, following the respective blood-vessels, supply the stomach (coronary and pyloric plexuses), the liver (hepatic plexus), the gall bladder (cystic plexus, derived from the hepatic), the pancreas and duodenum (pancreatico-duodenal plexus, also chiefly from the hepatic), and the spleen (plexus splenicus, or lienalis). These plexuses anastomose with each other, with the mesenteric nerves, and with the suprarenal plexus. All of them receive additional supply from the pneumogastric nerve.

7. *Superior Mesenteric Plexus.*—This plexus is derived chiefly from the lower part of the solar plexus and from the superior mesenteric ganglion, receiving also fibres from the right pneumogastric at its junction with the cœliac plexus. Following the course and distribution of the superior mesenteric artery, this plexus divides into subplexuses named after the respective vessels, which subplexuses finally pass upon the intestine along the line of attachment of the mesentery. A large number of the filaments terminate between the two layers of the mesentery in so-called Pacinian corpuscles. These are cerebrospinal fibres. In the wall of the intestine the peripheral plexuses (Auerbach's and Meissner's) are formed.

8. *Aortic Plexus.*—The aortic or intermesenteric plexus (plexus aorticus abdominalis) is arranged along the abdominal aorta between the origin of the superior and that of the inferior mesenteric artery, mostly in the form of two lateral cords, which are connected above with the semilunar ganglia and renal plexuses, and in front with each other by communicating branches passing in front of the aorta. The plexus is also supplied from some of the lumbar ganglia. It continues on the inferior mesenteric artery to form the inferior mesenteric plexus. The latter is connected with the inferior mesenteric ganglion, placed below the origin of the artery. The aortic plexus furnishes also part of the spermatic plexus. It gives some filaments to the inferior vena cava, and ends below in the hypogastric plexus.

9. *Inferior Mesenteric Plexus.*—This plexus, springing mainly from the left lateral part of the aortic plexus, clusters around the inferior mesenteric artery. It supplies the left or descending and the sigmoid colon, and the rectum. Its colonic branches anastomose with the middle colonic branches of the superior mesenteric plexus. Other branches connect in the pelvis with the pelvic plexus.

III. Hypogastric Plexus.—The hypogastric plexus, destined for the supply of the viscera of the pelvis, is a flat plexiform mass situated in front of the lowest lumbar vertebra, between the two common iliac arteries. It is the downward continuation of the two cords which form the aortic plexus, and it receives a considerable supply of branches from the lumbar ganglia. Below, it bifurcates to form the pelvic or inferior hypogastric plexuses.

The *inferior hypogastric or pelvic plexuses*, one on each side, are derived from the hypogastric plexus. They lie by the side of the rectum, and of the vagina in the female. After descending a short distance, they receive branches from spinal nerves, namely, the third and fourth and sometimes the second sacral, and from the sacral ganglion of the sympathetic.

The plexus ramifies with and along the branches of the internal iliac artery, forming the hemorrhoidal and vesical nerves which are common to both sexes, and other nerves or plexuses special to each, viz., in the male, for the prostate, vesiculæ seminales, and vas deferens; in the female, for the vagina, uterus, ovaries, and Fallopian tubes. Accordingly, the following plexuses can be distinguished:

1. *Hemorrhoidal Plexus.*—Originating from the upper part of the pelvic plexus, this plexus anastomoses with the nerves (superior hemorrhoidal) which descend with the inferior mesenteric artery and penetrate the coats of the rectum.

2. *Vesical Plexus.*—The nerve plexuses of the bladder are continued from the lower part of the pelvic plexus and are placed chiefly on the lower surface of the bladder. Besides supplying the latter, they furnish nerves to the vas deferens and to the seminal vesicle.

3. *Prostatic Plexus.*—Situated between the prostate gland and the levator ani, this plexus supplies the prostate and the seminal vesicle in the form of the nervi cavernosi or erigentes. It is then continued forward to supply the erectile substance of the penis.

4. *Vaginal Nerves.*—These nerves, derived from the lower part of the pelvic plexus, proceed directly to the vagina.

5. *Nerves of the Uterus.*—According to Foote and Chapman, from whom the description here following is taken,* the uterus has a double nerve supply, namely, from the uterine and from the ovarian plexus. The uterine plexus, they find, is formed by the union of the hypogastric plexus with the sacral sympathetic cord. At this point of union there is a cluster of small ganglia called the ganglion cervicale of Frankenhäuser, situated upon either side of the cervix just at its junction with the vaginal wall. From this point the plexus spreads out fan-like, following and encircling the branches of the internal iliac artery. It distributes its branches to the uterus, vagina, rectum, bladder, ureter, broad ligaments, and pelvic fascia. The branches to the uterus are few in number and supply the lower uterine segments, being composed mainly of fibres from the third sacral nerves. Thus far no fibres from the uterine plexus have been found to enter the uterus above the internal os, unless some of its branches, passing to the broad ligaments, enter the uterus after uniting with the branches of the ovarian plexus. As yet this is undetermined.

The uterine plexus receives its connections with the spinal cord from the third sacral nerve, with some branches from the fourth, and at times from the second. The hypogastric portion of the plexus also has spinal connections through the rami communicantes of the first and second lumbar ganglia of the sympathetic.

The ovarian plexus is derived from the renal plexus and the upper aortic. These plexuses derive their fibres from the solar plexus upon the left side, and from the solar and hepatic plexuses on the right. The connections passing from the plexus to the central nervous system are along the following paths: 1. Through the rami communicantes of the lower dorsal nerves. 2. The greater and lesser splanchnics. 3. The pneumogastric.

The ovarian plexus receives its filaments from the vagus through the renal plexus, from which it is probably derived. The uterine plexus has merely a spinal connection.

Chapman and Foote conclude that of the two plexuses described the ovarian is the controlling nerve supply to the ovary, tube, and uterus, and the path along which are conveyed the most important stimuli passing to these organs.

HISTOLOGY.

In discussing the histology of the sympathetic nervous system, it has been found convenient to divide the structures of the same into two groups, namely, first, the components of the sympathetic chain; second, the components of the nerve plexuses of the sympathetic and of the terminal monocellular ganglia.

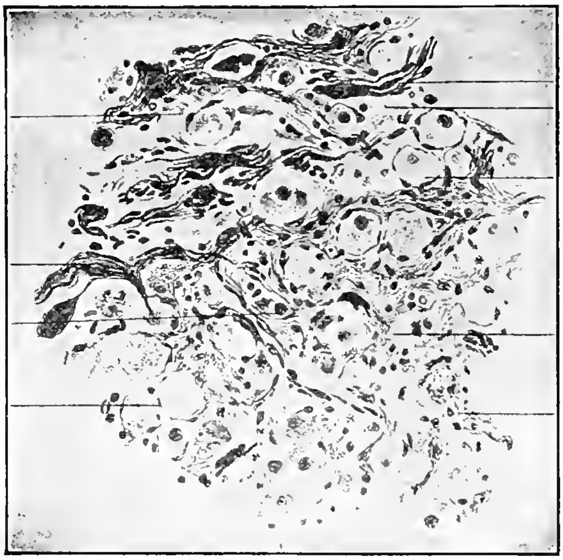

FIG. 4583.—Section of Stellate Ganglion of a Normal Young Cat. Double stain (carm., Pal.); *cps*, pericellular capsula with nuclei; *med*, medullated fibres; *non*, non-medullated fibres.

Histology of the Cords and Ganglia. — The nerves of the sympathetic nervous system are of variable appearance, white, gray, or grayish. The white contain proportionately a large amount of fine, white, medullated fibres; the gray a comparatively slight amount. In some parts of the sympathetic nerves the white and gray fibres run along for a considerable distance without blending, but usually after the white fasciculi have passed through one or more ganglia, the two sets of fibres become thoroughly mixed. The white fibres are about one-half the size of the gray, and measure from 2.5 μ to 3.3 μ in diameter. Most of them belong to the cerebro-spinal, but part of them to the sympathetic system; at least the investigations of Huber and Dogiel speak in favor of fibres of the latter kind. Besides the fine medullated fibres, coarse ones are met with in smaller number. These Roux has proved to be for the most part, if not all, cerebro-spinal sensory fibres.

The type of cells entering into the constitution of the sympathetic ganglia forms a very important distinction between mammalia and fishes and other vertebrates; it also furnishes a point of distinction between the sympathetic and spinal ganglia in each class. In the mammalia the cells are multipolar; in the fishes and amphibia they are unipolar and bipolar. Retzius has used this fact to great advantage in allotting certain ganglia of the cephalic extremity, previously regarded as belonging to the cerebro-spinal nerves, to their proper class.

The ganglia themselves are surrounded by a thin, firm, adherent covering of connective tissue, which sends prolongations through the ganglion and divides it into compartments of different sizes and shapes. The individuality of these compartments is obscured by the fibre constituents of the ganglion. The nerve cells of the ganglion are surrounded by a pericellular capsule (Fig. 4583, *cps*), a membrane in which nuclei are embedded at definite intervals. It is taught by some histologists (Schultze) that this transparent capsule is continuous with the primitive sheaths of the nerve fibres. On careful examination it is seen to consist of flat epithelial like cells, and contains a certain amount of connective tissue, probably the same as that entering into the formation of the compartments of the ganglion. In Fig. 4583, which

* The writer is indebted to these authors for a private communication of their results, part of which has not been published yet, while in part they have appeared in the form of a preliminary communication in the Brooklyn Medical Journal, December, 1901.

illustrates a piece of the stellate ganglion of a young cat (double stain: carmine, Pal.), the medullated fibres (*med*) appear as heavy black strands; the non-medullated (*non*) as reddish-brown fibres. The bundles of medullated fibres go predominantly toward the middle of the ganglion, where they undergo brush-like division. In the centre of the ganglion are seen bundles of medullated and non-medullated fibres, while toward the periphery the fibres are almost exclusively of the latter variety (fibres of Remak). Delicate bundles of these non-medullated fibres are seen passing between the constituent cells of the ganglia, particularly toward the periphery.

Fig. 4584 represents part of a sympathetic ganglion, showing the cells as they are brought out with Nissl's method of staining (methylene blue). The cells have usually one nucleus, but Huber and Bruckner observed

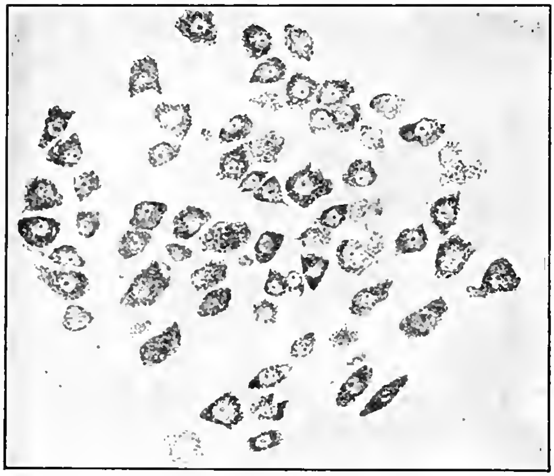

FIG. 4584.—Cells from a Part of a Sympathetic Ganglion.

cells with two nuclei, and Bruckner quotes Professor Obregia as having seen numerous cells with two nuclei make their appearance after electrical excitation. Some cells then also showed partial and others complete division. An endocellular network, apparently of the same nature as Golgi found it in the cells of the intervertebral ganglia, was observed by Veratti in the cells of the cervical ganglia of the sympathetic.

Besides nerve cells, Stilling has discovered in the sympathetic ganglia large polygonal cells, staining deeply in chromic acid and found also in the suprarenal capsules.

Each nerve cell has many protoplasmic processes of longer or shorter course that terminate not far distant from the cells of their origin, and a nervous process (axone) which goes to form a constituent of a peripheral ramus, of a ramus intermedialis, or of a ramus communicans.

The variation in form and extent of the dendritic processes of the multipolar cells of the sympathetic ganglia, as seen with Golgi's method, is considerable. In some dendrites the terminal ramifications are very numerous and cluster in the shape of a basket, forming a pericellular network around other cells. This network, however, does not come in contact with the cell bodies, but lies around the capsule of the cells (Huber). Ramon y Cajal is inclined to the belief that these clusters are of great significance in explaining the functional interrelationship of the cells, a belief which is not shared by von Kölliker and van Gehuchten. Others terminate very simply and free, each one of the dendrites having a number of nodes or varicosities developed upon it. When the protoplasmic processes terminate freely among the cells of the ganglion, their ulterior ramifications are very fine and it is difficult to distinguish them from the termination in the ganglion of the nerve fibres that enter and end there.

Dogiel assumes that all cells of a ganglion are associated by means of a network formed by the dendritic processes. Some of these processes reach even into the next ganglion.

Nerve Fibres of the Ganglia of the Sympathetic Chain and Their Connections.—The nerve fibres in a sympathetic ganglion may be enumerated as:

1. Fibres of passage.
2. Fibres originating from cells of the ganglion.
3. Terminal fibres from other sources.

The ganglion may also contain collaterals from communicating rami or commissural fibres, and probably from peripheral rami, if we assume that fibres arise from cells of the peripheral sympathetic ganglia.

Most nerve fibres in passing through a sympathetic ganglion give off collateral branches, which terminate by free ramifications between and around the cells which enter into the constitution of the ganglion. In every ganglion of the sympathetic chain there are found a number of fibres that terminate there. These may be longitudinal fibres belonging to the sympathetic chain, or peripheral (centripetal) fibres arising from nerve cells of peripheral ganglia and cerebro-spinal fibres conducted by the communicans ramus (see Fig. 4576). Many of those fibres which are continued as pale fibres lose their medullary sheaths on joining with the cells of the ganglia; others pass through the proximate ganglion without relationship to the nerve cells (*fibres de passage*, see Fig. 4576), and are continued toward the peripheral distribution as fine medullated fibres; but even these lose their sheaths in passing through the distal ganglia of the sympathetic system. All these terminal and lateral ramifications produce in the substance of each ganglion a most intricate interlacement of nerve fibrillæ enveloping the protoplasmatic prolongations and the bodies of the cells which make up the real ganglionic mass.

Fibres that come from the roots of the spinal nerves end in arborizations within the sympathetic ganglia. According to Ramon y Cajal, they form definite pericellular networks (not confirmed by Lenhossek), which Huber finds to be always intracapsular, *i.e.*, situated within the capsule of the cell. Directly before reaching the cell around which they terminate, many of these fibres describe a number of spiral turns around the neuraxon of such cell (Huber). These fibres that pass in from the spinal roots are some of them unquestionably motor (see Fig. 4576), and take their origin, according to Kölliker, from cells of the spinal cord (denied by Dogiel).

Sala describes two types of fibres in a ganglion: (1) The varicose fibres, so called because of the tortuosity in parts of their course; and (2) the dividing fibres, found chiefly in the periphery of the ganglion. The varicose fibres are probably identical with Remak's fibres. They remain undivided. Many of them take their origin from the cells of the ganglion within which they are seen, while others take their origin in adjoining ganglia (fibres of passage), without entering into any connection with it, as they do not give off collaterals. The dividing fibres send off collaterals, the ramifications of which constitute the diffuse network of the ganglion. Sala believed that the varicose, undivided fibres are the real sympathetic fibres, *i.e.*, that they originate from cells of the sympathetic ganglia, while the dividing fibres are in reality from the cerebro-spinal system.

Langley's conclusions: According to Langley, who based his conclusions upon the nicotine experiments (quoted in the foot-note on p. 587), all the cerebro-spinal motor fibres that enter into the sympathetic nervous system terminate in one or another sympathetic ganglion by establishing connection with the constituent cells of the ganglion. The axis-cylinder prolongations of the centrifugal sympathetic fibres terminate in the muscular walls of the blood-vessels, in the viscera, or in the glands. The sympathetic ganglia are in reality the ending-place of one set of neurones and the place of origin of a second set. Each ganglion of the sympathetic trunk is to be regarded as a primary centre apart from any connections with the spinal cord. The fibres which it sends off run in the main to the corresponding spinal nerve and follow the course of this nerve. These fibres, emerging from the ganglion as a primary centre, are connected with all the peripheral structures with which sympathetic fibres can be connected and which lie in their course, so that the function of the nerve fibres is determined by the structures in which they terminate and not by the nature of the nerve fibres. A nerve fibre proceeding from a sympathetic cell has no other sympathetic cell in its course (the cells of Meissner and Auerbach's plexuses are not considered by Langley to be types of sympathetic nerve cells). The fibres from the spinal cord to the sympathetic ganglion connect certain cells of the spinal cord with the cells of the spinal ganglia in the same way as the fibres of the pyramidal tract connect certain cells of the brain with the cells of the spinal cord. These spinal fibres become pilo-motor, vaso motor, secretory, according as the fibres from the sympathetic with which they are connected end within the erector muscles of the hair, the muscles of the blood-vessels, or within the glands.

The medullary fibres of the ciliary ganglion have been traced by Kölliker immediately into the eyeball through the ciliary nerve into the sphincter of the iris, ending in the ciliary body.

THE MORPHOLOGICAL ORGANIZATION OF THE VARIOUS RAMI.—I. Rami internodiales.

II. Rami communicantes.

III. Rami peripherales.

I. *The Rami Internodiales* (see Fig. 4576, ramus internodialis).—The fibres that are to be seen passing longitudinally from a ganglion into a ramus internodialis are the axis-cylinder prolongations of nerve cells situated in the same ganglion or in an adjacent ganglion. In other words, these rami internodiales or interganglionic longitudinal strands of the sympathetic are made up of vertical commissural fibres, coursing longitudinally through superimposed ganglia.

II. *The Rami Communicantes.*—The rami communicantes are connected with the so-called *anterior division* or ramus ventralis of the cerebro-spinal nerves to which they are joined. In a ramus communicans two classes of fibres, namely, fibres conducting toward the ganglion and fibres conducting away from the ganglion, are found. (See Fig. 4576, ramus communicans.)

Of those conducting toward the ganglion, part is of centrifugal * function, being derived from cells of the spinal cord, through either the anterior or the posterior † roots; another part are possibly fibres of afferent or centripetal (sensory) function, running from a peripheral nerve through the ramus communicans into the ganglion; at least the existence of such fibres is theoretically required. Of the second class of fibres of the ramus communicans—namely, of those conducting away from the ganglion—some are centrifugal or efferent (although not necessarily strictly motor), originating from cells of that or an adjoining ganglion, and, after having joined the cerebro-spinal nerve with which the ramus communicans of centrifugal function is connected, pass within the nerve toward the periphery, reaching the latter by way either of the anterior or of the posterior division of the nerve (see Fig. 4576, ramus communicans). Others of those fibres which conduct away from the ganglion also originate from cells of the latter or of an adjoining ganglion, but on reaching the cerebro-spinal nerve do not pass toward the periphery, but into the spinal ganglion of said nerve, terminating, according to Cajal, in free ramifications around the cells of that spinal ganglion, thus transmitting the sensory or, more generally speaking, afferent impulses from the sympathetic to the cerebro-spinal system. According to Dogiel, who distinguishes two types of cells in the spinal ganglion, the said fibres terminate around cells of the "second" type, and the latter cells again transfer to the *typical* spinal ganglion cells the impulses derived from the sympathetic system.

Grossly, a ramus communicans can usually be separated into two parts, a gray ramus and a white ramus. The white ramus contains fibres passing into it from both roots of the corresponding spinal nerve, principally from the anterior root; the gray ramus contains mostly fibres destined for the periphery, although some of them are distributed to the vessels of the spinal cord and the nerve roots.

The Peripheral Rami (see Fig. 4576, ramus periphericus).—The peripheral nerves of the sympathetic nervous system are made up of nerve fibres of two kinds, medullated and non-medullated (fibres of Remak). The non-medullated or fibres of Remak form the chief constituent of the sympathetic nerves. These nerves pass into the walls of the vessels of the viscera, or into the glands of the intestinal and urogenital system. The peripheral sympathetic nerves may be classified functionally into three kinds—motor, sensory, and secretory; and probably a group of inhibitory fibres corresponds to each of these three groups.

The motor are destined to innervate the muscles of the vessels and the viscera. The motor fibres innervate also a certain number of striated muscles, such as the heart (Huber), the upper part of the œsophagus, and the pharynx. The secretory fibres go to the glands of the intestine and urogenital system, to the sweat glands, the mucous glands, etc.

The sensory fibres terminate by free ramifications between the epithelial cells of the mucous membranes or in the depths of the walls of the viscera and the vessels, or between the formative elements of the glands (Dogiel, Schematkin, Huber). When they terminate between the two layers of the mesentery, they constitute the Pacinian corpuscles.

Kölliker thinks that all the sensory fibres of the sympathetic system belong in reality to the cerebro-spinal system. Dogiel, on the contrary, it seems to us, has shown, and is confirmed in this by Huber, that in the peripheral organs which are dependent on the sympathetic there exist special nerve cells of sensory nature, whose protoplasmic prolongations terminate between the epithelial or endothelial cells, and whose axis cylinders terminate centripetally in a sympathetic ganglion in order to make connection with the cells of origin of a motor fibre, and constitute with this last a reflex nerve arc, as in the cerebro-spinal system.

The peripheral nerves of the sympathetic nervous system present a mode of distribution which is characteristic and which distinguishes them from the cerebro-spinal nerves proper. They have a remarkable tendency to unite, to interlace one with another, and to form plexuses. The nodes of these plexuses, which are frequently of considerable size, constitute the peripheral ganglia. The nerve cells themselves are of the multipolar type, and they have innumerable protoplasmic prolongations and one axis-cylinder prolongation (van Gehuchten's researches on adult cat and dog).

Histology of the Plexuses and the Monocellular Ganglia.—The ganglia of the cœliac and hypogastric plexuses, the ophthalmic and sphenopalatine ganglia, and probably the ganglia of the heart are of a similar constitution to the ganglia of the great sympathetic chain. According to Ramon y Cajal, the cells have a fibre of Remak, or an axis-cylinder prolongation, which leaves the ganglion to join a ramus communicans or to form a peripheral branch passing to the organ which it supplies; and, in addition, there are the protoplasmatic prolongations which end near the cells of their origin within the ganglion itself.

The peripheral ganglia (visceral ganglia of Cajal), *i.e.*, the ganglia of the intestines, the bladder, the œsophagus, etc., are composed of small multipolar cells, the expansions of which, after extensive ramifications, pass into the plexuses which terminate either in non-striated muscular fibres or in glandular cells. In addition to these they

* *I.e.*, efferent function, usually motor but not necessarily so, as inhibitory fibres, too, may be of efferent function.

† That motor fibres are contained in the posterior roots has been demonstrated directly histologically by Lenhossek, who in the chick saw fibres which originated in the spinal cord enter into the posterior root, and indirectly, that is, by physiological experiment, by Morat, who proved the presence of vaso-dilator fibres in these roots.

contain, according to Cajal, fibres of passage* which are possibly the continuation of fibres from the grand sympathetic chain and collaterals which end between the nerve cells. He believes that there are no anastomoses between the visceral ganglia, the fibres of passage, or the collaterals of the visceral ganglia. Cajal describes small monocellular ganglia which are found in the interstices of the glandular tisssue or in the intestines within the villi; such are the interstitial nerve cells of the glands of Lieberkühn, the nerve cells of the pancreas, and those of the salivary glands. He calls these cells interstitial ganglia, in contrast with the ganglia of the order of Auerbach's and Meissner's plexuses, which he refers to as visceral ganglia, properly called.

Each gland, and perhaps each group of non-striated muscular fibres, no matter how small it may be, contains interstitial nerve cells, the expansions of which help to build up the plexus formed by the visceral ganglia and the fibres of the great sympathetic nerve.

Arnstein observed the neuraxon of a sympathetic neurone ending in smooth muscle tissue. Huber traced small branches of non-medullated fibres from some of the small ganglia found in the cat's auricle to their ending in heart muscle, and also the neuraxes of sympathetic neurones of the sublingual ganglion (Langley) to the epilamellar plexus surrounding alveoli of the gland of the same name.

In the pia mater of the brain Huber found two kinds of nerve fibres, medullated and non-medullated ones. The former he considers to be sensory and to end for the most part with their varicose, non-medullated, terminal branches in fibrous tissue—*i.e.*, adventitia of vessels—or in the pia. The non-medullated fibres he considers to be vaso-motor nerves, forming primary plexuses in the adventitia. Through frequent branching of the fibres of the latter an interlacing network is formed. Within this plexus is formed a second one, not so well defined, lying evidently internal to the muscular coat and giving off terminal fibrils to the muscular tissue of the vessels. In the dura cerebri Huber found sympathetic nerves forming perivascular plexuses and medullated sensory nerves, terminating in the dura. It would seem that the termination of the sensory fibres at one end must spread over a relatively large area, thus precluding a finer localization of sensory impressions.

PHYSIOLOGY.

General Facts and Functional Classification.—It may safely be said that the sympathetic system has, to a great extent, a controlling influence over the secretion of most of the glands, the lachrymal, the salivary, the sweat glands, the glands of the stomach and intestines, the liver, the kidney, etc.; that it presides over the circulation by regulating the calibre of the blood-vessels and the action of the heart; that it influences respiration; and, finally, that all involuntary muscles, those of the digestive apparatus, of the genito-urinary system, of the hair follicles (pilomotor nerves), are under its control to such extent that, for instance, in certain mammalians the bladder still continues to fulfil its function for weeks after all the cerebro-spinal motor nerves leading to it have been severed. In short, we find that all vegetative life of the organism is, to a greater or less extent, under the control of the sympathetic system. Therefore it may properly be called the vegetative nerve system *par excellence*.

In discussing the processes which are said to be under the influence of the sympathetic system, we shall subdivide the subject as follows:

I. Secretory influence:
  (*a*) Lachrymal glands.
  (*b*) Sweat glands.
  (*c*) Mammary glands.
  (*d*) Glands of the digestive apparatus.
    1. Salivary glands.
    2. Glands of the stomach and intestine.
    3. Liver.
    4. Pancreas.
  (*e*) Kidney.
  (*f*) Glycosuria.*
II. Vascular functions.
III. Cardiac functions.
IV. Respiratory functions.
V. Influence upon involuntary automatic motions.
  (*a*) Stomach and intestines.
  (*b*) Bladder.
  (*c*) Uterus, etc.
  (*d*) Pilomotor nerves.
  (*e*) Pupil.
VI. Trophic and tonic functions.
VII. Reflex action of the sympathetic.
VIII. Functional interrelation of cerebro-spinal and sympathetic systems.

I. Secretory Functions.—The sympathetic system has been proven to exert its influence on the secretion of the lachrymal glands, of the glands of the stomach and intestine (including the pancreas), of the salivary glands, of the sweat glands, and on the secretion of bile and urine. We shall mention here for convenience' sake, although not really coming under this heading, the relation of certain lesions of the sympathetic to the production of glycosuria.

Matthews (1897) has recently given the mechanism of secretion a careful experimental study, and his conclusions are of such vital interest that no one can afford to neglect them in discussing the physiology of secretion. We give these conclusions in his own wording:

"There is no single mechanism of secretion. In some glands the stored metabolic products are driven out of the cells by the action of muscle, as in amphibian skin glands and sudoriferous glands; in others they are removed by currents of lymph, which are probably the result of osmosis, as in the pancreas, stomach, salivary glands; in some cases the cells imbibe water until they burst and their contents rush into the gland lumen, as in the intestinal cells of ptychoptera larvæ; in others the inner end of the cell crumbles to pieces, as in the mammalian milk glands. Two or more of these mechanisms may coexist in one gland, and it is this which has rendered the physiology of such glands as the salivary so confusing. Whether secretory nerves exist or whether secretion is ever a function of the gland cell must be considered at present an open question."

(*a*) *Lachrymal Secretion.*—According to Demtschenko and Wolferz, excitation of the sympathetic nerve of the neck (in cats) causes lachrymal secretion. The sympathetic lachrymal secretion differs physically from the trigeminal secretion; for the former is cloudy, and the latter clear and transparent. Bechterew and Mislawski confirm this statement of the influence of the cervical sympathetic nerve upon lachrymal secretion. They find, moreover, that both the cerebral cortex (internal parts of the anterior and posterior portions of the sigmoid convolutions) and the thalamus (circumscribed spot in the depth of its internal part at the level of the anterior portion of the gray commissure) preside over lachrymal secretion by way of the fifth nerve, partly also by way of the cervical sympathetic.

G. Fischer excited the cervical sympathetic nerve with the faradic current in the heads of two decapitated men, and found as a result considerable lachrymal secretion besides the oculo-pupillary effects mentioned on page 587. Jonnesco also found the presence of secretory fibres for the lachrymal glands in the cervical sympathetic of man, his conclusions being derived from a study of epileptics in whom therapeutically the cervical sympathetic had been cut or removed.

(*b*) *Sweat Secretion.*—Although it stands unquestioned that sweat secretion is under the control of the nervous system, the manner of this influence is still a matter of debate. While it seemed to have been proven by Luch-

* Meaning fibres which only pass through the ganglion without in any way becoming connected with the cells of the latter.

* Taken under this heading for convenience' sake.

singer that this influence was a direct one, and not one acting indirectly, through vascular effect, his results have again been made doubtful by the recent researches of Matthews, who concludes that the sweat glands, like the salivary glands, receive a double nerve supply and probably possess a double mechanism of secretion, *i.e.*, a muscular and an osmotic, as explained on page 582.

Vulpian distinguishes for the salivary glands secretion-exciting nerve fibres (fibres excito-sudorales), and, antagonistic to these, sweat-moderating fibres. The subject has not been followed up, however, and the physiological facts, which have thus far come to the writer's knowledge, concern only sweat-exciting fibres.

The pathway pursued by the sweat-secretory fibres in their course from the spinal cord to the sweat glands is not fully known in its whole extent. They leave the spinal cord by the anterior roots. Whether the posterior roots conduct some of these fibres has never been debated. The statements as to their further course are very diverse. All authors admit, it seems, that part of the fibres pass through the great gangliated cords before joining the peripheral nerves, and some writers (Nawrocki and Luchsinger, and Langley) go so far as to say that all sweat fibres destined for the limbs are derived *indirectly*, *i.e.*, through intermediation of the sympathetic nerve, from the spinal cord, a view opposed by Vulpian and later modified again even by Luchsinger as far as the hind paws of the cat were concerned.

Regarding the sweat fibres for the fore paws, views have been equally divided; Vulpian claiming on the one hand that part of the sweat fibres go directly from the spinal cord to the brachial plexus; Luchsinger, and lately Langley, contending on the other hand that all sweat fibres for the forepaw enter the thoracic sympathetic and pass through the stellate ganglion before joining the nerves of the brachial plexus.

In two cats in which Dr. Collins and myself had extirpated a stellate ganglion, sweat secretion could be produced in the fore paw of the operated side three and four and one-half months after the operation respectively, in one case by hypodermic injection of pilocarpine, in the other by instillation of the latter into the eyes. In one of these two cats, when etherization was begun for the purpose of performing another operation, the struggles of the animal against being etherized produced considerable sweating of all paws except the forepaw of the side on which the stellate ganglion had been removed; this forepaw remained perfectly dry. These observations tend to throw some doubt on the contention of Langley and Luchsinger, mentioned at the end of the above paragraph, although their interpretation is by no means simple.*

For the sweat glands of the head, even Luchsinger admits both a sympathetic (fibres of the cervical sympathetic nerve) and a direct non-sympathetic nerve supply, the latter being furnished either by the spinal cord or by the oblongata. Luchsinger emphasizes the view, however, that the cervical sympathetic nerve is the principal sweat nerve for the head. (In pigs and cattle certain glands of the muzzle of cattle are the homologues of sweat glands.)

In man the presence in the cervical sympathetic nerve of sweat secretory fibres for the head was found by Jonnesco, who experimented on fifteen epileptics in whom the cervical sympathetic nerve was cut or resected for sake of treatment.

(*c*) *Lacteal Secretion.*—Of the special influence of the nerves upon the mammary glands and upon the secretion of milk, we know only that while erection of the nipple is impossible when the spinal nerves which supply the breasts are divided, the secretion continues and is not arrested even when the sympathetic as well as the spinal nerves are severed (Foster).

(*d*) *Secretion of the Glands of the Digestive Apparatus.*—1. *Salivary Secretion.*† Secretion of the parotid gland occurs not only by influence of cerebral nerve fibres, but also by that of the sympathetic nerve of the neck (von Wittich and Nawrocki). Secretory fibres for the salivary glands were also found by Jonnesco in the cervical sympathetic of man (experiments on fifteen epileptics who had the cervical sympathetic cut or removed). In their course toward the gland the secretory fibres of the cervical sympathetic become connected with the facial nerve (von Wittich).

The presence of real secretion-promoting or secretion-inhibiting fibres for the parotid gland in the cervical sympathetic nerve is denied by Jaenicke and doubted by Eckhard, the former explaining the "sympathetic" secretion of saliva purely by vaso-motor function.

Heidenhain finds (in rabbits and dogs) that parotid saliva secreted by excitation of the cervical sympathetic nerve differs from that obtained from excitation of the cerebral secretory fibres (nervus Jacobsoni) by its high percentage of organic, especially of albuminous, substances. To explain this effect—which, he says, takes place quite independently of the vaso-motor function of the sympathetic nerve—he assumes that the latter acts more through trophic than through secretory function upon the parotid.

Langley, who repeated Heidenhain's experiments, found that under the influence of excitation of the "trophic" fibres the number of granules seen in the protoplasm of the cells of the parotid gland increased considerably, while it diminished under the influence of the secretory fibres. He found, however, that in the *cat* the trophic fibres are not contained in the cervical sympathetic, but, on the contrary, in what is considered the cerebro-spinal secretory nerve, viz., in the chorda tympani.

In the light of Matthews' investigations Heidenhain's theories and the generally accepted trophic nerve mechanism of secretion are very questionable. Matthews concludes that the sympathetic nerve induces salivary secretion by acting on contractile tissue in the glands and thus causing a compression of ducts and alveoli; that, on the other hand, the chorda tympani or other dilator salivary secretory nerve probably causes secretion by its dilator action on the blood-vessels, thus increasing osmosis.

2. *The Glands of the Stomach and Intestine.* The secretion of gastric juice in frogs continues for days (until death) after all connections of the stomach, except the mesentery deprived of its nerves, have been severed, showing that the centres presiding over the secretion of gastric juice are situated in the intragastric plexuses (Contejean). In these animals the pneumogastric and sympathetic nerves have a regulatory influence upon the secretion of the stomach glands.

Regarding the intestine, Moreau observed that after separation of a piece of intestine from the rest of the gut by two ligatures and severance of all nerves of the mesentery leading to it, this isolated piece of gut filled itself with an apparently abnormal secretion fluid.

The influence of special nerves upon the secretion of intestinal juice was studied by Dr. J. Collins and the writer with this result: Disturbance of digestion followed the removal of the stellate ganglion and of the lower thoracic portion of the sympathetic cord, and also the removal of a semilunar ganglion in the cat. The digestive disturbances following extirpation of the stellate ganglion were, however, more marked and more persistent than those noted after removal of the lower thoracic sympathetic. They consisted of diarrhœa and of putrefaction of the fæces. The fæcal matter was semiconsistent, of yellow or dark grayish-brown color, and of exceedingly foul odor.

The putrefactive symptoms made their appearance sometimes as late as two and three months after the operations, and it was noted that the digestive disturbances had a tendency to increase, and, in two cases, persisted until the death of the animals, three and four and one-half months, respectively, after the operation. This

* For a detailed discussion of the question the reader is referred to the monograph by Dr. Collins and the writer. (See Bibliography.)

† Claude Bernard's observations on the submaxillary gland and ganglion are referred to farther on, under the heading "Tonic Influence."

tendency of the symptoms is most plausibly explained by degeneration progressing toward the periphery and affecting finally the intrastomachal and intra-intestinal plexuses.

Vomiting was observed occasionally after removal of the stellate ganglion or of the lower part of the thoracic sympathetic or of the semilunar ganglion, but this symptom was very inconstant and transitory.

3. *Secretion of the Bile.* Munk observed that excitation of the splanchnic nerve in rabbits was followed first by an acceleration, then by a retardation of the flow of bile. He attributes this effect chiefly to vaso-motor influences and to stimulation of the muscles of the gall ducts. The latter effect was also noted by Doyon (quoted from Howell), who states that the corresponding nerve fibres reach the liver through the semilunar plexus.

Afanassiew noted that section of the nerves of the liver gave rise to polycholia: (*a*) increased secretion of bile; (*b*) dilatation of all the blood-vessels of the liver to a marked degree, and afterward dilatation of the lymphatic pathways; (*c*) excess of urobilin, its presence being caused partly by the polycholia and partly by compression of the fine gall ducts by the dilated blood and lymph vessels, the consequence being retention of bile; (*d*) absence of glycogen in the liver; (*e*) swelling of the liver cells, which take on an appearance similar to that observed after fibrin feeding.

Howell concludes that, as far as our knowledge goes, the physiological evidence is against the existence of true secretory nerves controlling the formation of bile. On the other hand, he says, there are some experiments (Morat and Dufour), though not absolutely conclusive, which indicate that glycogen formation within the liver cells is influenced by a special set of glyco-secretory fibres.

4. *Influence upon the Pancreatic Secretion.** According to the investigations of Pawlow and his students, stimulation of the vagus nerve or the sympathetic causes, after a considerable period of latency, a marked flow of pancreatic secretion Howell says that, in harmony with the theory of trophic and secretory fibres, the experiment seems to indicate that trophic fibres are more abundant in the sympathetic, and, similarly, the secretory fibres proper in the pneumogastric.

(*e*) *Renal Secretion.*—Howell concludes that the majority of purely physiological experiments upon direct stimulation of the nerves going to the kidney are adverse to the theory of secretory fibres, the marked effects obtained in these experiments being entirely explicable by the changes produced in the blood supply of the organ. Hermann comes to similar conclusions.

The vascular nerve fibres of the kidney are supplied by the renal plexus, and are preponderatingly but not exclusively derived from the splanchnic nerves (Hermann). According to Bradford, the innervation of the vessels of the kidney is furnished by the anterior roots of the dorsal nerves from the fourth downward and of the lumbar nerves down to the third and fourth; most abundantly, however, by the eleventh, twelfth, and thirteenth dorsal. The existence of fibres passing within the splanchnic to the kidney, fibres which exert a tonic influence, cannot be proven (Hermann). According to Langley and Dickinson, the splanchnic vascular fibres of the kidney are interrupted by cells of the renal plexus.

Peyrani has found that section of the cervical sympathetic causes a lessening of the quantity of urea and urine to a minimum, while excitation of the peripheral (head) stump of this nerve causes increase both of urea and of urine. Kuelz could not confirm these results, and denies that the cervical sympathetic has any influence upon the above-mentioned secretions.

(*f*) *Glycosuria Produced by Influence of the Sympathetic.*—The subject of glycosuria is ranged in here for convenience' sake, although not properly belonging here.

Since Claude Bernard showed that irritation of the floor of the fourth ventricle, the so-called hepatic vaso-motor centre or area, causes glycosuria, physiological and pathological evidence has been accumulated to show that the production of grape sugar stands in causal relationship to the function of the sympathetic nervous system. Schiff demonstrated that section of the vaso-motor pathways in the spinal cord at any level down as far as the exit of the nerves for the liver, caused glycosuria. Pavey noted that destruction of the superior cervical ganglion caused glycosuria, and Eckhard observed that a similar condition resulted when the inferior cervical and first thoracic were destroyed. Trambusti showed experimentally that after extirpation of the cœliac plexus there was deposition of glycogen in the kidneys. Dr. J. Collins and the writer found much sugar in the urine in one cat four weeks after removal of the lower part of the thoracic sympathetic nerve on one side, in another cat four months after the same operation. Nearly every physiologist who has experimented on the abdominal sympathetic, and has afterward carefully observed the constitution of the urine, has found that lesion of this part of the sympathetic is accompanied usually by glycosuria (Klebs, Munk, Hensen); but in most if not all of these experiments only the immediate effects of lesions in the domain of the sympathetic were studied, while in the observations of Dr. Collins and the writer the remote effects of such lesions were the subject of inquiry.

The hypotheses that have been advanced to explain the occurrence of glycosuria with these experimental lesions of the sympathetic nervous system are numerous. The majority of writers seem to be of the opinion that the occurrence of grape sugar with such lesion is immediately conditioned by change in the tonus of the blood-vessels of the liver and in the quantity of blood passing through the liver.

From the large amount of sugar found four months after the lesion of the thoracic sympathetic, it is fair to conclude that the glycosuria caused by such lesions is not temporary but permanent, and seems, if we are allowed to judge anything from the observations of Dr. Collins and myself, limited to two cases only, to have a tendency to increase rather than to diminish.

We find, then, that nearly all secretory glands are under the influence of the sympathetic system. The facts indicate, as Claude Bernard showed for the submaxillary ganglion and gland, that there are independence and dependence of action of the peripheral (that is, sympathetic) secretory nerve apparatus from the central nervous system. The fibres of the latter (cerebro-spinal fibres, motor fibres of the first order—Kölliker; preganglionic fibres—Langley) exert a controlling influence upon the secretions, which influence is either stimulating or inhibitory, purely secretory or partly vascular, or solely vascular, as in the case of the kidney, for instance, in which organ the existence of purely secretory fibres could not be proven. For some glands (salivary, pancreas) the existence of true trophic nerves is possible, although rendered questionable by Matthews' conclusions, and it would seem that most of the trophic fibres are derived from the sympathetic cord.

II. Vascular Functions.—The investigations of Claude Bernard, Dastre and Morat, Ostroumoff, Gruetzner, Heidenhain, and others have demonstrated the existence of two kinds of vascular nerve fibres (fibres calorifiques of Claude Bernard). The excitation of one kind causes vaso-constriction—"vaso-motor or vaso-constrictor fibres"; while excitation of the other kind produces vaso-dilatation—"vaso-dilator or vaso-inhibitory fibres." The vaso-constrictor fibres usually predominate in number or strength, and are therefore more easily demonstrated than the vaso-dilators.

As to *sensory* vascular nerve supply, Spallita and Consiglio find that the entire vascular surface is provided with special sensibility, capable of producing notable modifications in the general distribution of the blood. It is the opinion of these investigators that the function of the vaso-sensitive nerves is to prevent a superabundance of blood in the peripheral parts of the circulatory

* See results of Matthews' experiments, p. 582.

system, an action analogous to that which Cyon admitted for the sensory nerves of the heart and of the liver.

The motor vascular fibres leave the spinal cord for the most part with the anterior roots, but a part of the vaso-dilator (vaso-inhibitory) fibres seem to be contained in the posterior roots (Stricker, Gaertner, Morat). In their further course the vascular fibres either join the great gangliated cord by means of communicant rami, which is the case for most if not all vascular fibres of the limbs (Claude Bernard, Ostroumoff, Heidenhain and Gruetzner, Langley), or they pass from the spinal nerve directly to one of the great prevertebral plexuses. We find thus, for instance, that part of the vascular fibres supplying the pelvic viscera are derived from the lumbar plexus and join the periphery by intermediation of the great gangliated cord, while the other part, arising from the sacral nerves, pass directly to the hypogastric plexus without connection with the gangliated cord (Langley).

Many of the vascular fibres enter the gangliated cord and become interrupted by cells of the ganglia of the latter. This is probably the case with most of the vaso-motor and vaso-inhibitory fibres for the limbs. Others again, those which are contained in the posterior roots, are said to be interrupted by cells of the spinal ganglia (Morat). Still others take an uninterrupted course through the sympathetic cords, using the latter only as a kind of commissure. This has been demonstrated to be so for the vascular fibres of the splanchnic nerve, which pass without interruption from the spinal cord either to the semilunar or to the superior mesenteric ganglion (Langley and Dickinson).

The presence of both vaso-constrictor and vaso-dilator fibres has been proven in almost every division of the sympathetic system.

Recently the section or resection of the cervical sympathetic unilaterally or bilaterally has given opportunity of studying the vascular functions of this part of the gangliated cord in man. Jonnesco, making his studies on fifteen epileptics thus operated, concludes that the cervical sympathetic contains vaso-constrictor fibres for the head, face, and heart, made evident by excitation with strong electric currents; that it contains, furthermore, vaso-dilator fibres for the inner parts of the cheeks and lips, for the gums, inner and lateral part of the tongue, and for the brain, brought out by the application of feeble currents.

In rabbits, Lafforgue had observed as the direct result of stimulation of the cervical sympathetic nerve (peripheral stump) a spasmodic ischæmia of the whole cerebrum, cerebellum, and oblongata.

A common central organ for the vaso-motor nerves is situated in the medulla oblongata, by stimulating which (the spinal cord and sympathetic being uninjured) contraction of all the small arteries, increase of the blood pressure in the arterial trunks, and turgescence of the heart (Ludwig and Thiry, quoted from Hermann), will be produced. It extends in rabbits from about 3 mm. above the calamus scriptorius to the upper portion of the fourth ventricle. It is bilateral, situated at some distance from the median line.

Reinhold, in several cases of vascular disturbances which by exclusion were interpreted as being of central origin, found multiple hemorrhages at the floor of the fourth ventricle.

The outflow from the spinal cord, of the vaso-motor fibres for the lungs (in the dog) takes place between the first and fifth dorsal nerves, with a maximum at the level of the third dorsal. Some of these fibres leave the thoracic sympathetic chain at the level of the stellate ganglion and pass through the ansa Vieussenii to the inferior cervical ganglion (Bradford, Dean, and François Frank).

III. Cardiac Functions.—The striking autonomy of the peripheral nerve apparatus of the heart is shown by the fact that the latter, when removed from the body or deprived of all the nerves passing to it, still continues to beat for some time, in cold-blooded animals even for days. Recently Engelmann has called attention to a still more marked autonomy of the heart's action, pointing out that in the fœtus pulsations of the heart begin at a period when the latter is still absolutely devoid of nerve-cells (and consequently also of nerve-fibres). In the human embryo the first beginnings of cardiac ganglia are not found before the end of the fourth or commencement of the fifth week (His), while Pflüger saw regular pulsations of the heart in a human embryo of hardly three weeks, which denotes the possibility of purely myogenic heart action entirely independent of any nervous influence. Yet its action is under the control of certain nerves, part of which have an accelerating and at the same time augmenting (intensifying) influence—augmentor nerves; while the others have an inhibitory effect by lessening the number of beats and the force of the contractions—inhibitory nerves of the heart. Most of the inhibitory nerves are contained in the pneumogastric nerve, which is the cardiac inhibitory nerve *par excellence*.

In the dog the augmentor fibres are said to leave the spinal cord by the anterior roots of the second and third and to some extent the first and fourth, possibly the fifth, thoracic nerves. They travel by the several rami communicantes to the stellate ganglion, and pass thence to the cardiac plexuses and to the heart by nerves from the ganglion itself or from the ansa Vieussenii, or from the so-called lower cervical ganglion. In the cat, and probably in mammals generally, the path of the augmentor impulses is very similar. They leave the spinal cord by the upper thoracic nerves and pass to the heart through the lower cervical and upper thoracic sympathetic ganglia (Langley, Foster).

Part of the augmentor fibres, however, are derived from the pneumogastric nerve (Hermann). Schiff, who goes so far as to claim that the pneumogastric alone contains augmentor fibres, says that when this nerve is completely degenerated no acceleration of the heart action can be obtained through any nerve. He concludes that the influence which the sympathetic ganglia have upon the acceleration of the heart's action is due to the action of the pneumogastric nerve connected with them.

IV. Respiratory Functions.—Graham finds that the splanchnic nerve exerts a reflex, inhibitory influence upon respiration. If the splanchnic nerve of the one (left) side is severed and the central stump excited by the faradic current, the respiration arrests itself in the state of expiration—diaphragm perfectly relaxed, abdominal muscles contracted. The tests succeed also when both pneumogastric nerves are severed at the neck.

Section of the oblongata above the region of the respiratory centre does not influence the result, which remains also unchanged when the spinal cord is severed between the eleventh and twelfth dorsal vertebræ, while the excitation of the splanchnic nerve loses its effect if the section is made between the fourth and fifth dorsal vertebræ. This shows that the fibres in question enter from the splanchnic nerve into the spinal cord above the eleventh or twelfth dorsal, and below the fourth or fifth dorsal vertebræ, and then ascend to the oblongata to influence the respiratory centre.

Guillebeau and Luchsinger confirm Graham's observation of the influence of faradic excitation of the splanchnic nerve upon respiration if the spinal cord is intact; but if the oblongata is severed from the cord, the effect of the faradization of the splanchnic nerve is contraction, not only of the abdominal muscles, but of the diaphragm. They contend that the spinal cord contains the primary centres for abdominal *pressure* (*Bauchpresse*), because after isolation from the oblongata the mechanics of the abdominal pressure can be brought into action reflexly by excitation of sensory nerves.

It may be of some interest briefly to mention here the remote effects of lesions of the sympathetic on respiration and on the respiratory tract in general, as observed by Dr. J. Collins and the writer after removal of the lower part of one thoracic sympathetic nerve in some cats and of one stellate ganglion in others. These effects, as a rule, made their appearance as late as weeks after the operation, and, in the case of lesion of the thoracic sympathetic, even four months after the injury inflicted. They consisted in either case in the occurrence of attacks of sneezing and of paroxysms of coughing and hiccough. Removal of the stellate ganglion caused, in addition, first a mucous, then a purulent secretion from the nasal mucous membrane, and in one case it produced a chronic purulent bronchial secretion with lobular infiltration of the lungs.

The respiratory symptoms were more grave in the case of removal of the stellate ganglion than in the case of resection of the thoracic sympathetic in its lower portion. To account for this we must not forget that in the cat the vagus nerve sends a powerful communicating branch to the stellate ganglion. This may also explain the presence of the catarrhal condition in case of removal of the stellate ganglion and its absence in the case of resection of the lower portion of the thoracic sympathetic. The cough and hiccough, however, could not be due to involvement of the pneumogastric alone, since they were observed also after resection of the lower part of the thoracic sympathetic, an operation which involved chiefly the splanchnic nerve. For the innervation of the pulmonary vessels, see page 585, end of section on vascular functions.

V. Involuntary and Automatic Movements.—Under this heading I class the movements caused by non-striated muscles. The heart muscle has a structure which forms a transition between the striated and non-striated muscles. Owing to the intimate connection which exists between the heart and the blood-vessels, it was found most convenient to discuss the sympathetic influence upon this organ directly after discussing the vascular functions.

It now remains to discuss the influence of the sympathetic system upon the movements of the stomach and intestines, the bladder, the uterus, the pupil, and on the erectors of the hair follicles (pilomotor nerves, Langley).

(*a*) *The Movements of the Stomach and Intestines.*—In this paragraph we may at the same time discuss the vascular influence upon the stomach and intestines. The nerves presiding over the secretions of these parts have been spoken of in a preceding chapter.

The movements of the stomach and smaller intestine are under the control chiefly of the pneumogastric and the splanchnic nerves, which nerves are to a large extent functionally antagonistic to each other (Pflüger, Mayer and Basch, van Braam-Houckgeest). The pneumogastric is chiefly a vaso-dilator nerve and excites the movements of the intestine and the stomach; the splanchnic inhibits the movements, and it is at the same time vaso-constrictor. Morat has demonstrated, however, that this antagonism is not absolute, he being able to demonstrate the inhibitory activity of the pneumogastric and, on the other hand, the excito-motor (augmenting) activity of the splanchnics.

One splanchnic nerve can functionally replace the other (van Braam Houckgeest). Both the vaso-constrictor and the motor inhibitory action of the splanchnics are under the tonic innervation of the nerve centres (spinal) with which they are connected (van Braam-Houckgeest).

According to Contejean, the pneumogastric nerve in the frog innervates the longitudinal system of muscular fibres of the stomach, and contains also inhibitory fibres which may counteract reflex action of the stomach; the sympathetic, on the other hand, presides chiefly over the circular system of muscles.

Ehrmann, on the other hand (quotation from Hermann), finds that the pneumogastric excites the circular muscular fibres of the stomach and intestine and inhibits the longitudinal fibres, while the splanchnic excites the longitudinal fibres and inhibits the circular fibres. This conclusion is contradicted by Langley.

According to Langley, the splanchnic fibres are derived directly from the spinal cord; that is, they undergo no cell interruption in the ganglia of the sympathetic cords. But they have their termination in the semilunar ganglia, and from the cells of the latter new fibres arise which establish the connection with the muscles and blood-vessels of the stomach and upper intestine.

The lower segments of the intestine (colon and rectum) receive likewise a double nerve supply, namely from the lumbar (second to sixth in the cat), and from the sacral (second to fourth) nerve roots (Langley and Anderson). The fibres derived from the lumbar roots (visceral lumbar nerves) join the sympathetic and leave it for the most part with the cœliac or hypogastric nerves. The fibres derived from the sacral roots (visceral sacral nerves) pass into the nervi erigentes.

The two nerve plexuses differ not only in origin, but also in function (Langley and Anderson). In the first place the visceral lumbar nerves contain vaso-constrictor fibres for the descending colon, for the rectum, and for the mucous membrane of the internal sphincter. These nerves further contain inhibitory fibres for the muscles of the colon and rectum and for the mucous membrane of the internal sphincter. Finally, the visceral lumbar nerves have a relationship to the skin surrounding the anus; they supply motor fibres for the non-striated muscles and for the constrictors of the blood-vessels of this region.

The visceral *sacral* nerves are to a great extent antagonists of the visceral *lumbar* nerves. Excitation of them produces hyperæmia of the intestinal mucous membrane and strong movements of the longitudinal and circular muscles of the colon and rectum. The non-striated muscles of the skin of the anus are inhibited by these fibres.

In regard to the movements of the rectum Fellner had come to the following conclusions, which are, as we have seen, contradicted in part by Langley and Anderson: (1) The nervi erigentes cause contraction of the longitudinal fibres and relaxation of the circular fibres of the muscles, shortening and thickening of the rectum, increase of volume, and diminution of pressure; (2) the hypogastric nerves have the opposite effect: relaxation of the longitudinal, contraction of the circular muscular fibres, lengthening and narrowing of the rectum, lessening of volume, and increase of pressure.

(*b*) *The Movements of the Bladder.*—It is proven by the investigations of Budge, Sokownin, Gianuzzi, Nussbaum, Nawrocki and Skabitschewski, Langley and Anderson, and Sherrington that the bladder receives a double supply of motor nerves, viz.: (1) From roots of lumbar nerves (lumbar supply); and (2) from sacral nerves (sacral supply).

The fibres derived from the *lumbar nerves* leave the spinal cord by the anterior roots of the (third) fourth and fifth (in the monkey from the second, third, and fourth) lumbar nerves, and join the abdominal sympathetic nerve by the rami communicantes. From the abdominal sympathetic part of the fibres pass directly to the hypogastric and vesical plexuses (Nussbaum); the greater part, however, reach the inferior mesenteric ganglion by way of the mesenteric (superior, median, inferior) nerves, and pass then into the hypogastric nerves, which latter connect the inferior mesenteric ganglion with the hypogastric plexus.

The fibres derived from the *sacral nerves* leave the spinal cord with the anterior roots of the second, third (sometimes also the fourth, and very seldom the fifth) sacral, and pass from these nerves *directly to the hypogastric plexus*, without mediation of the main trunk of the sympathetic.

According to Langley, part of the motor fibres of the bladder are interrupted by cells of the inferior mesenteric ganglion, others probably by the cells of the hypogastric or vesical plexuses.

As the descent of the fibres to the bladder occurs in two different pathways, so their origin in the cord is probably twofold; that is, we must assume for many mammals the presence of two separate spinal centres of the bladder, one being situated in the lumbar, the other in the sacral portion of the cord. The position of these centres, although not exactly known, is indicated more or less by the level of the roots through which the motor fibres for the bladder leave the cord. Gianuzzi claims that in the dog they are situated at the level of the third and fifth lumbar vertebræ respectively. Sarbo reported a case of a man in whom there had been incontinence of fæces and of urine, and in whom the autopsy revealed a gliosis that had effaced the structure of the spinal cord almost entirely at the levels of the third and fourth sacral segments.

Erection and Ejaculation. The vaso-dilator fibres, stimulation of which causes erection, are contained in the nervi erigentes (Eckhard, quoted from Hermann) which are formed by filaments passing from the sacral nerves (chiefly the second and third) to the hypogastric plexus; but some of these vaso-dilator fibres come from the lumbar sympathetic (dog), passing from there to the hypogastric plexus (François Franck).

Concerning the pathways of the nerves presiding over ejaculation, nothing definite seems to be known. At least nothing is said about them in the well-known physiological text-books.

The centres of erection and ejaculation (dog) are situated in the lumbar portion of the spinal cord (Goltz).

As has been mentioned in another paragraph, the bladder can act independently of the spinal centres, at least in the higher mammalians (cat, monkey). After all the motor fibres leading to the bladder have been severed from the spinal cord, this organ still continues its functions for weeks (Zeissl). Its rhythmic action is the result of the nerve apparatus (hypogastric and vesical plexuses) placed within or on its wall (Zeissl, Sherrington).

(*c*) *The Movements of the Uterus.*—According to Langley, all motor fibres to this organ are supplied exclusively from lumbar nerves, and their further course is within the main trunk of the sympathetic, from which they pass through the inferior mesenteric ganglion to the pelvic plexuses. Some authors, however (Frankenhauser, Kehrer, and others), claim a sacral supply in addition to the lumbar, stating that part of the motor fibres of the uterus pass directly from sacral (third, fourth) nerves to the pelvic plexuses. According to Basch and Hoffmann (quotation from Hermann), the lumbar nerves act as motor nerves only of the longitudinal fibres, the sacral only of the circular fibres of the uterus. These statements are contradicted by Langley.

A great part of the motor fibres to the uterus are interrupted by cells of the inferior mesenteric ganglion (Langley).

For parturition, the centre situated in the lumbar portion of the spinal cord is sufficient, as this act has been observed in bitches with isolated lumbar portion of the spinal cord (Goltz and others). As to whether parturition can take place if the connection with this spinal centre is severed, we can find no data.

Chapman and Foote conclude that the ovarian plexus is the controlling nerve supply to the ovary, tube, and uterus, and the path along which are conveyed the most important stimuli passing to these organs. For further details of their work, see the paragraph on the "Nerves of the Uterus" in the anatomy of the sympathetic, page 579.

(*d*) *The Erector Muscles of the Hair Follicles and the Pilomotor Nerves.*—The name of pilomotor nerves is given by Langley and Sherrington to those nerve fibres which innervate the erector muscles of the hairs. According to these authors, the pilomotor fibres pass through the anterior roots into the sympathetic nerve from which they take their course to the periphery. Experiments with nicotine prove that the fibres become interrupted* by cells of the sympathetic ganglia of the two gangliated cords. The pathway that the impulse takes from the spinal cord to the periphery consists thus of two sets of neurones, one of which originates from cells of the spinal cord, the other from cells of the ganglia of the main trunk of the sympathetic.

The outflow of the pilomotor nerves from the spinal cord occurs through the rami communicantes of the fourth dorsal (seldom the third) down to the third or fourth lumbar nerves. (In cats and monkeys it is somewhat otherwise.)

Excitation of the individual ganglia of the sympathetic nerve causes erection of hairs in definite circumscribed regions. Usually, but not always, the sympathetic (peripheral) fibres arise from cells of the nearest sympathetic ganglia, sometimes from the second nearest.

The pilomotor fibres and the sensory fibres can be traced running together up to their entrance into the skin. There is no difficulty in showing that the greater part of the area supplied with pilomotor nerves by a given gray ramus is also supplied by sensory fibres of the corresponding spinal nerve (Langley).

Langley and Sherrington allot to the various communicant rami definite circumscribed although partly overlapping areas of distribution of pilomotor fibres.

The results of some of the experiments conducted by Dr. J. Collins and the writer lead us to the conclusion, however, that although the pilomotor nerves probably have, on the whole, the segmental distribution which Langley and Sherrington attribute to them, there must be a collateral supply or a direct cerebro-spinal supply, which in the case of removal of three or four successive ganglia can in the course of time entirely replace the functional loss thus created.

(*e*) *Influence upon the Pupil, Eyeball, and Eyelids.*—In 1727 Pourfour du Petit first demonstrated that section of the cervical sympathetic nerve is followed by contraction of the pupil and sinking in of the eyeball of the corresponding side. The contraction of the pupil was interpreted as being due to paralysis of the dilator pupillæ muscle. The sinking in of the eyeball was explained partly by vaso-motor effect, partly by the paralysis of Müller's muscle (Heese).

G. Fischer (quotation from Moebius) excited the cervical sympathetic nerve in the heads of two decapitated men. Faradic excitation produced opening of the palpebral fissure, dilatation of the pupil, protrusion of the cornea, and considerable lachrymal secretion These effects on the pupil, palpebral fissure, and eyeball in man were confirmed also by Jonnesco in epileptics in whom for therapeutic purposes the cervical sympathetic was resected or cut.

Budge and others showed that the pupil-dilating fibres of the cervical sympathetic are derived from the anterior roots of certain spinal nerves, which, joining the sympathetic nerve of the thorax by means of rami communicantes, pass through the ansa Vieussenii to the stellate ganglion, from whence they take their course within the cervical sympathetic to the pupil.

Comparing the results of the investigators (Budge, Salkowski, Nawrocki, Sherrington, Langley, Müller) in this field, we find that the outflow of the pupil-dilating fibres from the spinal cord occurs with the greatest constancy in the anterior roots of the first dorsal and almost as constantly of the second dorsal, to less extent and less constantly of the eighth cervical and third dorsal, and least constantly, it would seem, of the seventh cervical and fourth dorsal nerves. This distribution varies not only with the species of the animal, but also individually in the same species.

Budge placed the origin of the pupil dilating fibres of the cervical sympathetic in the so called cilio-spinal centre, which he found to occupy the region between the exits of the sixth cervical and third dorsal nerves in the

* Langley believes that there are justifiable grounds for the conclusion that by stimulating the nerve fibres running to and from any peripheral ganglion before and after applying dilute nicotine to it, the class of nerve fibres which end around nerve cells of the ganglion can be distinguished from those which run through the ganglion without being connected with its cells. Nicotine seems to paralyze the conductive action either of the nerve cells of the ganglion or of the nerve endings in the ganglion, that is, it seems to prevent the transmission of a stimulation from one neurone to another while it does not affect the conductivity of the nerve fibres. Therefore, if the ganglion is smeared with nicotine, direct stimulation of the nerve fibres passing out *from* the ganglion to the periphery retains in every case its full effect; but if, after the application of the nicotine, stimulation is applied central of the ganglion, *i.e.*, to the nerve fibres passing *into* the latter (instead of *from* it) this stimulation will remain effective if the said fibres pass uninterruptedly through the ganglion, while it will have *no* effect if the stimulated fibres terminate around cells of the ganglion.

spinal cord. Dastre and Morat confirmed Budge's conclusions. Salkowski and Knoll denied the existence of a cilio-spinal centre, and placed the origin of the pupil-dilating fibres higher, Salkowski in the oblongata, Knoll in the anterior corpora bigemina.

On the other hand, clinical experience tended to confirm the existence of a cilio-spinal centre, since oculo-pupillary symptoms were found to accompany transverse lesions of the spinal cord in the lower regions of the cervical and the upper regions of the dorsal portion of the cord (Kraus). This evidence was not conclusive, however, since in a case of transverse lesion of the spinal cord the fibres would also be severed in their course through the white substance, even if they originated from the oblongata or corpora quadrigemina. We might say that although the evidence is preponderatingly in favor of the existence of a cilio-spinal centre, yet the question has not been definitely settled.

Coleman Balogh and François Franck showed, however, that not all pupil dilating fibres contained in the first branch of the trigeminal nerve are derived from the cervical sympathetic, but that part of them reach the Gasserian ganglion by way of the roots of the trigeminal nerve.

The observations of Dr. J. Collins and the writer corroborate the contention that not all pupil-dilating fibres are contained within the cervical sympathetic nerve, since the narrowing of the pupil following removal of the cervical sympathetic (*i.e.*, of the stellate ganglion) in cats disappeared almost entirely in the course of months, and since, furthermore, in one case in which *one* stellate ganglion was removed first and the other one three months afterward, both pupils were still found to dilate in darkness.

Concerning the further course of the pupil-dilating fibres of the cervical sympathetic, only so much is known that they all finally join the Gasserian ganglion and leave the latter with the first branch of the trigeminal nerve (Coleman Balogh, quoted by Jegorow and Dogiel). They then pass through the long ciliary nerves to the pupil without forming connections with the ciliary ganglion (Jegorow and Dogiel, Nawrocki and Przybylski).

The question whether the cervical sympathetic contains also pupil-contracting fibres has, to our knowledge, been considered only by one investigator, viz., by Dogiel, who answered it affirmatively. The experiments of Dr. J. Collins and the writer tend to confirm his view, although not in an altogether unobjectionable manner. Dogiel's researches are quoted in detail in our report.

In addition to contraction of the pupil, section of the cervical sympathetic nerve causes a sinking in of the eyeball into the orbit, slight ptosis of the upper lid, and paralysis of the nictitating membrane. Heese finds that excitation of the sympathetic nerve causes protrusion of the eyeball in cats and dogs, while in rabbits it produces very marked sinking in of the eyeball. This discrepancy he explains by the fact that the sympathetic nerve displays its effect upon the eyeball in two ways: first, by the contraction of Müller's muscle; second, by vaso-motor influence. The former causes protrusion, the latter a sinking in of the eyeball. In cats the effect upon Müller's muscle predominates, therefore the protrusion; in rabbits the reverse is true.

According to Langley, the nerve fibres causing retraction of the nictitating membrane (third lid) and opening of the eyelid have in the cat a more extended origin than the dilator fibres for the pupil. They arise from the first four thoracic nerves, and sometimes from the fifth also. In nearly every case the second thoracic is most effective, the first more than the third; the fourth has slight effect, the fifth at best causes but a trifling movement.

That the cervical sympathetic has an influence upon the shape of the cornea is claimed by Claude Bernard, Brown-Séquard, and Hermann, who find that section of the cervical sympathetic causes flattening of the cornea. Their statements have been contradicted by Heese. Heese declares that the conclusions of Morat and Doyon, who contend that the sympathetic nerve influences the shape of the lens by displaying an effect antagonistic to that of the third nerve upon accommodation, are likewise erroneous. Jaboulay found amelioration of vision in two patients after severing of the cervical sympathetic nerve between the superior and middle cervical ganglia. He attributed this amelioration, however, not to any effect on accommodation, which latter he found quite unaltered, but to the narrowing of the pupil, which influenced myopia and astigmatism favorably in the manner of a stenopaic slit.

The trophic disturbances observed in the eye after removal of the stellate ganglion will be discussed in the next section.

The hypotension of the eyeball following removal of the superior cervical ganglion disappears entirely in the course of time, at least in non-glaucomatous cases (Jonnesco, Lagrange, H. Pachon).

VI. Trophic and Tonic Functions.—(*a*) *Trophic Functions.* Regarding the supposed trophic action of the sympathetic on the salivary glands, liver, and pancreas, the reader is referred to the paragraphs of this article which treat of these organs (pages 583 and 584).

Of other trophic effects, I mention, first, the retraction of the face and loss of hair as it was observed after lesions of the cervical sympathetic in man.

Moebius contends that the true form of facial hemiatrophy, characterized by discoloration and wasting of the skin, discoloration and disappearance of the hairs, wasting of the bones and cartilages, differs entirely from the slight flattening of the cheek observed with disease of the cervical sympathetic nerve. On the other hand, Angelucci has seen very marked trophic disturbances follow extirpation of the stellate ganglion. He found that in new-born dogs and in adult cats defect of one stellate ganglion gave rise (on the side of the operation) to alopecia of the face, dystrophy of the cranial bones, and deficient development of the teeth. In adult rabbits and monkeys these conditions were not usually met with.

Dr. Collins and the writer observed in young cats, in which one stellate ganglion or one thoracic sympathetic nerve had been extirpated, the appearance of red, hairless spots, which later became scaly, psoriasis-like, and then turned pale, smooth, till finally they healed up entirely, becoming covered with a new growth of hair. The distribution of these patches seemed quite irregular and arbitrary in case of resection of the thoracic sympathetic nerve, although in case of removal of the stellate ganglion they were confined to the head, affecting, however, both sides of the latter.

Max Joseph (*Virchow's Archiv*, vol. 107, p. 119) operated on the second cervical nerve in young cats and extirpated a continuous portion, including a piece of both roots, the entire spinal ganglion, and a piece of the peripheral nerve. This operation evidently implies tearing off the ramus communicans of the nerve, and it is interesting to note that he also observed, on the faces of the animals, hairless spots such as we found. Of no less interest is the fact that when he cut both roots of the second cervical nerve without injuring the spinal ganglion or any part of the nerve trunk peripheral to the ganglion, the hairless spots did not appear. From this the inference seems justified that the trophic influence of the sympathetic efferent fibres of the ramus communicans is sufficient to prevent the loss of hair, since in the latter experiment the cerebro-spinal motor fibres of the ramus communicans were cut in their course through the anterior (and posterior?) roots, while the sympathetic efferent fibres were left untouched. Fig. 4576 makes these conditions clear.

The almost instantaneous changes in the biceps femoris and psoas muscles noted by Gaule in rabbits after lesion of the stellate ganglion, which changes he attributes to this lesion, are interpreted differently by Salvioli and Hering and need not therefore to be dwelt upon.

Angelucci has seen, in addition to the trophic changes referred to, interesting alterations in the eye follow extirpation of the stellate ganglion in new-born dogs—such alterations as lesser development of the circumference of the cornea and sclera, the eyeball showing a lessening of about 1 mm. in its diameters. Both in new-born dogs and in adult cats, a long time after the extirpation of the stellate ganglion, distinct dystrophies characterized by simple atrophy and sclerosis occur, especially of the texture of the iris and of the choroidea. In the iris of new born dogs the sclerosis of the tissue formed large plaques. The fundamental structure of the retina, however, was never found altered. Angelucci attributes the dystrophies reported, to changes in the blood-vessel walls, to which Vulpian and Giovanni had already called attention.

Floresco found that in rabbits section or resection of the cervical sympathetic nerves gave rise to an abundant production of fat tissue and to the hypertrophic development of the thyroid glands, the suprarenal bodies, the respiratory and digestive apparatuses, the heart, and the genital organs; while, on the contrary, the skin, the nervous and muscular systems, and probably also the osseous system became retarded in their development.

From all the facts mentioned, the important relation which the sympathetic nervous system bears to the trophic functions of the organism becomes highly evident.

(*b*) *Tonic Functions.*—It has been shown that many nerves of the sympathetic system are under the tonic influence of spinal or cerebral centres. Section of the cervical sympathetic nerve is followed by dilatation of the blood-vessels of the head; section of the abdominal sympathetic by dilatation of the blood-vessels of the hind paws; section of both splanchnics by the same phenomenon in the stomach and intestine. Severance of the nerves connecting the submaxillary ganglion with its encephalic centre gave rise to an unceasing continuous secretion of the submaxillary glands, proving the regulatory influence of the cerebro-spinal system upon the submaxillary ganglion (Claude Bernard). We recall further the experiments of Spallita and Consiglio, which showed that the tonus of the whole vascular system is kept up and regulated by means of the vaso-sensitive nerves.

Regarding the tonic influence of ganglia of the sympathetic itself, the views still differ. Tuwim claimed tonic effects of the stellate ganglion upon the pupil-dilating fibres, but such effects were denied by Schipiloff. We know, however, that the heart removed from the body still continues to beat, and that the bladder deprived of the motor nerves leading to it continues to perform its functions. It is quite questionable if the functions of maintaining tonus are different materially from the functions discussed under the heading of Vascular Functions (pages 584 and 585).

VII. Reflex Action of the Sympathetic System.—We have already mentioned some facts that point to a considerable functional independence of the sympathetic system apart from the spinal and cerebral centres. We remind the reader of the two facts regarding the independence of the bladder and of the heart functions mentioned at the end of the preceding section, and of the observations of Contejean, according to which the secretion of gastric juice continues after the stomach has been deprived of all its nerve connections.

This independence of the sympathetic system from the cerebro-spinal system is further demonstrated by the reflex action of sympathetic ganglia, which seems a fairly well established fact. Sokownin, Nussbaum, Nawrocki and Skabitschewski, and Langley and Anderson produced evidence that made such reflex action very probable for the inferior mesenteric ganglion.

Claude Bernard apparently established the fact of the reflex action for the submaxillary ganglion. François Franck claimed it for the ophthalmic (ciliary) and for the superior thoracic ganglion. The details cannot be discussed here.

VIII. The Functional Interrelation of the Sympathetic and Cerebro-Spinal Systems.—While, as has been shown in previous paragraphs, the sympathetic may to quite a degree functionate independently of the cerebral and spinal centres, its dependence upon the cerebro-spinal system is clearly shown by certain facts.

In this connection I recall Claude Bernard's observation of the paralytic secretion which occurs in the submaxillary gland after all nerve connections of the submaxillary ganglion with the cerebro-spinal axis are severed, and which finally leads to functional destruction of the gland. I also recall the fact that certain fibres or nerves of the cerebro-spinal system exhibit a marked tonus upon certain vegetative functions as well as upon the cerebro-spinal centres.

Space does not allow us to discuss here at length the nature of the relationship which exists between the sympathetic and the cerebro-spinal systems; we can only point out some principal facts. It is a characteristic of the vegetative functions, including in general the action of non-striated muscles, that while they can be stimulated to strong action by emotions—as evidenced by the blush of shame, the diarrhœa of fright, etc.—they cannot be influenced directly by the will. An exception to this rule was observed by Bechterew in a hysterical patient who by force of will could change the size of her pupil, and it is furthermore claimed by some persons that they can voluntarily arrest the action of their heart—an assertion which, it is true, still needs confirmation. However, on the whole, the rule holds good.

Another characteristic of vegetative or visceral functions is the fact that under normal circumstances visceral nerve stimuli do not rise to consciousness, although we do become conscious of them in case of increased visceral action; for instance, we feel palpitation when, owing to exertion, the heart beats with increased vigor and frequency, or in case of sensory hyperexcitability of central origin, such as occurs in hypochondriasis and neurasthenia. But even then the sensation is of a vague, indefinite character. This vagueness of visceral sensation is probably one of the factors preventing direct voluntary influence on vegetative functions. Another factor is probably the lesser excitability of the non-striated muscle as compared with that of striated muscle. A third factor might be sought in the manner of connection of the nerve endings in the vegetative organs with the parts which they supply (glandular cells, non-striated muscular fibres), and another one in the more numerously linked chain of neurones that has to be passed till a motor nerve impulse reaches a vegetative organ, as compared with the chain of fewer links to be passed by a motor impulse in the case of a voluntary striated muscle. (For further details consult the monograph of Onuf and Collins.)

General Physiological Remarks.—The essential influence which the sympathetic system exercises on the vegetative life of the organism has been amply demonstrated in the foregoing review. Inasmuch as some vegetative functions are exquisitely vital, we may say also that the sympathetic system possesses in high degree vital functions. This is confirmed by the fact that in very young cats lesions of the important parts of the sympathetic invariably proved fatal. Even if the animals outlived such operations as extirpation of the semilunar ganglion or removal of the stellate ganglion or resection of the lower part of the thoracic sympathetic, they invariably died, and usually a few hours or days after the operation (Onuf and Collins).

The death of many animals during the operations was caused by pulling upon the sympathetic nerve or by bruising a sympathetic ganglion. This was especially the case in operating to remove the stellate ganglion. Although the animal would be breathing vigorously and freely immediately before, as soon as the stellate ganglion was pulled upon or as soon as its connections with the thoracic sympathetic nerve were severed, respiration suddenly became arrested and the animal promptly died.

Older animals—that is, cats which had reached the age of five or six weeks—stood these lesions much better, and three of them lived for from three to five months after the operation, when they were killed.

In man the upper cervical ganglion of the sympathetic has been frequently removed of late for the relief of glaucoma, and no deleterious effects on the heart action or respiration were noted. However, the patients thus operated upon were usually adults.

A fact recently brought out by Cleghorn deserves mention here. Cleghorn found that glycerin extracts of sympathetic ganglia, when injected into the femoral or jugular vein, caused a fall in blood pressure which was not observed if glycerin extracts of spinal ganglia, or of spinal cord or brain matter, or of nerve or abdominal tissue, were injected instead. Cleghorn seems recently to connect this vascular effect of the glycerin extracts of sympathetic ganglia with the presence in the latter of large polygonal cells, discovered by Stilling, which cells stain deeply in chromic acid and are found also in the suprarenal capsules.

In concluding this subject, attention is called once more to the remote effects of lesions of the sympathetic, these being often late in their appearance and showing a tendency to progression, as was the case with the digestive and respiratory disturbances following removal of the stellate ganglion or of part of the thoracic sympathetic nerve.

Representation of the Sympathetic in the Spinal Cord and Brain.—The rôle of the rami communicantes and their homologues, in establishing a connection between the cerebro-spinal and sympathetic systems, has been amply discussed in previous paragraphs (see pages 580 and 581). It remains now to describe in detail the manner of representation of the sympathetic in the spinal cord and brain.

From a study of the degenerations following resection of portions of the gangliated cords, Dr. Collins and the writer (see the monograph above mentioned) came to the following conclusions regarding the course and spinal representation of the afferent and efferent fibres of the sympathetic nerve proper in the cat:

1. Most, or at least many, of the afferent (sensory) fibres of the sympathetic nerves do not originate from cells of the spinal ganglia, as Kölliker claims, but must have their cells of origin within the ganglia or plexuses of the sympathetic system.

2. The chief terminal station for the afferent fibres of the sympathetic is *Clarke's column*, the said fibres probably ending there around the cells of this column. Other terminal stations of such fibres are probably the lateral horn and the zone between the anterior and posterior horns which we called the intermediate zone. The fibres probably terminate around the large cells of these regions.

3. Clarke's column, besides being a terminal station for afferent fibres from the vegetative organs, may be instrumental also in conducting sensory stimuli from the muscles, tendons, joints, and bones to the cerebellum, being thus largely concerned in maintaining equilibrium.

4. The afferent fibres of the sympathetic nerve after entering the spinal cord probably send reflex collaterals to the nuclei of the efferent fibres of the sympathetic (see Fig. 4581).

5. The afferent fibres of the *lumbar* sympathetic nerve, entering the spinal cord by way of the posterior roots, after having arrived at Clarke's column, evidently describe a longitudinal course upward (cephalad) to terminate around cells of a considerably higher level (see Fig. 4579).

6. The afferent fibres coming from the ganglia of the lower half of the thoracic sympathetic take on the whole a rather horizontal course in the spinal cord, to become connected with spinal cells of the same level, but part of these fibres probably descend either in the spinal cord or in the sympathetic nerve through the distance of one or more segments before reaching the cells around which they terminate. This is illustrated diagrammatically in Fig. 4580.

7. Many of the afferent fibres derived from the stellate ganglion probably make a long descent in the spinal cord or possibly in the sympathetic nerve, becoming connected partly with the same cells with which the fibres from the lower portion of the thoracic sympathetic nerve form connections (see also Fig. 4580).

8. The efferent (motor, secretory, inhibitory, etc.) fibres of the sympathetic probably take their origin from the cells of the following cell groups of the spinal cord: (*a*) The paracentral group; (*b*) the small cells of the lateral horn; and (*c*) probably the small cells of the zone situated between the bases of the anterior and posterior horns (intermediate zone). The situation of these groups is diagrammatically illustrated in Fig. 4581. That most (or all) of these fibres do not pass uninterruptedly to the peripheral organ innervated by them, but terminate in some ganglion of the sympathetic, and that from there a new set of neurones originates, giving rise to "sympathetic" fibres which pass to the periphery, has been discussed in other paragraphs, chiefly pages 580 and 581.

9. The paracentral group has possibly a vascular function.

10. The pathway of the efferent fibres of the sympathetic is probably similar to that of the afferent fibres as outlined under 5, 6, and 7; with this difference, that most of them pass through the anterior and not the posterior roots, and that they conduct the impulse in the opposite direction to that of the afferent fibres.

11. The spinal representation of both the afferent and the efferent fibres of the sympathetic nerve is probably bilateral.

12. The homologon of Clarke's column for the oblongata is probably a large-celled nucleus accompanying the so-called solitary or respiratory bundle at its ventro-lateral border.

13. The homologon of the paracentral group for the oblongata is evidently the so-called dorsal vagus nucleus, called also vagoglossopharyngeal nucleus, situated at the floor of the fourth ventricle.

It probably has the function of supplying the non-striated muscles innervated by the pneumogastric nerve, while those nerve fibres of this nerve which supply striated muscles probably originate from the nucleus ambiguus.

The relations between: (1) the ninth, tenth, eleventh nerves, (2) solitary bundle, (3) vagoglossopharyngeal nucleus, and (4) nucleus ambiguus are illustrated in Fig. 4582.

14. Higher up in the cerebral axis the paracentral group (of the spinal cord) is possibly and even probably represented by the vesicular cells accompanying the so-called cerebral fifth root (known formerly under the name of the descending fifth root) and by the cells of the substantia ferruginea.

To the views arrived at by Gaskell by a most ingenious method we can only allude here, giving his conclusions as to the centres for the efferent fibres (including those of the sympathetic) in the form of a table:

A. (Cells of the anterior horns.) Nucleus of efferent nerves to somatic muscles.	Represented in the medulla oblongata by the hypoglossal nucleus.
B. (Large cells of lateral horns.) Nucleus of efferent nerves to striated splanchnic muscles.	Represented in the medulla oblongata by the nucleus ambiguus (motor vagus nucleus).
C. (Cells of Clarke's columns.) Nucleus of anabolic (inhibitory) nerves to splanchnic glandular system and to muscles of viscera.	Represented in the medulla oblongata by the nuclei at the floor of the fourth ventricle, known as the accessory and the dorsal vagus nuclei.
D. (Solitary cells of posterior horn.) Nucleus of motor nerves to muscles of viscera.	No mention made respecting their possible representation in the medulla oblongata.
E. (Small cells of lateral horn.) Nucleus of katabolic (motor) nerves to splanchnic glandular system and to muscles of vascular system.	

This shows that in many respects Gaskell had come to conclusions similar to those reached by Dr. Collins and the writer.

To enter on the conclusions of other workers in this field, for instance Mott, the space allotted to this subject does not allow. *B. Onuf (Onufrowicz).*

PARTIAL BIBLIOGRAPHY.

Bruckner, J.: Sur la structure fine de la cellul. sympathique. Arch. d. sc. méd. de Bukarest, Paris, 1898, iii., pp. 197-204.
Chapman, C. L., and Foot, Lewis N.: The Ovarian Plexus and Its Controlling Influences. Brooklyn Med. Journ., December, 1901.
Cleghorn, A.: Sympathetic Ganglia and Blood Pressure. Journ. Boston Soc. Med. Sci., 1898-99, iii., p. 207.

Engelmann, Th. W.: Ueber den myogenen Ursprung der Herzthätigkeit und über anatomische Erregbarkeit als normale Eigenschaft peripherischer Nervenfasern. Arch. f. die ges. Physiologie, Bonn. 1896-97, vol. lxv., pp. 535-578.
Floresco, N.: Influence de la section et de la résection totale et bilatérale du nerf sympathique cervical sur l'organisme; second mémoire: Influence sur les dimensions, le poids et le volume des organes. Arch. d. Sci. méd., Paris, 1900, vol. v., pp. 1-18.
Franck, François: Nouvelles recherches sur l'action vaso-constrictive pulmonaire du grande sympathique. Arch. de Physiol. norm. et path., Paris, 1895, vii., pp. 744 and 816.
Hermann: Lehrbuch der Physiologie.
Huber, G. C.: A Brief Account of Some Observations on the Sympathetic Ganglia of Vertebrates. Brit. Med. Journ., 1897, ii., p. 881.—Lectures on the Sympathetic Nervous System. Journ. of Compar. Neurol., 1897, vii., pp. 73-145.—Observations on Sensory Nerve Fibres in Visceral Nerves and on their Modes of Terminating. Journ. Comp. Neurol., Granville, 1900, x., pp. 135-151.—Observations on the Innervation of the Intracranial Vessels. Journ. Comp. Neurol., 1899, vol. ix., No. 1.—A Contribution on the Minute Anatomy of the Sympathetic Ganglia of the Different Classes of Vertebrates. Journ. of Morphology, vol. xvi., No. 1, 1899.
Jaboulay: La section du sympathique cervical dans ses effets sur la vision chez l'homme, 1895, p. 341.
Jonnesco: Physiologie du sympathique cervical. XIII. Congr. Internat. de Méd., Section d'Histologie et d'Embryologie, 1900, Paris; 1901, Comptes rendus, pp. 26-38.
Jonnesco and Floresco: Physiologie du nerf sympathique cervical chez l'homme, Rapport par M. François Franck. Bull. de l'Acad. de Médecine, 1900, 3ème s., vol. xliv., pp. 213-214.
Lafforgue, E.: Rech. expér. sur l'action du grand symp. cerv. dans la production de certains accidents syncop. (syncopes reflexes). Indép. médicale, 1897, iii., p. 409.
Lagrange et Pachon: Des effets à longue echéance de la resection du ganglion cervical supérieur sur la tension oculaire. XIIIème Congrès. intern. de Méd., Section d'Histologie et d'Embryologie, 1900; Paris, 1901, Comptes rendus, pp. 139-141.
B. Onuf: A Tentative Explanation of Some of the Phenomena of Inhibition on a Histophysiological Basis, Including a Hypothesis Concerning the Function of the Pyramidal Tracts. State Hospitals Bulletin, April, 1897.—B. Onuf and J. Collins: Experimental Researches on the Central Localization of the Sympathetic with a Critical Review of Its Anatomy and Physiology. Arch. Neur. and Psycho-path., vol. iii., Nos. 1-2, 1900. This monograph contains an exhaustive bibliography on the anatomy and physiology of the sympathetic. See also abstract of same monograph in Journ. of Nerv. and Ment. Dis., 1898, p. 661.—B. Onuf: On the Arrangement and Function of the Cell Groups of the Sacral Region of the Spinal Cord in Man. Arch. Neur. and Psycho-path., vol. iii., No. 3, 1900.
Roux, J. Ch.: Note sur l'origine et la terminaison des grosses fibres de myéline du grand sympathique. Comptes rend. Soc. de Biol., Paris, 1900, lii., pp. 735-736.
Stilling, H.: Die chromophilen Zellen und Körperchen des Sympathicus; eine Berichtigung. Anatom. Anzeiger, Jena, 1898, xv., pp. 229-233.
Veratti, E.: Ueber die feinere Structur der Ganglienzellen des Sympathicus. Anatom. Anzeiger, Jena, 1898, xv., pp. 190-195.

SYMPATHETIC NERVOUS SYSTEM, DISEASES OF. (GENERAL.)—A systematic discussion of the diseases of the sympathetic nervous system is, at the present state of our knowledge, not feasible. The anatomy, physiology, and pathology of this part of the nervous system are still quite obscure.

At the bedside symptoms referable to and explicable by disordered function of the vegetative neural mechanism are encountered quite frequently. These symptoms are mainly expressions of exaggerated, diminished, or perverted trophic, circulatory, secretory, viscero-sensory, and viscero-motor functions.

Diseases of the sympathetic nervous system may be divided into two large groups:

1. Primary (idiopathic).
2. Secondary (deuteropathic).

Many general diseases were, and some are still, looked upon as expressions of primary functional or structural derangement of the sympathetic nervous system. Such are, for example, migraine, angioneurotic œdema, Basedow's disease, facial hemiatrophy, erythromelalgia, scleroderma, Raynaud's disease, and Addison's disease. These and other trophic syndromes are frequently interpreted as primary diseases of the sympathetic nervous system.

The familiar syndrome of irritation or paralysis of the cervical sympathetic is a good illustration of a secondary affection. Very little is known of primary or secondary diseases of the thoracic part of the sympathetic chain. Oppenheim records a case which presented during life a unilateral œdema, the explanation of which was found in an abscess near the thoracic vertebral column. The writer published a case of abscess formation implicating the thoracic chain of the sympathetic, which presented rather obscure symptoms during life (*Med. Rec.*, June 16th, 1900).

The rôle that diseases of the thoracic part of the sympathetic chain may play in the pathology of asthma and cardiac neuroses is entirely unknown.

The relation of the abdominal sympathetic to the pathogenesis of Addison's disease, diabetes, colica mucosa, is still under discussion. Symptoms referable to disorder of the functions of the sympathetic nervous system are frequently accompaniments of almost any organic lesion of the cerebro-spinal nervous system.

The gastric and other visceral crises arising in the course of tabes, the trophic manifestations accompanying this disease as well as syringomyelia, are good illustrations in point. *Joseph Fraenkel.*

SYMPATHETIC OPHTHALMIA includes two quite distinct diseases—sympathetic inflammation, or sympathetic ophthalmitis; and sympathetic irritation. These conditions are liable to arise in a previously healthy eye, after the fellow-eye has been injured and has become the seat of chronic inflammation due to such injury. In addition to these two definite forms of disease, to be described below, there are cases in which a blind degenerated eye seems to exert an unfavorable influence upon the fellow-eye.

Many surgeons believe that any blind and degenerated eyeball should be removed, if the fellow-eye becomes impaired by chronic progressive disease. Thus, if one eye presents an absolute glaucoma and the other a beginning glaucoma, the prospect of arresting the process in the latter may sometimes be improved by removing the blind eye. Or if one eye be blind with general detachment of the retina and softening of the globe, it is thought that choroidal degeneration or cataract affecting the other may be favorably influenced by removal of the blind eye. Such a belief in the dangers of sightless, degenerated eyeballs is not universal and should not be acted upon unless there is some evidence of disease in the second eye or danger of sympathetic inflammation. But if other disease of the better eye arises, the possibility of influencing it favorably by removal of a sightless degenerated stump should be carefully considered.

It is possible that in some cases inflammation of the uveal tract not caused by injury may extend from one eye to the other. But this is not certainly established. It is convenient to speak of the injured and primarily inflamed eye as the *exciting eye*, and of the other as the *sympathizing eye*.

Sympathetic Ophthalmitis.—(Synonyms: Sympathetic uveitis, Cyclitis, or Irido-cyclitis, Malignant Uveitis, or Migratory Ophthalmia.) This is an inflammation involving chiefly the uveal tract of the eye, but liable to extend to all the tissues of the eyeball, running a chronic course marked by repeated relapses, and ending in the majority of cases in complete blindness.

Causes.—Sympathetic inflammation is caused by non-purulent traumatic inflammation in the uveal tract of the fellow-eye. Injury of one eye unattended with uveal inflammation of the injured eye does not cause sympathetic uveitis. Uveal inflammation not due to traumatism does not excite this disease. Injuries to the eyeball, which are followed by severe purulent uveitis or panophthalmitis, are not likely to excite sympathetic inflammation. Disease in other organs may cause metastatic inflammation of the eye, but not the form of inflammation now under consideration. The character of the wound of the exciting eye greatly influences the liability to sympathetic disease.

The lodgment of a foreign body within the eyeball constitutes the most dangerous form of injury, unless the eye be promptly destroyed by suppuration. Yet the character of the foreign body and the structure in which it is lodged modify its evil influence. Minute aseptic foreign bodies sometimes remain in the eyeball indefinitely, without causing serious impairment of the injured eye or danger of sympathetic ophthalmia in its fellow. They are least dangerous when lodged in the crystalline lens or in the corneo-scleral coat. They are most dangerous when suspended in the vitreous or embedded in the ciliary processes or choroid. Comparatively small or punctured wounds are more to be feared than extensive cuts or lacerations.

Wounds that pass through the anterior chamber are less dangerous than those which enter through the sclera directly into the vitreous. When the body which inflicts the injury reaches the eyeball only after passing through the lid, the danger is lessened. Wounds attended with free hemorrhage or an abundant flow of aqueous humor are less dangerous. Wounds in the ciliary region have long been recognized as especially dangerous. They are made by bodies which have not passed through the lids. They enter directly into the vitreous chamber. The track of the wound is likely to be obstructed by a prolapse of the ciliary body into it or by swelling of the injured margin of the lens. These wounds, furthermore, involve the most complex and functionally active part of the uveal tract. However, any perforating wound of the sclero-corneal coat, even the incision of a smooth, clean operation, may be followed by sympathetic ophthalmitis. Perforations of this coat by disease, as by corneal ulcer, may also cause it. Cases are reported in which injury without perforating wound, such as bruise of the eyeball with dislocation of the crystalline lens, has given rise to sympathetic ophthalmia. But it is not certain that such injuries cause sympathetic uveitis.

The form of inflammation after injury, which makes an eyeball dangerous to its fellow, is a plastic uveitis. In its typical form it is characterized by marked involvement of the ciliary body, prolonged pericorneal redness, tenderness of the ciliary region, punctate deposits on the back of the cornea, diminished tension of the eyeball, and shrinking of the globe. There are also apt to be marked involvement of the iris, posterior synechia, alteration of color or appearance from degenerative changes, and with these more characteristic symptoms may occur changes in any part of the globe. Sight is usually entirely lost.

But it must be remembered that in rare instances the changes in the exciting eye may be comparatively slight yet equally dangerous. In numerous cases sympathetic ophthalmitis has been excited by an eye which retained useful or even good vision. The redness and ciliary tenderness may be transient, the diminution in the tension of the eyeball but slight, and the changes in the iris and deposits on the cornea barely perceptible, and still sympathetic uveitis may arise and destroy the other eye. On the other hand, free suppuration is not sure to prevent an eye from exciting sympathetic ophthalmitis. Neither is mechanical traumatism essential An eye that has had the cornea perforated by an ulcer, especially if this has been followed by prolapse of the iris, or an eye that contains a tumor, especially sarcoma or glioma, may also be the seat of a uveal inflammation that will cause sympathetic ophthalmitis All eyes, the coats of which have been perforated either by mechanical violence or by ulceration, must be objects of suspicion.

Premonitory Symptoms.—Previous to an outbreak of sympathetic ophthalmia, the exciting eye is noticeably red and tender. Either it has failed to become entirely quiet or symptoms of irritation and inflammation have reappeared. In the sympathizing eye there may be undue sensitiveness to light, decided loss of the power of accommodation, and quick tiring of the eyes with ordinary use. Symptoms of this kind should be watched for, when there is reason to fear sympathetic ophthalmia, and their presence should excite alarm. But they cannot be wholly relied upon to foretell an outbreak of sympathetic inflammation They may be so slight as to occur unnoticed, or all of them may be absent.

Symptoms and Course of the Disease.—The actual beginning of sympathetic inflammation is insidious. Slight photophobia, increased lachrymation, or a little redness of the eye is noticed. But it is difficult to fix the exact time at which it began As happens with other forms of uveitis, the hyperæmia may at first seem general, involving the conjunctiva as much as the pericorneal or deep scleral vessels. There may be slight discoloration of the iris and sluggishness in its reaction to light, or even one or two minute posterior synechiæ, by the time it is realized that the eye is inflamed. A little impairment of vision and faint haziness of the dioptric media may be present at the first examination.

From day to day the symptoms of uveitis become more severe and unmistakable. The lachrymation becomes excessive, the pericorneal and deep redness predominate. The photophobia becomes severe, the iris assumes the greenish or brownish tint of iritis, loses its lustre, and becomes distinctly thickened. It yields slowly and imperfectly to a mydriatic. The posterior synechiæ become more numerous and broader. The vitreous grows noticeably cloudy and the vision is greatly impaired. Points of tenderness appear in the ciliary region, and the tension of the eyeball is perceptibly diminished. There may be the severe pain of an acute iritis, but generally the pain is not great as compared with the tenderness, photophobia, and impairment of vision.

After a period of from two to six weeks the symptoms cease to grow worse, and some days later improvement is noticed. The pain and photophobia become less and vision may slightly improve. But some hyperæmia and ciliary tenderness remain, and after a remission, which may vary from a few days to several months, all the symptoms grow worse again, vision sinks lower than it has been before, the media become more obscured, and the tension of the eyeball still further diminished. Other remissions and relapses may occur, and it may be two or three years before the eye reaches its final condition of complete blindness, with greatly lowered tension, degenerated iris, and shrinking of the globe. The retina, vitreous, and lens directly suffer from the disease of the nutritive coat of the eye. The lens and vitreous become opaque. The latter shrinks and the retina becomes detached and completely altered. The cornea, besides the deposits of opacity on its posterior surface, becomes more or less opaque and shrunken. This condition may be reached in a few weeks, before the first remission has occurred, the subsequent relapses being marked merely by increased pain, soreness, and hyperæmia in the sightless and shrunken eyeball.

Atypical Cases.—The course of the disease as altered by treatment will be discussed under that head. In a few cases impairment of vision is at first the only symptom noticed. Ophthalmoscopic examination reveals hyperæmia, haziness, and slight swelling of the head of the optic nerve, with haziness and change of color, and perhaps swelling of patches of the choroid and retina. Cases of this kind usually develop later the more characteristic symptoms of sympathetic uveitis. They have been described as cases of sympathetic neuro-retinitis. But they are probably essentially uveal, the choroid being at first chiefly affected

As with other forms of uveitis, structures outside the uveal coat, and not directly dependent on it, are liable to be involved. Quite apart from the usual deposits on the posterior surface and the opacity due to degeneration, the cornea may be early affected with interstitial or ulcerative inflammation; or severe conjunctivitis may be present. So prominent are these complications in certain cases that they have been reported as cases of sympathetic keratitis or conjunctivitis. But in all cases in which the sympathetic character of the disease can be regarded as demonstrated there has also been distinct evidence of uveitis.

Diagnosis.—The symptoms presented by the sympathizing eye are not in themselves a sufficient basis for the positive diagnosis of sympathetic ophthalmia. They are merely those of a severe uveitis which tends to become chronic, to relapse, to go on to complete blindness and degeneration of the eyeball. This uveitis is especially insidious in its manner of beginning and progress, and it exhibits a special tendency to cause great diminution in the vision and in intraocular tension. But these features are not alone sufficient to distinguish it from other forms of uveitis. The history of traumatism and uveal inflammation of the other eye are essential to the diagnosis; not traumatism alone, for this does not cause sympathetic disease, unless it has been followed by uveal inflammation.

The time which has elapsed since the injury must also be considered. Sympathetic inflammation rarely if ever arises within three weeks from an injury. Usually the interval is six weeks or more. On the other hand, it rarely begins more than two or three months after the injured eye has become entirely quiet and free from inflammation. Cases beginning more than six months after the exciting injury are unusual, and more than a year afterward are quite rare. Still a few cases are recorded in which the exciting eye has remained quiet for many, sometimes thirty or forty, years before causing an outbreak of sympathetic ophthalmitis. Eyes that have been so long injured are more apt to cause sympathetic irritation. The diagnosis between these two conditions will be considered in connection with the latter.

An attack of iritis or other form of uveitis occurring years after an injury to the other eye should not be regarded as necessarily one of sympathetic inflammation, although that should be suspected. If the injured eye remains free from tenderness and irritation, even though it be entirely blind, and especially if its tension is normal or nearly so, and the attack does not show the special characteristics of sympathetic uveitis, the case is probably not one of sympathetic disease.

Pathology.—The anatomic changes which mark sympathetic ophthalmia are those of plastic uveitis. There are exudates which become organized into connective tissue, which may in time ossify, while the characteristic elements of the ocular tissues degenerate and atrophy. But although the transmission of disease from one eye to the other has been observed with especial interest for two hundred years, the method of transmission is still unknown. Mackenzie, in 1844, suggested transmission along the optic nerve. Müller, in 1858, suggested transmission by the ciliary nerves. A morbid functional activity was assumed, a reasonable hypothesis to explain sympathetic irritation, which was then confused with sympathetic inflammation. In 1881 Snellen argued that this was a specific inflammation, caused by organisms transmitted through the lymph spaces of the optic nerves. Berlin suggested that micro-organisms causing it might be carried to the exciting eye by the blood current, and find conditions suitable for their development only in the uveal tract of the sympathizing eye. Deutschmann claimed to have produced sympathetic ophthalmia in the rabbit, and to have demonstrated its extension along the optic nerve. Gifford and others failed to confirm his experiments, and showed that the probable explanation of his results was a general infection rather than a sympathetic ophthalmia. Randolph, using dogs, which are less liable to general infection, found that the fellow-eye was unaffected. Finally, it has been suggested that reflex influences through the ciliary nerves may prepare the uveal tract of the sympathizing eye for the invasion of organisms reaching it through the circulation.

That nerve influences starting from the exciting eye may powerfully affect the sympathizing eye is demonstrated by sympathetic irritation and its immediate relief by the removal of the exciting eye. It is equally certain that such nerve influences do not alone cause sympathetic ophthalmitis. In this disease some other factor must be added. Infection with a distinct period of incubation is the factor that best accords with our present ideas of such inflammations. The period of incubation may cover the two or three weeks that always elapse between injury of the exciting eye and sympathetic ophthalmia, or during which sympathetic inflammation is liable to occur after the removal of the exciting eye.

Prevention.—With a disease which tends to cause complete blindness, and which often goes on to this termination in spite of all treatment, prophylaxis is of the highest importance. In timely enucleation of the injured eye we have a certain preventive. The only questions that arise in connection with it are: In what cases should it be applied, and have we any other equally or sufficiently reliable prophylactic?

It cannot be said in any case of injury that enucleation is demanded to prevent sympathetic disease until a plastic uveitis has been set up. But with regard to an eye known to contain a foreign body of more than the most minute size that cannot be extracted, it may be assumed with almost absolute certainty that such dangerous uveitis will occur; and if an eye be so injured that future vision with it is impossible, immediate enucleation will so shorten the period of disability that it will often be justified. When the eye has become the seat of uveitis due to injury, and the inflammation does not begin to subside within three or four weeks, especially if the tension of the globe is much below normal, if blind it should be promptly enucleated. If not blind, but with vision no longer useful and diminishing, the eye should be enucleated if the patient cannot remain under observation. If the eye be blind with greatly diminished tension from an injury that has occurred within two years, even though it be free from hyperæmia or tenderness, it should be enucleated if the patient cannot remain within reach of competent professional assistance. The location of a wound in the ciliary region is an added reason for enucleation. Any blind eye that is known to contain a foreign body should be enucleated.

None of the substitutes for enucleation are so certain to prevent sympathetic inflammation. They have a field of usefulness, but not for this purpose. Nevertheless, if a patient absolutely refuses enucleation, but will allow evisceration, it may be proper to do the latter operation rather than decline further care of the case. In doing evisceration the sclera should be freed from all remains of its contents and mopped with a strong germicide, as carbolic acid or a solution of formaldehyde.

Enucleation of an injured eye does not instantly confer immunity from sympathetic uveitis. In a good many cases the inflammation has appeared within two or three weeks after the removal of the exciting eye, and in a few cases as late as four weeks. But almost invariably sympathetic inflammation arising in this way has yielded to treatment and has ended in recovery.

Treatment.—The first step is removal of the exciting eye. The only exception is when the exciting eye retains useful vision. There are a number of cases on record in which the sympathizing eye became entirely blind, while the exciting eye retained useful vision for many years or throughout life. It has sometimes been thought that removal of the exciting eye was followed by increased violence of the sympathetic inflammation. But probably this was nothing more than the increase observed when the exciting eye was not disturbed. On the other hand, the cases in which the exciting eye has been removed especially if removed early, show a much larger proportion of recoveries than do those in which the exciting eye was allowed to remain. The strong tendency to recovery in cases of sympathetic inflammation arising after enucleation also attests the value of this measure.

The sympathizing eye should be placed under the influence of atropine as soon as possible. A strong solution, two per cent., may be instilled, one drop every ten minutes for an hour; or after the use of cocaine a small crystal of atropine sulphate may be placed in the conjunctival sac, near the external canthus. Until this crystal is dissolved, or while instilling the strong solution, we should guard against atropine poisoning by everting the lachrymal puncta through traction on the skin at the side of the nose, and holding in contact with them a little absorbent cotton, thus keeping the atropine solution from getting into the tear passages. After this first mydriatic attack the strong solution of atropine should be instilled two or three times a day.

Before each instillation of atropine, or at more frequent intervals if the eye is painful, it should be bathed with very hot water, not longer than five minutes at a time. Dry heat, best from the electric coil, may be applied for periods of one half hour to two hours. If the hyperæmia is severe, and especially if there is pain, one or two fluidounces of blood may be taken by leeches or by the artificial leech applied to the temple. Subconjunctival injections of physiologic salt solution may be made at intervals of two or more days. These should be placed rather deeply within the capsule of Tenon. On going out in daylight the eye should be protected by very dark glasses or an opaque shade; but it should not be kept continuously covered by thick dressings.

As in other forms of uveitis, general treatment is of great importance. Mercury should be given freely up to the point of causing tenderness of the gums or other evidences of its poisonous action. At first, calomel may be given until it acts as a purgative, with large inunctions of mercurial ointment twice daily. Later, any form of mercurial that will sustain the mercuric influence without symptoms of poisoning may be employed. Nothing will be gained by carrying the action of mercury beyond the point indicated. But its administration should be continued until all symptoms of inflammation have disappeared.

Next to mercury, the most important drug is sodium salicylate. This should be given in the largest doses that will be tolerated; from twenty to forty grains, three or four times a day, in an adult. But such doses need not be continued more than a few days. Later, it may be given in smaller doses or discontinued. Should this drug cause serious disturbance of the stomach, other salicylates or aspirin may be substituted. For a chronic case or at a later stage, the iodides may be beneficial.

It is very important that the patient should be kept in as good a state of general health as possible. On this account the administration of mercury and the salicylates must be closely watched. The patient must not be confined to a dark room. The use of alcohol in any form should be forbidden. Diet and rest must be carefully attended to, and general tonics, especially iron, may be indicated. After apparent cure the patient should be kept under observation, and should avoid excessive use of the eyes or indulgence in alcoholic drinks for many months.

When the attack of inflammation has been finally subdued, it may leave the pupil closed by exudate, with or without an opaque lens. This condition might require for its relief an operation, but the eye should be allowed to remain quiet for years before any such operation is attempted. If done within a year or two after the inflammation has subsided, it will almost certainly cause a recurrence of the disease. Nothing will be gained by the attempt, and much will be lost.

Prognosis.—Sympathetic inflammation, untreated, ends in blindness; and, if those cases which arise after the enucleation of the exciting eye be excluded, probably less than half can be cured by treatment. The nature of the injury or the violence of the inflammation in the exciting eye has little influence over the prognosis when once sympathetic disease has actually occurred. Attacks beginning with lesions in the fundus show a rather better proportion of cures than those commencing with marked iritis. The first remission must not be mistaken for a cure. But when recurring exacerbations grow less severe and the sight is left no worse by them, an ultimate cure with partial or complete restoration of vision may be hoped for. Not until the eye has been free from inflammation for a year should the case be considered cured.

SYMPATHETIC IRRITATION, OR SYMPATHETIC NEUROSIS.—This is a condition set up by disease in the fellow-eye and characterized by extreme irritability, photophobia, excessive lachrymation, moderate general hyperæmia, and inability to use the eye, sometimes equivalent to complete temporary blindness.

Cause.—This is disease in the fellow-eye, generally of long standing and marked by very extensive degenerative changes. The exciting eye may show no symptoms of present inflammation, no hyperæmia or tenderness. Its condition may be the result of injury, or it may be the result of disease quite independent of traumatism. Intra-ocular tumor, without perforation of the ocular coats, may cause it. Ossification of the choroid is a quite common cause.

Symptoms.—It begins with inability to use the eyes for ordinary work, photophobia, and increased lachrymation. The symptoms vary in severity from time to time, but tend on the whole to grow worse, until any use of the eyes becomes impossible. On close examination the cornea will be found free from deposits, the pupil small but reacting well, the iris normal; and if photophobia does not prevent an ophthalmoscopic examination, the media are found clear and the fundus is normal. The hyperæmia is quite general, may disappear when the eye is kept quiet in a dark room, but increases rapidly on attempting to use the eyes or even with examining them.

Diagnosis.—Sympathetic irritation has to be distinguished from eye strain and from sympathetic inflammation. Hyperopia, astigmatism, or presbyopia may cause apparent lack of accommodation, excessive irritability of the eye, lachrymation, photophobia, and difficulty with near work. Therefore the refraction and accommodative power should be carefully measured before adopting the diagnosis of sympathetic irritation, even though the fellow-eye presents all the conditions that would make it the cause of this neurosis. By placing the suspected eye under the influence of a mydriatic, eye strain can be excluded.

To differentiate between sympathetic inflammation and sympathetic irritation is often of great practical importance. Their chief points of difference may be contrasted as follows:

Inflammation.	*Irritation.*
1. Follows perforation of the sclero-corneal coat, usually by traumatism, especially if the wound is in the ciliary region or if a foreign body is lodged in the eye.	1. Follows extensive degeneration of the fellow-eye, with or without traumatism, especially if the eye contains a foreign body or new-formed bone.
2. Occurs at from three weeks to six months after injury; is rare after one year.	2. Occurs usually many years after injury, or disease, of the exciting eye.
3. The exciting eye is almost always red or sore before the outbreak.	3. The exciting eye may be entirely quiet and free from irritation.
4. There are deposits on the posterior surface of the cornea, the iris is discolored, its reaction impaired. There are posterior synechiæ; the vitreous is hazy; vision is permanently diminished.	4. The cornea is free from deposits, the iris normal; the vitreous clear, and the eye may for a short time be capable of normal vision.
5. There are always marked organic changes.	5. There are no organic changes.
6. There are relapses at intervals of many days, weeks or months.	6. The severity of the symptoms may vary from hour to hour.
7. It terminates in slow recovery under treatment; or, more frequently, in complete blindness.	7. It tends to continue indefinitely; but ends in immediate restoration to normal after removal of the exciting eye.

The differential diagnosis is only difficult at the outset before the organic changes of sympathetic inflammation have had time to occur.

Pathology.—No anatomical changes occur, and the morbid influence is undoubtedly transmitted from the exciting to the sympathizing eye through the ciliary nerves.

Prevention is of little importance. The only effectual preventive measure is removal of the eye that is liable to cause it, and this is equally efficient after the condition of sympathetic irritation has actually developed. And since a degenerated eyeball may be retained many years without causing sympathetic irritation, the possibility of that event at some future time does not justify enucleation.

Treatment.—This is enucleation of the exciting eye or one of the substitutes for enucleation. Where sympathetic irritation alone is to be feared, probably evisceration or even optico-ciliary neurotomy will be as efficient as the removal of the eyeball. If preferred by the patient or operator, resort to one of them, preferably evisceration, in place of enucleation, is entirely proper. If the patient strenuously objects to operation and the case is clearly not one of sympathetic inflammation, palliative measures may be tried. Avoidance of close work and keeping the eye under a mydriatic, as atropine sulphate 1, distilled water 100, instilled twice a day, will often give partial or temporary relief. The internal administration of bromides is also useful. In a few cases freedom from irritation is thus secured, and it may last for months or years. But in nearly all cases the return of the symptoms, and the continual annoyance and disability which they cause, will in time overcome the strongest objections to operative treatment.

Prognosis.—Without treatment the irritation continues or recurs indefinitely. With removal of the exciting eye the prognosis is entirely favorable. Donders reported a case in which the patient had believed himself entirely blind for two years, but was proved to possess normal vision two hours after the removal of the exciting eye.

Edward Jackson.

SYMPHOROL-SODIUM, SYMPHOROL-LITHIUM, and **SYMPHOROL-STRONTIUM** are the respective caffeine sulfonates of these metals. They are white, odorless, and bitter, are readily soluble in water, except the sodium salt, and are insoluble in ether, benzol, or chloroform. These salts are strongly diuretic in dosage of 1–4 gm. (gr. xv.–ʒ i.) a day, and are claimed to retain the diuretic effect of the caffeine without its stimulating action on the heart and nervous system. The sodium salt is in common use under the simple term "symphorol."

W. A. Bastedo.

SYMPHYSEOTOMY. See *Obstetric Operations* and *Pelves, Deformed.*

SYNCOPE. See *Brain Diseases: Anæmia.*

SYNCYTIOMA.—(Synonyms: Deciduoma malignum, Sarcoma uteri deciduocellulare, Chorionic epithelioma, Choriocarcinoma, Syncytioma malignum, and Carcinoma syncytiale.)

Under syncytioma are to be considered those new growths which consist largely or in part of syncytium such as is found covering the chorionic villi. In order to understand clearly the relation and origin of this class of tumors, it is necessary to have a knowledge of the placenta and its development. Of especial importance in this relation is the development of the chorionic villi. The villi are at first clothed with fœtal ectoderm, which, we have reason to believe, becomes two-layered in early embryonic life; the inner layer, the "cell layer" of Langerhans, being composed of separate individual cells with large vesicular nuclei and reticular protoplasm; the outer, or "syncytial" layer, being composed of a continuous mass of dense, deeply stained protoplasm containing smaller nuclei than the preceding layer. The syncytium resembles not a little a huge giant cell. In tumors of this group both the syncytium and the cell layer of Langerhans are usually represented in varying proportions. The origin of the syncytium has long been a matter of dispute, some observers maintaining that it is derived from the epithelium of the uterine mucosa, while others believe that it arises by delamination from the ectoderm covering the ovum. A study of preparations of developing placentas furnishes convincing evidence that the uterine mucosa takes no part in the formation of the syncytial layer. The close relation of the syncytium to the cell layer of Langerhans and the presence of transitions between the two make it clear that the syncytium arises from the fœtal ectoderm.

From the above observations it would appear that a syncytioma is to be regarded as a malignant form of new growth originating from fœtal ectoderm. In the discussion of these tumors the term "syncytium" applies only to a special tissue, identical with or closely resembling the so-called syncytial layer of the chorionic villi. Syncytia other than this special form have no relation to the tumors in question.

Syncytiomata may be divided into two groups:

1. Certain rare cases of teratomata in which a syncytium develops.

2. Those tumors arising in the uterus after pregnancy to which the terms "deciduoma malignum," "syncytioma malignum," etc., have been applied.

Several teratomata of the testicle have been recently described in which a portion of the growth resembles in every respect a true syncytioma of the uterus. Such growths are described by Carey, Wlassow, and Schlagenhaufer. The syncytium in these teratomata represents one of the many lines of tissue differentiation found in these neoplasms, and, from morphological characteristics as well as on theoretical grounds, it may be considered as homologous to the true chorionic syncytium. Teratomata in which the syncytium forms a large portion of the tumor appear to possess a considerable degree of malignancy; for example, metastases have been described as well as a tendency of the growth to infiltrate surrounding tissues. On account of the rarity of syncytial growths associated with teratomata, and since they comprise only a portion of these neoplasms, they are here given but brief mention. Concerning the further characteristics and the theories of origin of teratomata, one should consult monographs on that subject.

DECIDUOMA MALIGNUM.—*Historical.*—The term deciduoma malignum was first applied by Sänger in 1888 to a peculiar malignant growth of the uterus with metastases following an abortion. Although this term is considered to be a misnomer, it is generally deemed advisable, on account of the multiplicity of terms, to retain, for clinical usage at least, Sänger's original terminology. Sänger believed that the tumor in his case consisted of decidual cells, and he placed it among the sarcomata. Following this and quite independently of Sänger, Pfeiffer described a case and also applied the term deciduoma malignum. In 1893 Sänger published a monograph which comprised all that was then known of this subject. In 1895 Williams and Marchand published monographs. Williams, after reviewing the literature, came to the conclusion that in the various cases reported there is some variation in the nature of these tumors, that is, that some consist for the most part of decidual cells and are thus of maternal origin, others consist of tissue analogous to the syncytium and Langerhans' cell layer and are of fœtal origin, while it is not improbable that others are of both maternal and fœtal origin.

Marchand believed that both the syncytial and the cellular portions of these tumors are of fœtal origin. A great many cases have been reported since the publications of Williams and Marchand. Ladinski, in 1902, was able to collect one hundred and thirty-two cases. Such is the comparative frequency of their occurrence that they are worthy of consideration to the clinician in cases of uterine hemorrhage.

Occurrence.—Deciduoma malignum may occur at any time during the child-bearing period. That it may not be discovered until after the menopause is shown by a few cases. It is always associated with pregnancy, appearing after a full-term labor, an abortion, or the expulsion of a hydatidiform mole. It is evident that in certain cases the tumor has begun to develop before the expulsion of the mole. The frequent association of this tumor with vesicular moles is to be noted. Dorland, in a series of fifty cases of deciduoma malignum, found that twenty-two cases (43.3 per cent.) gave a history of the expulsion of a mole at some time prior to the appearance of the growth.

Gross Appearances.—Metastases of the growth are often found in the vaginal wall. They appear as soft, vascular nodules, friable, often necrotic and ulcerated, and sometimes protruding from the vulval orifice. The cervix is usually soft and enlarged from the preceding pregnancy. On opening the uterus the primary growth will usually be found bulging from some part of the uterine wall. It varies in size and form, is reddish in color, sometimes mottled with gray. The primary growth is often necrotic and is always soft and friable. The uterine wall may be infiltrated. Metastases in other organs are of similar character.

Histological Appearances.—In all cases that are to be regarded as syncytiomata the growth consists essentially of tissue identical with the syncytium and the cell layer of Langerhans. The relative proportion of these two varieties of tissue varies in different tumors and in different portions of the same tumor. In four cases from the collection of the Pathological Laboratory of the Massachusetts General Hospital the appearances agreed closely with Williams' descriptions and plates. The growth consisted of irregular masses of large cells, in every instance associated with syncytium. Both the syncytium and the cellular portion were identified by comparison with chorionic villi derived from an early pregnancy. The cellular masses are almost invariably surrounded by layers of syncytium, that is, the syncytium presents itself at the growing surface of the tumor. It is vacuolar over certain areas (see central portion of Fig. 4585). Some

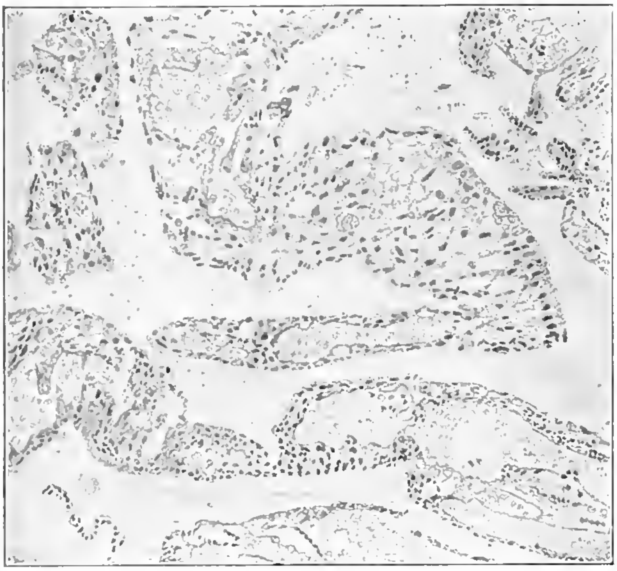

FIG. 4585.—A Section of Syncytioma which has Infiltrated the Uterine Wall. The tumor is made up of two sorts of tissues, a portion consisting of syncytium (to the right of the central portion of the figure), the remainder of separate cells corresponding to the cellular layer of Langerhans. There is no stroma in the structure of the tumor.

cells of the cellular portion attain a large size. Mitoses are numerous and atypical multipolar mitoses are not uncommon. There is no stroma and no blood-vessels are present, although blood is found free between the tumor cells. Large portions of the growth are necrotic, and a fibrinoid change is present, similar to that occurring normally in the placenta. In one case the growth is composed of villus-like masses. No mesenchyma and no decidual cells were found in these cases. The uterine muscle was infiltrated in each case. Metastases present the same histological appearances.

Theoretical Considerations.—As in other tumors, it is impossible here to arrive at an explanation of the causal agency of deciduoma malignum. It is not possible to ascertain whether the fœtal tissues for some unknown cause take on abnormal activity or whether the maternal structures are unable to resist the normal growth of this tissue. When, however, it is considered that these growths in all recorded cases follow pregnancy, that they arise at the placental site, and that they are composed of tissue derived from the fœtal ectoderm, their origin is clear. Whether there exist tumors agreeing clinically with these, but consisting of both fœtal and maternal tissues or consisting wholly of maternal tissue, as Sänger claimed, is a matter of dispute. Assuming, for the time being, their existence, they are not to be considered under syncytiomata.

MALIGNANCY AND METASTASIS.—The malignancy of deciduoma is striking, symptoms usually appearing during labor or within four weeks of that time. In a large percentage of the cases death occurs within six months after the appearance of the first symptoms. As a rule, metastases are abundant. In Dorland's series of 52 cases, metastases occurred in the lungs in 78.37 per cent., in the vagina in 51 per cent., in the kidneys, spleen, and ovaries in 13.5 per cent., in the pelvis and in the broad ligament in 10.8 per cent. respectively, and in the brain in 5.4 per cent. In a small number of cases the vaginal metastases have occurred where no primary growth could be found.

Clinical History.—The first symptoms noted are repeated and profuse uterine hemorrhages, while in the later stages there may be foul watery discharges. There is usually pelvic pain. Metastases may appear in the vagina with vulval œdema. The patient becomes cachectic, there is anæmia, and hæmoptysis may take place from pulmonary metastasis. Slight fever and occasional rigors arise from the absorption of septic material.

Diagnosis.—The possibility of deciduoma malignum should always be borne in mind after the expulsion of a hydatidiform mole or upon the appearance of profuse hemorrhage or obscure symptoms following delivery. In such instances curettage should be resorted to and the diagnosis made from the uterine scrapings. Vaginal metastases may be the first indication of the growth. Microscopical diagnosis is made by the appearance of syncytium in the growth.

Treatment.—If microscopical examination of the curettings reveals the presence of deciduoma, immediate hysterectomy should be performed and the metastases excised wherever they are accessible. The chances for ultimate recovery are, however, slight, so great is the rapidity of metastasis-formation.

Neumann claims to have obtained early evidence of the appearance of deciduoma through the examination of hydatidiform moles. He found among the cases which he examined certain moles in which the syncytium invaded the villi in a manner very suggestive of malignancy. The most marked of these cases afterward developed deciduoma. From his results it would seem justifiable to curette the uterus following the expulsion of a hydatidiform mole, in order to examine the scrapings histologically for the presence of deciduoma and for the purpose of removing the same. Hysterectomy is not justifiable on the evidence of a vaginal tumor, but should be performed only after a positive diagnosis from the curettings, for in certain instances the vaginal tumor exists without uterine involvement and its removal has been followed by complete recovery.

Ernest Edward Tyzzer.

SYNOVITIS, ACUTE.—(Synonyms: Hydrops articulorum acutus, Acute serous synovitis, Arthro-meningitis, Sero-synovitis; French, Synovite aiguë; German, Die Synovitis.)

ANATOMY.—Synovial membranes approach so closely to the serous membranes that they are often classified with them. But, although structurally much the same, they differ from the serous membranes in secreting a peculiar fluid, synovia. In all joints where motion takes place (diarthrodia) a lubricating fluid is necessary, and this fluid is furnished by the so-called synovial membrane. Every diarthrodial joint is lined with a layer of synovial membrane, except in the places where the articular cartilages are in contact. Here there is no membrane, except at the edge of the cartilages, which the synovial membrane may overlap for 2 or 3 mm. before merging into the cartilaginous structure. Fasciculi and folds of the capsule, the internal ligaments, and fatty internal protrusions are all covered by the membrane. The limits of the synovial membrane are most easily made out in inflammation, when a red collarette is seen surrounding the white cartilages.

Synovial membrane is thin and elastic. Externally it merges into the tissue of the joint capsule, while its inner surface is smooth and moist. Histologically the structure is a basement tissue of elastic and connective-tissue fibres, upon the inner surface of which lie endothelial cells. In gross, the inner surface of a joint presents a smooth and shining surface, interrupted, especially where the membrane folds to pass from one surface to another, by the synovial fringes (plicæ synoviales)—villous structures of varying size and length, somewhat resembling intestinal villi, the largest being perhaps 1 cm. long. They are richly supplied with blood-vessels, for each villus contains the convoluted twig of an artery. Some of the fringes, however, are merely hernia-like protrusions into the joint of small masses of fat covered by synovial membrane; these fill up unoccupied spaces. The nerves are derived from the same nerve trunks that supply the muscles of the limb. The nerve filaments terminate in small plexuses, unequally distributed, under the synovial membrane. Coloring matter injected into the joint disappears very quickly, to reappear in the lymphatic channels of the limb.

Synovia is a clear, alkaline fluid, much like the white of egg in general appearance; when rubbed between the fingers it imparts an oily sensation. It is largely secreted by the cells which cover the synovial fringes. In composition it contains albumin, mucin, some fat, leucocytes, and epithelial cells. A fluid identical in composition with synovia can be produced by rubbing up a portion of the epidermis in a weak alkaline solution. This fact suggests that most of the mucin is derived from the endothelial cells soaking in the weak alkaline fluid secreted by the fringes, and this view is strengthened by the fact that, when joints are quiet, the synovia in them contains only half as much mucin as when they are in motion.[1]

PATHOLOGY.—The classification of acute inflammations of the synovial membranes is best made according to the character of the effusion: (1) Serous; (2) serofibrinous; (3) purulent.

(1) Acute serous synovitis is the most common of all. The pathological process is simple; for some known or unknown cause a joint, most frequently the knee, becomes the seat of an inflammation which is manifested in the usual way. There are hyperæmia of the vessels of the membrane, an increased rapidity of the blood current, and then dilatation of the capillaries, with stasis. Migration of the white corpuscles from the vessels follows, and a profuse serous secretion is poured out from the dilated vessels into the perisynovial tissues and into the joint. The endothelial cells are very rapidly produced, and are cast off, half formed, into the joint. This process, carried far enough, constitutes "catarrhal synovitis," a purulent form. To the naked eye the surface of the membrane is seen to be bright red, from the dilatation of the surface capillaries; it is not so shiny as usual, and has ordinarily a boggy, softened, œdematous appearance, from infiltration, which is most noticeable in the synovial fringes. Here and there, especially in the more acute cases, may be seen a patch of extravasation, where a distended blood-vessel has burst. The fluid in the joint is often colored more or less red by these extravasations. The cartilages in an inflammation of this grade are not affected, but are seen to be of a clear bluish white color, and surrounded by the sharply marked line of inflamed synovial membrane.

The joint at this stage is more or less distended with an abnormally large amount of synovial fluid, at first thinner than usual, on account of the copious effusion of serum into the joint, then becoming more or less opalescent as the endothelial cells are cast off into it and become macerated, and as the leucocytes increase in number. The amount of fibrin in the fluid varies greatly; in severe acute attacks the amount is generally so large that the fluid is glairy and sticky, and, on standing, distinct flocculi separate out and float around. When there is so much fibrin in the joint fluid that it consolidates on the synovial surfaces, the case belongs rather to the class of serofibrinous effusions. At this stage, unless it become chronic, the inflammation subsides or goes on to the formation of a purulent exudation. If it subsides, the blood supply diminishes, the newly formed capillaries are obliterated, the distended ones resume their normal calibre, the cell proliferation ceases, the cells already thrown off furnish mucin to the synovia, the excess of fluid is absorbed, and everything returns to a normal condition. The synovitis is cured.

(2) Acute synovitis of the serofibrinous type may be manifested more in the synovial tissue than as an effusion. In such cases the swelling is more dense than fluctuating. Thickening of the capsule may be prominent. The joint is filled with a yellowish fluid, and the synovial membrane is bluish-red in color and the surface is smooth but irregular. Adhesions between opposing surfaces occur very early. Microscopically, more leucocytes are found in the tissues than in the serous form, and extravasations of blood are frequent in the capsule. A layer of fibrin adherent in places is to be found, and in parts the joint surfaces seem to have degenerated into fibrinoid tissue. The likelihood of the growing together by adhesions of parts of the joint which are in contact must again be mentioned as the most striking and most dangerous characteristic of the affection.

(3) Synovitis with purulent effusion (empyema articuli; katarrhale Gelenkeiterung, von Volkmann) may be a continuance of the serous form or may originate *de novo*. In the catarrhal or more superficial form[2] the pus is secreted by the surface layers of the synovial membrane and no deep-seated lesion necessarily results. In a severer grade, spoken of sometimes as suppurative synovitis, in contradistinction to the term purulent synovitis as applied to the catarrhal form, the deeper layers of the joint membrane are involved. In synovitis with purulent effusion cell proliferation and the migration of leucocytes become a prominent part of the process; and besides, where there was formerly serum there is now a seropurulent or purulent fluid. The synovial surface becomes velvety in appearance, and the cartilages become yellowish-white and their surface is indistinct and covered with lymph and flocculi of pus. Pyogenic cocci are present. In some cases the destructive process seems localized, and ulcerations of synovial tissue, and even of cartilage, take place, while the surrounding parts show only a moderate grade of inflammation. From this it is easy to see how any amount of mischief may result. The whole synovial membrane may become granulating tissue, the cartilage is perhaps eroded also, the bone is bare, and the periarticular tissues become the seat of abscesses as soon as the capsule breaks, perhaps before. It is hard to set a limit to so destructive a process as this.

Recovery from purulent synovitis may be complete, and no trace of the mischief may be left behind. Generally, however, recovery from suppurative synovitis means a joint impaired by adhesions. On the other hand, as we have seen, there is no limit to the destructive possibilities of suppurative synovitis; complete disorganization of the joint, dislocation of the bones, and, worst of all, systemic infection are only too apt to follow.

SYMPTOMS.—In few pathological conditions are the four classical symptoms of inflammation more marked than in acute synovitis. Pain, heat, redness, and swelling comprise a large part of all that can be said of it.

Pain.—In simple acute synovitis, a few hours after the receipt of a wound or blow, some wrench, some exposure, or overexertion of a joint, commonly the knee, an uneasy, hot feeling is noticed, and before long it becomes a positive pain. This is associated with a tense, burning feeling and a sense of helplessness in the affected limb. Any motion adds to the discomfort, and manipulation of the joint, if carried to extreme flexion or extension, causes pain; sometimes any motion at all is painful. The feeling of distention that accompanies the height of the effusion may be distressing, but from the sixth, seventh, or eighth day, when this height is reached, the pain rapidly subsides. The pain is ordinarily felt in the joint that is inflamed, but it may be "reflected" to some other joint supplied by the same nerve trunks. This curious phenomenon is most frequently noticed in hip-joint inflammation, in which disease the pain may be referred to the knee of the affected side. The intimate relations and anastomoses of the sciatic, obturator, and anterior crural nerves seem to furnish the best explanation of this. When the synovitis becomes purulent, or is so from the first, pain is a more prominent symptom and much more severe than it is in simple synovitis. The pain is severe in serofibrinous synovitis; these are the cases of joint disease in which pain, and not swelling, is the prominent symptom, in which no pus can be found, and in which ankylosis is most rapid and unexpected. If it goes on to destruction of the joint structures and to ostitis, the pain becomes extreme, and the patient is waked from sleep at night by the muscular jerks (starting pains), which press the inflamed and ulcerated joint surfaces together. Even in simple synovitis the pain is worse at night.

Tenderness.—Along with the pain goes tenderness in most cases, as one would expect from the inflamed condition of the synovial sac and the irritable state of the articular nerves. In purulent synovitis the tenderness is generally greater than in the serous variety. The ordinary tenderness is the pain felt on deep pressure and manipulation of the inflamed joint. There is a spot in each joint where tenderness is apt to be especially marked. In the knee it is over the inner condyle, about a finger's breadth inside of the inner border of the patella; in the ankle-joint, in front of the outer malleolus; in the hip, in front of the great trochanter. The pain meantime is by no means localized, but there is a bruised, helpless feeling extending to the whole joint. Certain cases, however, are characterized by severe local pain and tenderness in some one spot.

Swelling.—In simple serous synovitis intra-articular swelling begins on the first, second, third, or fourth day. It is of two kinds—effusion into the joint and effusion around the joint. In simple synovitis the infiltration into the periarticular tissues is slight, but if pus appears the skin becomes red and boggy. The same is true of the synovitis associated with acute rheumatism, where the peri-articular infiltration makes a shapeless and puffy joint; whereas intra-articular distention betrays itself by a characteristic shape in each superficial joint, dependent upon the elasticity of each synovial sac. This intra-articular distention varies from a small effusion up to a condition in which the skin is shiny, tense, and pale, and the venous return from the lower segment of the limb may be impeded. The capacity of the sac of the knee joint, when extremely distended, is some six or seven ounces, in average cases of simple synovitis it holds about four ounces. The average capacity of the shoulder-joint sac is three ounces. But in the deeper joints swelling may not be so readily discoverable. The common state of affairs in both hip- and shoulder-joints acutely inflamed is a general enlargement of the joint, without the clearly articular shape which is to be seen, for instance, in the knee and elbow.

Redness and Heat.—Redness is not regularly present in simple synovitis. The pyæmic and the gouty or rheumatic forms of synovitis are apt to be attended by a blush, which is generally quite marked in the two latter affections. In the case of the deeper joints redness as well as heat is ordinarily absent. In superficial joints more or less local heat about the inflamed joint is present. If the synovitis is purulent, the local rise of heat is as great as in any acute purulent inflammation.

Position.—When in a state of acute inflammation a fairly constant abnormal position is assumed by each joint; the semiflexion of the knee in knee-joint synovitis will serve well enough as a type. The hip is flexed and adducted or abducted, the ankle is slightly extended, the arm is carried at the side, the elbow is flexed at about a right angle, and the wrist drops slightly and is somewhat flexed. Fixation of the muscles holding the joint is present at the same time, and the abnormal position is firmly maintained by them when manipulation of the joint is attempted. At first this muscular guard seems to be purely voluntary, and is only excited by the pain which movement causes, but in time it becomes involuntary, until in chronic joint disease it may be present in cases in which movement causes no pain at all. This is apparently due to the fact that in that position the joint is more comfortable than in any other.[3,4,5,6,7]

Muscular Atrophy.—Atrophy of the muscles controlling an inflamed joint begins early and may be very marked, even in a simple acute synovitis. The character of the joint disease seems to matter but little in the production of this phenomenon. Traumatic or simple, acute or chronic, serous or purulent synovitis, all show muscular atrophy, and the more acute the disease, the faster the wasting goes on. That this is something more than the mere atrophy of disuse is shown by the facts that it begins so sharply and so early, that it is greater in the diseased limb than in the well one, even when the patient has been in bed from the first, and that the muscles, although atrophied, are not soft and flabby, but tense. Valtat[8] injected the joints of guinea-pigs and dogs with irritant solutions, mustard-oil and ammonia, and found that muscular atrophy came on quickly. In one case, in eight days there had been a loss of thirty-two per cent. by weight in the anterior thigh muscles, and twenty-four per cent. in the anterior calf muscles; in another case it reached forty-four per cent., and in all cases the extensors wasted more rapidly than the flexors. He attributes much influence in the matter to the amount of pain present.

Paralysis.—Valtat also calls attention, in this connection, to the paralysis of the muscles of the affected limb often accompanying acute joint disease, the loss of power already mentioned, and also a diminution of faradic excitability after severe muscular wasting. Such a paralysis, to a greater or less degree, seems to precede the wasting of the muscles.

General Condition.—The general condition of a patient with simple acute synovitis suffers but little. The rise of temperature, if any, is slight, unless a rheumatic condition exists, and only with the advent of pus does the temperature rise to any extent. A sudden chill, an increase of pain, a tendency to fever, all make one suspect the formation of pus, and when that has once come the general condition may become really serious. Gonorrhœal, rheumatic, and pyæmic synovitis are accompanied by fever and the other symptoms of the affections which they represent.

VARIETIES.—Considered in relation to cause, acute synovitis may be divided into two classes, traumatic and non-traumatic.

Traumatic synovitis results from a sprain, a blow, or a wrench to a joint, or from an intra-articular fracture, and is characterized as a simple serous synovitis. Often a simple synovitis may arise without an obvious trauma, and such cases may be classed as traumatic, assuming that they arise from overuse or some similar cause; but such cases are more usually, without sufficient evidence, classed as rheumatic. It would seem better to restrict the use of the latter term to those cases which occur in connection with other rheumatic manifestations.

Traumatic purulent synovitis is likely to result from penetrating wounds of the joints, where micro-organisms are introduced by the penetrating instrument. In a day or so after the infliction of the wound swelling, pain, and malposition come on, and the joint is found to be distended with a seropurulent or purulent effusion.

Among traumatic causes must be mentioned a very important class of cases in which some mechanical imperfection of the joint is the cause of the attack. This is especially to be observed in the knee. A semilunar cartilage may be torn loose and cause one or a series of attacks. An hypertrophied synovial fringe may be present and by being caught in the joint may cause an effusion. Or a foreign body may act as an irritant cause.

The most frequent of the non-traumatic forms of acute synovitis is the rheumatic, classed by Schuchardt as a hæmatogenous infection. *Rheumatic synovitis* is in the lighter cases serous or serofibrinous, while in the severer ones it is fibrinous. Purulent synovitis is very rarely observed. It is generally polyarticular and the swelling involves the parts about the joint as well as the synovial membrane. Even the apparently monarticular form is apt to be preceded by pain in other joints. It shows a strong tendency to become subacute or chronic, and in the severer grades is likely to result in a distinct loss of mobility.

Gonorrhœal synovitis, known as "gonorrhœal rheumatism," follows no definite type, being monarticular or periarticular.[9] It occurs in the later stages of the gonorrhœa and affects most often the knee, then the ankle, foot, wrist, etc., in the order named. The effusion if serous is thick. It may be seropurulent or purulent, and is at times colored with blood. In the severer cases the changes do not differ essentially from those which occur in pyæmia, the striking feature being the large amount of granulation tissue formed.

Impairment of motion and ankylosis are greatly to be feared. The affection is due apparently to the gonococcus. This may be found present in the joint effusion, it may be absent, a mixed infection with pyogenic organisms may exist, or pyogenic organisms may be present alone. The most notable feature of the affection is its obstinate and intractable character.

Synovitis in Acute Infectious Diseases.—Synovitis from hæmatogenous infection may occur in various other acute infectious diseases. The type of such inflammations is to be found in pyæmia.

The diseases in which synovitis thus develops are the following: Scarlet fever, measles, variola, varicella, typhoid fever, pneumonia, diphtheria, dysentery, cerebrospinal meningitis, pertussis, glanders, pyæmia and septicæmia. It is also occasionally encountered in other infectious diseases. The varieties may be the serous, the serofibrinous, or the purulent.

The cause is to be attributed to the organisms which give rise to the original disease, and one finds most often a mixed infection with pyogenic cocci; but the bacteriological findings are uncertain, the fluid may be sterile, it may contain the specific organisms of the original disease, or it may contain pyogenic organisms.[10]

The nature of such cases is most often serious, and joint destruction may be rapid and extensive in the purulent forms. General intoxication is likely to be present, and metastatic foci in other organs may coexist. Especial attention has been paid to the pneumococcus joint infection which occurs at times in pneumonia.[11]

Synovitis from Immediate Infection.—The form of synovitis resulting from penetrating wounds has been classed here as traumatic and mentioned above. Areas of infection in the neighborhood of the joint may, however, cause a joint inflammation, most often of purulent character. The most common form of this is to be found in acute infectious osteomyelitis existing in the ends of the long bones and reaching the joint. Such an infection results in an acute destructive purulent synovitis, an example of which is to be found in many if not most cases of the so-called "acute arthritis of infants." In these cases a very severe purulent joint affection appears in young babies,—an affection which is characterized by rapid and destructive progress and severe general infection.

Among other causes of infection by contiguity may be mentioned all the cases of synovitis which occur when phlegmon and abscesses develop near a joint or when erysipelas passes over it. Acute periostitis and acute and chronic ostitis occurring near a joint are other causes of joint infection.

Syphilitic Synovitis.—Simple serous synovitis may accompany the secondary stage of syphilis, The more characteristic syphilitic lesions are chronic. Acute synovitis is rare in hereditary syphilis.[12]

Synovitis in Hæmophilia[13] is rather a chronic than an acute affair; but acute swelling, pain, and disability occur in connection with trauma, and as an accompaniment of the chronic process existing in the joint. There may be extensive intra- or extra-articular hemorrhage in connection with this.

Intermittent synovitis, which is an affection characterized by a succession of acute attacks of synovitis (of the knee) is an affection the pathology and etiology of which are very imperfectly understood, and for which no satisfactory treatment has been formulated. Periodicity is a marked feature of the attacks.[14]

Gouty Synovitis.—Gouty synovitis is the local manifestation of the general disease. It is a serous synovitis, ordinarily of the great toe joint, with considerable periarticular infiltration and redness of the skin. It tends to involve other joints in succession. There is a chronic structural change in the joint, which is merely interrupted by these attacks of acute synovitis.

Similar acute attacks occur in other forms of chronic synovitis.

Catamenial Synovitis.—A synovitis is described as occurring in girls and women in connection with menstrual irregularity or uterine trouble. It is usually bilateral and painless.[15]

DIAGNOSIS.—The swelling produced by the distended capsule is the most characteristic sign; it is irregular in outline, bulging, and fluctuating, where the joint is superficial. In the ankle-joint the swelling is not very clearly marked, but it ordinarily is chiefly anterior and the capsule bulges out in front of the malleoli. In the knee the patella is lifted by the effusion and floats. In examining for this the knee should be fully extended and the muscles relaxed, the fingers of both hands should encircle the limb firmly in front, above, and below the patella, thus confining the effusion to the space directly under the patella and over the intercondyloid depression on the femur. The forefinger of one hand then lightly but sharply presses on the patella, which can be felt to descend and hit the femur. This matter of fully extending the leg and confining the effusion under the patella is of much importance, as otherwise a small effusion may escape detection. Acute synovitis of the hip is a rather obscure affection, and in children the diagnosis from beginning hip disease is not always possible. In cases with much effusion in adults, however, swelling may be found in the groin above Poupart's ligament and behind the great trochanter. In the hip there is generally limitation of motion and the leg may be flexed and abducted. In the case of the shoulder the whole joint is larger than usual, without any definite outline; and if the distention is great, the axilla may be more shallow than is normal, and the depression beneath the acromion behind is lost. In the elbow there is bulging of the sac behind on each side of the triceps tendon. The wrist, when inflamed, shows an encircling swelling. The positions assumed by the various joints, when inflamed, have been given above, but simple position is of little service in differentiating synovitis from other joint and bone affections, and the same is true of muscular atrophy.

It is important to remember not only that synovitis is made evident by effusion, but also by swelling of the synovial membrane, and in the more superficial joints the latter is easily detected. In the knee-joint, for instance, by palpating the parts at the sides of the patella where the synovial membrane lies over the bone, much information may be obtained by contrasting the affected with the sound joint. The inflamed membrane feels thick and masks the clear outline of the bone.

Synovitis is to be distinguished from ostitis, bursitis, articular neuralgia, and hysterical joint disease. A diagnosis of acute synovitis in children should be made with very great care, for they are not prone to have acute synovitis, and are prone to have chronic ostitis. Typical bone disease begins with stiffness of the joint and pain—the latter especially at night, interrupting sleep; wasting of the muscles of the limb, and effusion are not necessarily present. There is generally some constitutional disturbance and the course is slow.

In children, however, the bone disease may have escaped attention and a supposed fall may be the first thing to call attention to the fact that a child limps. A very considerable number of cases of hip disease, for example, come to out-patient clinics with a history of the trouble having dated from a fall a few days previously, when it is obvious that the disease must have existed for weeks at least.

From bursitis, synovitis is distinguished by the different location of the swelling, the less degree of joint stiffness and pain, except when manipulation bears directly on the inflamed bursa, and the absence of muscular atrophy. In the case of deep bursæ the differential diagnosis may not be easy at first. Bursitis, however, rarely begins without cause; it is associated oftenest with mechanical irritation, as the names "housemaid's knee," "miner's elbow," etc., show. At the same time it should be remembered that bursæ often communicate with joints, and that synovitis and bursitis may exist together during an acute synovial inflammation. The bursæ, when inflamed, form in their way as characteristic a swelling in each joint as does the joint capsule itself when distended by intra-articular effusion.

Articular neuralgia is said to exist apart from joint disease.[16] Local symptoms are absent and the condition is too vague and too little known to deserve more than mention.

Hysteria simulates chronic oftener than acute joint disease, yet sometimes, following a fall or an overexertion, sensations closely simulating the symptoms of an acute synovitis may be complained of. Ordinarily the diagnosis is easily enough made by the absence of heat, swelling, and localized tenderness, and by the general make-up of the patient, but some cases offer much difficulty, as muscular wasting and rigidity may be present.

Pyæmic, gouty, and rheumatic synovitis are to be distinguished from each other by the presence of the constitutional affections of which they are merely the symptoms, while gonorrheal synovitis often offers some little trouble from the fact that the patient is anxious to conceal his urethral discharge. Rheumatoid arthritis belongs rather to the class of chronic joint diseases, and would hardly be confounded with acute synovitis.

As to the diagnosis of dry synovitis, few rules can be formulated. Its acuteness, severe pain, and the absence of marked swelling are its leading characteristics. To diagnosticate it from ostitis would be sometimes impossible, but ordinarily its more acute course will establish its identity. At best it must remain an obscure affection.

Prognosis.—The prognosis in simple serous synovitis of traumatic origin in adults is good, if the general condition of the individual affected be even fair. Suppuration is not common, except from wounds; and when it occurs, there is generally some evident cause for it, such as infection by tapping, a broken-down constitution, etc. Under effective treatment a complete restoration of the joint is the rule. From the sixth to the eighth day the effusion will ordinarily begin to subside, and its absorption is much aided by pressure and rest. The third possibility, in a simple synovitis, is that it may become chronic. In some cases the swelling does not subside much, but the pain goes away, and, although the joint remains swollen, the patient may go to business and use the leg to a moderate extent; but he has dropsy of the joint, chronic serous synovitis, or an irritability may remain after the absorption of the fluid, and succeeding light attacks may follow one another, each leaving the joint worse than it was before. Cases like this are apt to eventuate in chronic joint disease.

In acute synovitis which is caused by displaced cartilages, by hypertrophied fringes, or by foreign bodies, the disease is likely to recur. Rheumatic synovitis, on the other hand, has a tendency to become subacute or chronic and to leave stiff joints. The occurrence of suppuration in either rheumatic or simple synovitis is a serious matter, and, although prompt treatment will, in most cases, be efficient, a much more doubtful prognosis will have to be given, especially if the suppuration should have come on without apparent cause. The prognosis must depend on the treatment, and the prompt making of a free incision improves the outlook greatly. However, in purulent synovitis of any severity some impairment of motion is to be feared. The occurrence of a joint affection in pyæmia does not make very much difference in the outlook, for the prognosis depends wholly upon the general character of the disease, whether mild or malignant. If it is mild, in from five to ten days the joint symptoms improve, and a complete restoration of the joint is not impossible.[17] On the other hand, the destruction may go on to any extent, preceding a fatal termination. In general, however, it is not common to find complete restoration of joint function after purulent synovitis, although it may take place. The synovitis which occurs after the exanthemata is said to tend toward recovery after a few days. At the same time, bearing in mind how often chronic joint disease follows these exanthemata,[18] the physician should be careful not to give an unreservedly favorable prognosis. The synovitis which develops in typhoid fever is generally purulent and more grave. Gouty synovitis, when left alone, lasts for a week or ten days; efficient treatment will generally shorten its course to three or four days. Gonorrhœal synovitis is at best a slow affair; it is characterized by a slow course, with a tendency to relapse and to become chronic. Recovery does not ordinarily take place in a less time than a month or six weeks, and ankylosis is common.

The occurrence of synovitis as a complication in chronic ostitis is merely an incident in the course of a long disease.

Treatment.—The most important points in the treatment are: to put the joint at rest and to keep it at rest; and, secondly, in the severe cases, to put the joint at rest in good position, so that if ankylosis should take place, as useful a limb as possible may be obtained. The knee, for example, should be put up very slightly flexed, the elbow at a right angle, with the thumb upward, the hip very slightly flexed on the trunk and neither adducted nor abducted, the ankle at a right angle, the wrist in the line of the arm, and the shoulder with the arm at the side. The splint that offers the most definite and absolute support to the two segments of the limb is to be chosen. Ordinary wooden and tin splints, accurately padded and firmly applied, are generally the most serviceable, except in the ankle, where in severe cases carved wooden side-splints often will not answer, and wet millboard or plaster of Paris must be applied; and in the hip, where bed-extension and a long outside splint, as in fractured thigh, will be most serviceable. Millboard splints are applied according to the directions of Gamgee.[19] The joint is wound by rollers of sheet-wadding until one or two layers cover it everywhere; then wet millboard is shaped to the joint and bandaged on by cotton rollers, applied with firm, even compression, which may be considerable if the method is properly applied. Plaster-of-Paris splints are made by the application of crinoline-gauze bandages impregnated with finely divided plaster. The limb is first wound in sheet-wadding or gauze, and then the plaster rollers are applied. The method does not give in all cases certain, definite support.

The problem of getting a limb into good position for the application of a splint is not always an easy one. The knee, for example, is apt to be more flexed than is desirable, especially in a case of some days' duration; and, if easy manipulation fails to bring it into correct position, recourse must be had to manipulation under ether, or to extension by weight and pulley, before a ham-splint can be applied. The former of the two methods should be chosen in most cases of acute synovitis. Once obtained, this good position is easily kept. It is not generally practicable to apply extension to the wrist or the ankle. The plan of putting up the limb in whatever position it happens to be, and waiting for it to straighten under rest, is not always effectual. With the larger joints rest in bed should be enforced for a day or two in cases of severe sprain.

After the limb has once been placed in a good position, and after precautions have been taken for maintaining it in this position, it will not be necessary, in a case of simple synovitis of moderate severity, to do very much more. The distended sac may advantageously be subjected to a moderate degree of compression. This may be effected in a variety of ways. A flannel bandage affords light compression; small dried sponges, laid over the joint and held in place by stout linen rollers, and then wet, afford either the lightest or the most severe compression. The application of a rubber bandage is one of the most common forms of producing compression. It can be loosely applied so as to produce but light pressure, or, by stretching it only slightly during its application, very severe compression may be obtained. The method of Gamgee, above alluded to,[19] is applicable to almost any joint, and affords even, comfortable, and efficient compression. If, however, the intra-articular distention is extreme, or if at the end of a week it does not begin to diminish, the joint should be aspirated and compression at once applied.

The application of cold to the joint often gives relief to the pain and a sense of comfort. This can be done by a poultice of ice and sawdust, by the ice-bag, or by the rubber coil wound around the limb. In other cases hot applications are more agreeable and equally useful. Hot-water bags can be used, or poultices, or fomentations of laudanum and hot water. In synovitis of a severe character in a full-blooded individual the application of leeches to the joint might be of value. Painting with iodine, blistering, firing, and the other forms of counter-irritation seem a needless and bothersome infliction in simple acute synovitis; if, however, it shows a tendency to become chronic, then the time for counter-irritation has come, and blisters encircling the joint, in connection with aspiration and subsequent compression, should be made use of. When the effusion has subsided and only a moderate thickening of the tissues is left, the splint should be removed for a little while at a time and passive motion begun, along with massage. The tendency which inflamed joints have to become ankylosed should always be borne in mind. If the splint is kept on too long, muscular atrophy is increased and the subsequent weakness of the limb may continue a long time and be a source of discomfort and of irritation of the joint. If the patient be permitted to use the joint too soon, there may be a recurrence of the effusion and other acute symptoms. In the knee, for instance, free use should not be allowed until the effusion has wholly disappeared and the thickening of the synovial membrane about the joint has greatly diminished.

Massage is indicated as soon as the heat and extreme tenderness of the early stage have disappeared. As to methods of manipulation and massage, a skilled masseur is, of course, the best person to handle the limb, but deep kneading of the muscles and gentle flexion and extension of the joint, increasing in extent each day, are better than nothing. The muscular atrophy will cause the limb to be weak; and, if the atrophy has reached an advanced degree, although the muscular tone would probably in the course of time be restored without such help, the restoration can be hastened by the use of a weak continuous current, or, if preferred, the faradic current may be employed. The use of hot-air baths is of great value in the later stages of acute synovitis.

It is not worth while to attempt to use the limb very much until its function is fairly well restored by passive motion. The use of oil, etc., is, of course, much inferior to massage with the dry hand, but if the pain persists, on using the limb, stimulating liniments and iodine are useful.

If ankylosis should have already taken place, there are two methods to pursue: (1) To break it up at once under ether, a method which will ordinarily cause a relapse of the synovitis; or (2) to wait some months before attacking it. The latter method will generally be advisable.

Slight grades of acute serous synovitis of traumatic origin are best treated by massage from the first. The massage should be given by some one of skill and experience and not oftener than twice daily. The patient may be permitted to use the joint provided it be properly protected. In the ankle, for instance, a pad of felt under the arch of the foot, held in place by a firm bandage or strips of sticking plaster running under the foot and winding around the ankle (Cottrell's dressing), will enable the foot to be used without pain, whereas its unprotected use would be harmful and accompanied by much pain.

The application of dry heat in a hot-air oven is also of much value in these cases. The joint loosely wrapped in flannel is exposed to a temperature of 300–400° F. for half an hour or more once daily. This treatment may often be profitably combined with massage, one treatment of each being given daily.

The constitutional treatment of acute serous synovitis amounts to nothing more than the routine of keeping the bowels open and administering diaphoretics if the temperature is elevated. If, however, there is any reason to suspect a rheumatic cause for the attack, salicylate of sodium should be given in full doses.

Traumatic purulent synovitis, where a penetrating wound of the joint exists, requires the enlargement of the penetrating wound and the free flushing out of the joint with hot sterile water or with weak antiseptic solutions. The wound may then be closed if the case is recent. If the case is not recent and if the infection of the joint is well established, free incisions should be followed by prolonged flushing out of the joint with a weak corrosive solution used hot, and the wounds should be drained.

Rheumatic synovitis should be treated by rest, compression, and ice-bags, along with the appropriate use of salicylic-acid compounds for the general condition.

Gonorrhœal synovitis should be treated in the acute stage by rest and compression. As soon as this passes, the use of hot air and massage will be found of value. Should the case prove intractable, much improvement may often be secured by opening the joint, flushing it out freely with hot water, and closing it again.

Synovitis in acute infectious disease, so long as it remains serous, is treated like any severe case of serous synovitis. So soon as it becomes purulent the joint should be opened freely and washed out and the wound closed or not, according to circumstances.

In *synovitis from infection from contiguous parts*, the opening of the joint is indicated, and at the same time the cause of the infection should be removed, if possible.

Syphilitic synovitis is treated on the general lines indicated, and antisyphilitic treatment should, of course, be given.

Synovitis in hæmophilia is treated by rest, cold, and compression.

Gouty synovitis is treated by rest and constitutional measures.

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REFERENCES.

[1] Frerichs: Wagner, Handwörterbuch der Phys., iii., 1, 446.
[2] Volkmann, Pitha, und Billroth: Handbuch der Chir., Bd. ii., 2, 494.
[3] Bonnet: Mal. des artic., t. i., p. 92, Lyons, 1845.
[4] Hilton: Therapeutic Influence of Rest, p. 156.
[5] Lücke: Deutsch. Zeit. f. Chir., March 9th, 1885.
[6] Sonnenburg: Deutsche Zeit. für Chir., vii., 485.
[7] Fischer: Deutsche Zeit. für Chir., viii., 1, 37.
[8] Vallat: L'Atrophie musc. dans les mal. articulaires, p. 54, Paris, 1877.
[9] Northrup: Trans. Assn. Am. Physicians, vol. x., p. 150. Bradford and Lovett: Orth. Surgery, second edition, p. 197.
[10] Witzel: Die Gelenk-u. Knochenentz. bei akut-infektiösen Krankheiten, Bonn, 1890.
[11] Colé: Amer. Med., May 31st, 1892.
[12] Lancet, 1886, i., 391; Deutsche Chir., Lief. 66, p. 291.
[13] Gocht: Deut. Zeit. f. Chirurg., xlix., 614.
[14] Senator: Berl. Klinik, 1898, 119.
[15] Bennett: Lancet, February 23d, 1901.
[16] Ranney: Surgical Diagnosis, third edition, p. 61.
[17] Sedillot: De l'infection purulente, Paris, 1849. Roser: Wagner's Archiv, i., 329.
[18] Gibney: Diseases of the Hip, p. 212, New York, 1884.
[19] Gamgee: The Treatment of Wounds and Fractures, London, 1883.

SYNTHETIC PRODUCTS, POISONING BY.—Out of the large number of synthetics obtained from the hydrocarbons of coal-tar a few have come into general medical use, and one of these, acetanilid, is a common ingredient of the headache cures sold by druggists. Antipyrin and phenacetin are also much used, but, being more expensive, are less common in proprietary articles. All these bodies are antipyretics, and when taken in overdose, produce depression of the heart, with slow respiration and lowered temperature. Marked cyanosis is also observed. Nausea and vomiting may occur. The effects of the drugs are much influenced by idiosyncrasy. The treatment should be free washing out of the stomach, artificial warmth to counteract the antipyretic action, and stimulants, alcohol and coffee, to counteract collapse. Inhalations of oxygen have been suggested; also the hypodermic use of strychnine.

Sulfonal, trional, and tetronal are members of a group of synthetics that have hypnotic action, and have been used as substitutes for morphine. Sulfonal has been much used. These agents may cause vomiting and purging, but not usually. In fact, the bowels are often constipated. Sometimes the most marked symptom is depression, but the typical effect is sleepiness which deepens into coma, and may last for a long while. The urine is diminished and becomes very dark, owing to excess of a coloring matter. This symptom, known as hæmatoporphyrinuria, is generally early developed. In a case of trional poisoning recently reported, the patient, a woman aged twenty-eight, had well-marked hallucinations with dizziness, staggering, and loss of reflexes. The change in the urine came on late. The patient was in bad health when she took the drug. She died from the effects.

Treatment of this class will be carried on along somewhat the same lines as those given above. The stomach should be washed out well. As the drugs are eliminated by the kidneys in unchanged form when the dose is large, it is deemed advisable to use warm water freely as a diuretic. Constipation will be, of course, met by mild purgatives or enemata. *Henry Leffmann.*

SYPHILIS.—The word syphilis was probably first suggested by *Syphilus*, the name of one of the characters in a pastoral poem composed by Fracastor in 1530. This name was unquestionably coined by the poet for his fictitious character, by a combination of σῦς, hog, and φίλος, fond of—a not uncomplimentary designation for swine herd.

Definition.—Syphilis is a specific, infectious, and chronic disorder, resulting either from inheritance or from immediate or mediate transference of the disease from an infected to a sound individual, beginning always, in the latter event, after the lapse of a characteristic incubative period, by the appearance of an initial lesion, at the site of infection, commonly termed a chancre; and followed after an interval of time by symptoms of systemic derangement, often evolved in a determinate order, which eventually may affect any organ of the body, one attack usually conferring upon the subject of the disease immunity against subsequent infection.

Synonyms.—Many of the names which have been employed to designate the disease seem to have originated in attempts to shift the reproach of its origin and existence from the people of one nation to those of another. It has been called morbus gallicus, the French disease, lues venerea, mal vénérien, vérole (in France), sifilide (in Italy), French pox, chronic pox, "bad disorder," "bad disease," Lustseuche, Krankheit der Franzosen, radezyge (in Sweden), and other names. The discovery of the micro-organisms responsible for the production of frambœsia and yaws has differentiated completely the three affections.

History.—Toward the close of the fifteenth century—soon after, in fact, the discovery of a new continent—syphilis made its appearance among Europeans and became the subject of discussion in medical literature. By many it was then supposed to have originated in consequence of the relations newly established between the inhabitants of the Old and those of the New World, and it was therefore often termed the "American disease." Later investigation, however, makes it appear possible that syphilis appeared among the races of men at a more remote period of antiquity. Evidence of supposed syphilitic disease of the bones has been recognized in the skeletons of prehistoric man.

Interest has been revived in the questions relating to the supposed American origin of syphilis by fresh studies of original documents, and by discoveries, in different portions of the continent, of bones supposed to exhibit changes due to the disease. Papers touching on the theme originally well elucidated by Joseph Jones, of New Orleans, have appeared from the pen of Bruehl and others, throwing further light upon both sides of the problem. The writings of Sahagun, Torquemada, Roman, Mendieta, Pane, and others have been found to show, as to New Spain, that the bodies of those affected with syphilis were interred, as distinguished from those dead of other disorders, which were cremated; that the infected were not deemed fit for religious sacrifices; that they were not represented at the festivals; and that the disease was counted a punishment sent from the gods for the non-performance of religious rites and for other offences. The Mexicans not only recognized the connection between the earliest and later manifestations of the disorder, but distinguished between several types of the former, understanding also its remedial treatment far better than the Spaniards, and even seeking thermal resorts for the purpose of securing relief. In seventeen Indian dialects, each of which has a primitive and native term for designating the disease, none of the terms thus employed suggests confrontation with a new malady, although soon after contact with the whites the natives were compelled to apply new names to many novel objects with which they were to become familiar. These new names either bear witness to the impression on their ears made by the speech of the Castilians, or describe some prominent feature of the object to be newly named, a rule distinctly observed by them in the case of diseases known to have been imported from Europe to America, as, for example, measles and smallpox. The singular confusion, existing in the Mexican language of the sixteenth century respecting the terms employed to indicate ideas of power, divinity, and the special disease here under discussion, possesses an interest in view of the fact that this is recognized in the dialects of Quechua and Aymeras, three hundred years before Pizarro conquered the capital of the Incas.

Symptoms scarcely to be distinguished in their description from those of syphilis are described in the ancient literatures of China, Mexico, Peru, Arabia, Greece, Rome, and in the sacred writings of the Hebrews. It is probable that, at the periods which have been assigned for the origin of the disease in the fifteenth century, its rapid extension was largely due to the awakened activities of mankind in the direction of geographical discovery and international traffic. It is a well-known fact that epidemics of infectious diseases are usually most severe in communities which have long been virgin of such accidents.

The literature of syphilis may almost be said to date from the period so long assigned as that of its first appearance among the races of men. It has since been adorned by the names of such eminent medical authors as Astruc, Van Swieten, Boerhaave, Bell, Sydenham, Colles, Hunter, Ricord, Gross, and Bumstead. The contributions to the subject made by contemporary authors have been as voluminous as valuable. The evolution and involution of the syphilitic process in every organ and tissue of the body have been observed and described with as much detail and accuracy as have been bestowed upon any of the problems in medicine.

Geographical Distribution.—Syphilis exists to-day in almost every country to which commerce has pushed its ventures. The degree of its depredations in any province may be wellnigh regarded as a measure of the extent of the intercourse of the inhabitants of such a country with the world at large. It exists in Great Britain, Russia, France, Italy, Norway, Sweden, Denmark, Prussia, Austria, Portugal, Switzerland, and in every other country of Europe. Its victims are usually more numerous in the larger centres of population where the activities of trade are greatest. England, for example, with her enormous maritime traffic, pays a heavier price of this character for her commercial profits than France, which is popularly supposed to suffer in larger measure. In a few of these countries, Italy, for example, where many of the people are densely ignorant, filthy, and poor, epidemics of the disease have occurred with disastrous results. On the African coasts, in Egypt, Madagascar, and Abyssinia; in all countries of Asia with which Europeans sustain commercial relations; in Japan, where the disease is reported to be both widely prevalent and virulent; in the Levant; in all parts of Asia Minor, and throughout all districts lying upon the shores of the Black Sea, syphilis is found, varying both in types of intensity and in preponderance. The same is true of all the countries of North and South America, Oceanica, and the Hawaiian Islands. In the United States of America, syphilis may be recognized in every hospital and in the practice of almost every physician of repute. It is fortunately, however, much more common in the large cities, the rural populations escaping to a happy extent. It is found here among those who are native to the soil, including the negroes and Indians, as well as among the Chinese and other individuals of foreign birth who have immigrated hither.

It appears, in brief, that the extent and severity of the disease are not related to climate, isothermal lines, or degrees of latitude and longitude. They are intimately related, rather, to certain social traits in mankind, distinguished in their commercial, military, and religious excursions, trading ventures, pilgrimages, wars, fairs (*e.g.*, that of Nijni-Novgorod), and encampments of armies; their hygienic and medicinal methods; and, more or less in consequence of what precedes, to the density of population and the degree of intelligence possessed by infected classes as displayed in their management of the malady.

Nature of the Disease.—Syphilis is a specific infectious disease, always occurring in consequence of transmission from a diseased to a sound individual, and always transmitted as such. It does not sustain etiological relations with scrofulosis, tuberculosis, leprosy, or any other known disorder. It is capable of transmission by inheritance, and also by the medium of fluids furnished by the pathological tissues of diseased individuals. These fluids when isolated may be said to embody all the power and potency of the disease, and hence are described as virulent, or containing the virus of syphilis.

This virus, or contagious element of the secretion, which may be removed from one individual and artificially introduced into another with the result of thus assuring the complete evolution of the symptoms of the disease, has been the theme of much discussion. Its very existence has been doubted by Bru, Jourdan, and others.

The Bacillus of Syphilis.—After years of research and experimentation, the special micro-organism of syphilis would seem at last to be discovered, though there is yet lacking the production of the disease in man by inoculaton with pure cultures.

Max Joseph and Piorkowski, of Berlin (*Berl. klin. Wochenschrift*, Nos. 13 and 14, 1902), discovered in the spermatic fluid of a male subject, twenty-two years of age, a bacillus 4–8 microns in length and 0.2–0.3 micron in thickness. These were cultivated on sterilized placentæ; they closely resembled in size and other features the diphtheria-bacillus. Transferred to artificial media, there promptly appeared, in twenty-four hours after inoculation, a colony of micro-organisms scarcely visible to the naked eye, producing later a grayish, confluent, agglomerated mass in which, with the aid of the microscope, bacilli were recognized resembling the bacillus subtilis, staining readily with carbol-fuchsin and gentian violet. They were blunt-pointed; usually knobbed at one extremity; and were cultivated on artificial media for three generations; the last produced colonies showing diminution in the size, frequency, and vigor of the bacilli, all of which was materially changed by reinoculation upon blood-serum.

These experiments were verified by examination of the sperm of twenty-two male patients, control experiments with no recognition of the same elements having also been made on sound male subjects. The introduction of pure cultures of this bacillus into a sow was followed by morbid results which, however, might have been possibly due to swine cholera.

Claims to the discovery of a bacillus of syphilis have been made also by Lustgarten, Pisarevski, Klebs, Birch Hirschfeld, and others.

Syphilis without question belongs to the class of infectious granulomata, and is the result of the introduction of a parasite into the human economy. The disease should be classed to-day with tuberculosis and leprosy, the etiological bases of which are now beyond question.

Neisser believes that the bacteria may be transmitted by intra-uterine inheritance or extra-uterine infection at a given point where multiplication of the germs occurs. Whether instantaneous general infection follows by the sudden admission of these micro-organisms into the circulating fluid, or by the slower process of invasion of the lymph-channels and extension through the lymph-glands to the general economy, it seems clear that the initial sclerosis of the disease, a "chancre," becomes a focus of infection which only gradually participates in the same process of distributing the germs of the disease throughout the general economy. Later, the lodgment of these germs in various parts of the body determines the development there of the specific products of the disease; possibly also exercises there that specific local modification which renders the tissue then capable of reacting in a certain characteristic morbid behavior, after the operation of external irritants (mucous patches in the mouth of the smoker, etc.). Neisser believes that the nearer the date of infection, the larger the number of bacteria present at any one moment in the body; and, as a corollary from the above, the more numerous, symmetrical, and superficial the lesions. But in later periods, with a smaller number of bacteria and a gradual decrease in capacity for infection and hereditary transmissibility, there are fewer, deeper, more asymmetrically disposed, and more malignant manifestations of the disease.

Evolution of the Disease.—Between the moment of infection and the earliest appearance of a chancre to the unaided eye, there is usually a delay of from fifteen to thirty-five or forty days, a period of twenty-one days for the average of cases. This is usually called the first incubation. There is, however, neither an incubation, a "hatching," a delay, nor an arrest. If our methods were without flaw, we should be able to detect the movement toward general infection from its very first to its completed step. In the attempt to study the evolution of syphilis, questions of time, the crude hypothesis of an incubation, and all really artificial distinctions, should be, for the purposes of critical investigation, set aside.

By the late eminent Philip Ricord, the evolution of syphilis was divided into three stages, the primary, the secondary, and the tertiary. The primary included the symptoms concerning the chancre and its accompanying multiganglionic adenopathy. The secondary period included the symptoms displayed during the succeeding term, in which systemic infection occurs, with usually symmetrical and superficial cutaneous and other manifestations. This was loosely estimated at about one year in duration. Lastly, following this stage of efflorescence, came the tertiary period, that in which the deeper structures of the body are involved; that in which the disease commonly ceases to be transmissible, in which it may produce its most destructive effects, or pass into a complete innocuousness and decline. The influence of this doctrine of periods has been incalculably great and valuable. It once marked a revolution in the history, in the study, and in the treatment of the disease. It has dominated the minds of the medical men of all lands since it was first completely grasped by the intellect of its master.

But it has served its day. To thoroughly grasp the problems of syphilis, it is now needful, for the time being, to emancipate the mind wholly from the ingenious suggestiveness of this doctrine. It must be clearly seen to be nothing but an artificial device for classifying in a clumsy way the clinical phenomena of the disease.

As a matter of fact, there is no line of demarcation between the successive phenomena of syphilis as they appear in the evolution of the disease in any given case. From the moment when infection has been wrought to that of the gravest injury, or of the mildest efflorescence, there is, when no arrest occurs, a gradual but continuous progression of the disease. This advance is commonly marked by interludes as striking as they are salutary. They may be due to the intervention of treatment, or to changes in the general health of the infected due to other causes. Apparently capricious cessation of the advance of the disease may occur, since even the cutaneous symptoms of marked cases may wholly disappear without treatment. If we were in position to view with keenest scrutiny the unmodified progress of syphilis in cell and vessel, no one can doubt that the so-called period of incubation would disappear and the microscopic eye of the observer would be as busily occupied during that as throughout any other period of the disease. Similarly, there would be no sharp distinction possible between primary and secondary syphilis. One could scarcely note the hour when, from the first to the last, there was not in progress a slow and gradual progression, from point to point, of the toxæmic product originating in the changes wrought at the site and at the time of infection.

These suggestions are needed for a clear comprehension of the phenomena following the stage of so-called "primary syphilis." The "primary" hypothesis made it absolutely necessary to assume that after the primary came a secondary; and after a secondary, an inevitable tertiary stage. More, the mind thus habituated to a study of the evolution of the disease in periods looked to an evolution of symptoms in these periods in due order and line of procession. One was thus educated to expect in a typical and uninterrupted attack of syphilis (could such be observed) each and every one of the several manifestations of the disease. After macules, papules should appear and, in course, pustules, gummata, ulcers, and successive involvement of organ after organ of the body. Some such definiteness of order is, in point of fact, to be recognized in the evolution of variola, with which, unfortunately, syphilis has been too often and too closely compared.

But no such syphilitic history has ever been observed. It is the artificial manikin of the schools, the figment required by the domination of the medical mind by the time rules of the French school. It was this once useful and ingenious time-schedule which made it equally imperative for the French to coin for some of the manifestations of syphilis the striking terms "precocious," "galloping," and "tardy," words which embody a confession of the weakness of the schedule to explain all the exact clinical pictures of the disease.

Almost immediately after lymphatic adenopathy has declared to the eye and the finger of the observer that the toxic product of the chancre site is finding its way into the vascular channels of the body, the phenomena of the disease are evolved, not in the order of a time-card, but, to employ a different figure, in radii from a pathological centre. Early indeed, in many cases, can it be seen that the future of the malady is to be sought along one or another line toward exceedingly variant results. The complexus of these results may be conveniently classified in four divisions, which are named later.

Toward these the advance is either slow or rapid. The gravest may be imminent when the chancre is yet unhealed, the adenopathy unrelieved, the lymphangitis discernible. The mildest may be attained when months have passed, the early accidents are wellnigh imperceptible or forgotten, and the general health of the infected individual meanwhile not manifestly impaired.

Whether this apparent interval (the so-called "secondary period of incubation") be brief or protracted, none can doubt that when an ultimate evolution of the disease occurs there is a continuous progress toward complete or partial systemic intoxication. When well marked, this apparent interval occupies from forty to fifty days, but it has been noted as brief as twenty days and as prolonged as a twelvemonth. Its limits are usually defined between the date of the chancre's appearance on the one hand, and the date of the first cutaneous exanthem on the other. That this is a purely artificial distinction becomes at once apparent when one of these dates of limitation is questioned. There is nothing in a cutaneous exanthem which entitles it to pre-eminence above other symptoms of syphilitic invasion perfectly evident during the so-called second incubative stage. From the date first assigned to the last arbitrarily selected there is no real pause, no conspicuous absence of invasion signs. On the contrary, the symptoms of this period are often more suggestive and significant than when, for example, the skin of the patient's belly is beset with a macular syphiloderm.

The merest enumeration of symptoms possibly occurring in this period of apparent pause is sufficient to indicate that no real incubation can be observed. Yet here again it is important to note that not all of the enumerated symptoms are to be observed in one individual, and further, that they observe no definite order when two or more chance to be parts of one syphilitic history. Rather are they different surface-indications of the several lines along one or another of which the disease may advance toward its ultimate results.

After the chancre appears, and before the first exanthem of general syphilis follows, the condition of the average patient is far from in apparently sound health. The blood-globules commonly decrease, while the leucocytes by actual enumeration increase in number. The glands of the body elsewhere than those in the region of adenopathy near the chancre site, slowly or suddenly enlarge, become tumid, painless, much less indurated than those first noted in the disease, and are often symmetrically, rather than, as in the other instance, asymmetrically involved. The spleen, so intimately is it concerned with the fluids traversing the vascular channels, becomes tumid and at times tender. The liver function is often disturbed, as shown by an icteroid skin with muddy conjunctivæ and the appearance of bile-products in the urine. The functions of the stomach, of the bladder, of the suprarenal capsules, and of other viscera, may be seriously impaired. Continuous or interrupted febrile temperatures may be reached ("syphilitic fever"), the thermometer rising at times even to 105° F., the patient being not rarely treated by a physician ignorant of the nature of the effective poison for an intermittent or relapsing fever. The nervous system may seriously suffer. Atrocious neuralgias, substernal and periosteal pains, pains in the bones and joints, osteoscopic sensations, and even synovial effusions, may be the protest of the system against the advent of the recently introduced poison. Often there are signs of mischief even of a severer type. The lassitude and depression are profound; a condition of mental hebetude gives place to partial syncope; a headache results in a temporary strabismus, a pain in the upper or lower limbs is followed by muscular contracture. None can doubt that in a carefully studied case where the evolution of syphilis is actually in progress, however mild its future is to be, a skilled diagnostician could recognize, at one point or another of the body presumed to be in the stage of this so called secondary incubation, unmistakable evidences of an insidious advance of the malady.

The term "explosion" has been repeatedly employed, with other metaphorical phrases, to describe the moment when the first cutaneous exanthem appears. Its use is an index of the extravagant importance attributed to the onset of skin-symptoms in early syphilis. As a matter of fact, the latter are surface indications of more serious and deeper processes (probably involving the nervous centres) and are all-important to the eye only of the vulgar. As a matter of fact, too, they never occur by explosion. The first efflorescence of the disease may be as gradual as the dawn of a day and as impossible to define. Before the human eye traces its first expression, the camera of the photograph can produce with fidelity the faint mottlings of a skin that is to be later visibly the seat of a syphilitic efflorescence. No one who has with minute care watched the oncoming of the cutaneous manifestations of the disease, can have failed to note how insidiously the approach is made to the eye. An accident may change all. The excessive heating of the body in a bath or by dancing may simply precipitate the blushing of the first rash.

This once apparent, and let it be noted even without this, syphilis exposes its advance in numberless directions, probably in no two cases exactly the same. These advances may be, however, for practical purposes, classified in four principal directions, as previously suggested in these pages. They may be named and briefly sketched as follows:

1. Benign syphilis with mild and transitory symptoms.

Every vacciniculturist has recognized the fact that a few heifers fail to respond to all efforts to inoculate the udder with vaccinia. The reason is not explained; the system of a few individuals in every thousand simply refuses to react against the introduction of the poison. No expert of wide experience can fail to have been impressed with the fact of the existence of this exceptional class of human subjects with respect to syphilis.

There are persons who exhibit typical chancres with characteristic adenopathy of the vicinage, who never after exhibit the slightest signs of systemic disease. The objection to this statement is suggested at once to the mind of the profane. It is, that an error was made in the diagnosis of the initial sclerosis. That which seemed to be a syphilitic chancre was really not such, but spurious, an imitation of the genuine lesion. But, it is responded, such chancres have been not carelessly, but with exquisite skill, studied by experts, and found not different from others followed by grave syphilis. Further, the persons enjoying this immunity have failed later to contract the disease when exposed to it; and, more important than all else, individuals of this class correspond to others of the same class who, having actually exhibited such chancres, do later have systemic symptoms of such mild type as to astonish those unfamilar with these singular exceptions to the rule.

These interesting exceptions are either the triumphant proofs of the skill of the physician, or (what is far more probable) proofs that some of the phenomena of natural law defy ultimate analysis by the human mind. Persons of this class have typical, severe or mild, premonitory chancres. In due time they have also slight ganglionic engorgement, post-occipital, along the nucha, or in the line of the sterno-cleido-mastoid muscle. An exanthem occurs, of macular type, upon the belly, over the chest, slightly upon the face, or perhaps limited to the trunk. When this fades, with or even without medical treatment, the disease is absolutely at an end. These cases are annually observed in every extensive syphilitic practice. They are not rarely seen in women who have been infected without their knowledge by a husband, or through the innocent contacts of daily life.

2. Benign syphilis with relapsing or persistent superficial symptoms.

Cases assignable to this category are those in which typical chancres are followed by typical early manifestations of general syphilis, the patient continuing, for months or even years after, to be annoyed by intractably persistent or relapsing, but wholly superficial syphilitic symptoms. If described according to the former phraseology, these would be classed with the subjects of prolonged secondary syphilis, never proceeding to tertiary stages. Two, three, and four years after infection, such subjects are found with an infiltrated patch of scaling papules on buttock or back; with mucous patches of lips, tongue, or fauces; with a squamous scrotal, palmar, or plantar syphiloderm; or with a cluster of superficial and crusted papulo-pustules over the occiput or temple in the pilary region. After alternately trying and tiring of all methods of treatment, the disease at last yields. Throughout all, from first to last, there is no sign of a formidable malady. When recovery has at last occurred, no trace is left on the body of the infective process. There has been no deep ulcer, no cicatrix, no permanent impairment of any organ or tissue. The disease, viewed in retrospect, has been perhaps a long but always rather an annoying than a dangerous affection. It may never have for a day prevented attention to the routine work of the sufferer. Had it not been for the incidental apprehension of the future, it would not have attracted serious attention nor demanded assiduous care.

Such, without any question, is the course of the majority of all cases of syphilis. It is claimed that, however mild these histories, each is liable to result in the graver forms of the disease, and that which determines the difference is treatment, always of highest importance. The most superficial study of syphilitic statistics, however, demonstrates that the majority of all patients, with the best, with the poorest, and without treatment, escape what has long been termed tertiary syphilis; in other words, do not exhibit the destructive types of the disease. The percentage of the latter to the former, in both hospital and private practice, has been estimated at the lowest at about seven per cent., at the highest at nearly thirty per cent. The corollary, therefore, is trustworthy that at the least two-thirds of all patients in all countries, and subjected to all methods of treatment or none (homœopathy, ignored cases, expectant treatment, "mind cure," etc.), escape the destructive ravages of the disease. It is upon this issue in the majority, and not upon the dreaded results in the minority, that the evolution of syphilis in the average of cases is to be predicated. Nothing that is here set down is to be interpreted in denial of the equally palpable fact that the mildest case of syphilis at the outset may become the severest in the end; that the patient fairly launched in the direction of benignancy may be mischievously turned in a different and more dangerous course; that scientific treatment of the disease furnishes one of the greatest triumphs of human ingenuity and skill. It is here intended merely to look at the results of the evolution of the disease, among all classes of men and in all countries, from the broadest point of view.

3. Malignant syphilis with relapsing or persistent profound symptoms.

A recent French writer has well distinguished between the syphiloma that resolves and that which degenerates. In this third category are included all patients exhibiting gummatous lesions that are either resolved and do not return, but leave serious consequences behind; or that are resolved and return later with serious consequences after either or all outbreaks; or that persist with no less harmful results. Here, too, are variations from the less to the more dangerous grades.

Any one of these conditions may develop after the patient has exhibited only such lesions as would justify his being classed in the category just considered. But it is highly important to note that all the symptoms here described and catalogued may succeed the chancre stage without intervention of milder symptoms, and also without an important interval of time. Early, indeed, after the chancre has healed, often before this last is completed, there are indications of the evolution of the disease toward a malignant type.

The "malignancy" of this class of cases is seen in the deterioration of the general system and the production of a syphilitic cachexia, without absolute destruction of the tissues of the body. Gummata that never ulcerate or degenerate may form in the skin, subcutaneous tissue, bones, periosteum, periarticular and articular tissues, mammary gland, testis, or other organ. By the production of pain; by displacement or mechanical effects; by a subtle influence, that is difficult of analysis, on chylopoësis, sanguification, or nutrition, and by interference with other functions, a disastrous influence is exerted that justifies the term malignancy in describing the course of the disease. Its effect is most striking when the structural lesions are few and not in themselves grave. A patient with merely a submaxillary lymphoma or periosteal gumma, or with an obstinate pachymeningitis producing injury by pressure-effects rather than by destructive action, may be in a graver physical state than another with a profound ulcer of the leg or of the throat.

In this category are to be found the smaller number of all cases of syphilis. It is pre-eminently the category of the transitory. They who have suffered from a syphilis trending along these lines, either by force of good management or as a result of the self-limiting energy of the disease, or the reverse of these, are readily transferred to the class just described or to that which is considered below.

4. Malignant syphilis with relapsing or persistent and profound lesions that are ultimately destructive.

In this category are classed all those patients who exhibit the worst phases of what is called by the French "tertiarisme," the symptoms which have made the disease to be dreaded as much as any of the pestilences that have visited destruction upon the human family, the histories which have engendered the popular and quasi-professional belief in the non-curability of the disease, those which have led philosophers to wish that the disease were one that kills, rather than one that can so frightfully mutilate without killing.

Here the resolving or disintegrating gumma opens an avenue to ulceration that pierces through connective tissue, cartilage, periosteum, and bone; to resorptive results which, when the gumma has disappeared, leave in its site shrivelled secreting cells, nervous, hepatic, renal, osteoid; that leave the testicle a shrunken miniature of its former self; that leave a sclerotic tissue in the place of brain cells or spinal cells, whereby one-half of the body loses its motor function, or a portion of the brain its ability to preside over the function of speech. Here, too, remote as are these formidable consequences on the time-schedule of the French school, all are obliged to admit that but a few weeks may intervene between the chancre evolution and the worst ruin. In a few days, while yet the induration of the chancre persists, the hard palate may be perforated as readily as the finger may be pushed through a sheet of wet paper; or a liver may be stuffed with ominous nodules; or the surface of the body ploughed here and there with deep and even gangrenous excavations where a gummatous infiltration has rapidly melted to destruction. It is true that for the most part these grave results occur between the third and fourth years after infection; but the facts of early appearance of so called late symptoms in syphilis are by none better attested than by the French themselves. It is they who have coined for science the phrases "malignant precocious syphilides" and those of similar import. It is they who freely admit that the malignancy and precocity are in these cases intimately associated. It may even be asserted as a fact that the majority of all truly malignant manifestations of syphilis are precocious to the extent of violating the old rule of tertiary syphilis as a sequel of an orderly and classically developed secondary stage. It is the characteristic of these dreaded devastations of the malady that they are early declared and rapidly evolved as extremely formidable types rather than as dangerous complications or perilous sequels of lues. Even with the chancre unhealed, the surface of the body may be in these cases riddled with sloughing cavities.

Between the four main lines of evolution briefly delineated above, there are to be recognized clinically innumerable variations in the direction of both mild and severe symptoms. That these types mutually merge and are to a degree interchangeable by the accidents of environment, constitutional influences, and treatment cannot be questioned.

An examination of the symptomatology in 96 cases reveals several points of interest. The organs affected were, in 47 cases, the derma, subcutaneous, and adjacent tissues; in 11, the bones and periosteum; in 11, the brain and cord; in 7, the soft and hard palate; in 6, the tongue; in 7, the testes; and in one each, the vulva, the eye, the kidney, the rectum, the muscles, the lungs, and the joints. Fournier, of Paris, reported before the International Congress of Syphilography and Dermatology in Paris, in the year 1889, the fruits of twenty-nine years of private practice in the French capital. In these twenty-nine years he had been able to study 2,600 cases of tertiary syphilis occurring in private patients. Some of his results were in the highest degree confirmatory of the important data of tertiarisme given above. But he also demonstrated that among 3,429 instances of tertiary manifestations, he had tabulated 1,085, or nearly 32 per cent. of cases, in which there was some involvement of the brain and cord. Haslund, of Copenhagen, has studied patients treated in the Communal Hospital of his city. Of 514 cases of tertiary syphilis observed by him there, there were 133 in which there was involvement of the nervous and other systems, or a percentage of the latter to the entire number of cases of 25; while the derma was implicated in 290 cases, a percentage to the whole of nearly 60. Among Americans the statistics of private practice indicate that the nervous system is involved in but a trifle more than 13 per cent. of all forms of tertiary syphilitic manifestations under observation; while the derma and its connections were implicated in about 60 per cent. of all cases.

The recognized elements of importance in grave syphilis are, first, the constitutional condition of the patient. Malnutrition from whatever cause produces a marked decrease in the weight of the subject; and it is also true of the excessive weight of patients who are more fleshy than the average, a class in private practice decidedly outnumbering the others.

Second in importance, and often indeed co-operating with the cause already named, may be named the agencies producing debilitating effects upon the system, including among men alcoholism and excessive tobacco usage. All other debilitating agencies (anxiety, affliction, overwork in business or profession), all that engender anæmia, loss of vigor, neurasthenia, are here properly included.

At the foot of the list should be placed complete absence of treatment, insufficient or injudicious treatment, and even intolerance by the patient of mercury.

Syphilitic Chancre (Initial sclerosis of syphilis; Hard chancre; Infecting chancre).—After exposure to the active virus of syphilis there is commonly a period of delay before the first perceptible symptoms of local infection occur. This period, usually described as the first "incubation stage," extends on an average from about sixteen to thirty days, but it is claimed that exceptional cases occur in which it may be as brief as two or three days only, or prolonged beyond the larger number days named above.

The resulting chancre which therefore, in acquired syphilis, points to an infection occurring within the month preceding its appearance, develops at the site of introduction of the germ of the disease, and may occur in many types according to its location and the accidents of its environment. There is no single lesion, the appearance of which invariably signifies that a chancre is present.

Every chancre is characterized: First, by the delay after infection before it appears (described above); second, by a characteristic induration, or hardness, of its base; third, by a coincident or succeeding enlargement of the glands in proximity to its site, the "syphilitic bubo."

A chancre may be either a modification of the normal tissue of the skin or mucous membrane, or a modification of any possible morbid condition, such as a cigarette burn of the lip, an excoriation of the mucous membrane of the genital or progenital region of either sex, etc.

In general, the clinical features of chancres correspond more or less closely to the following types:

1. *Erosions*, or superficial roundish or irregularly outlined macules, shallow losses of the superficial layers of the skin or mucous membrane, reposing on delicate beds of induration. The type of the latter is that often described as "parchment induration," the sensation it produces to the fingers of the surgeon, suggesting that a thin sheet of parchment has been let in under the excoriated surface. These may be pin-head- to bean-sized lesions, dry, or scantily secreting and slightly moistened, very rarely indeed, unless greatly irritated, degenerating into ulcers. For the reason that they may have an innocent aspect, they are often misinterpreted, but they should always be regarded as the precursors of syphilis when accompanied by the characteristic bubo of that disease.

They may be complicated by the occurrence of very considerable induration or may be transformed into large flat elevations of the surface, suggesting condylomata, but readily differentiated from the latter by their exceedingly dense induration; and when cauterized or otherwise improperly treated, they may even ulcerate, a change for which they have no aptitude when pursuing their usual career. They are occasionally represented by odd-looking ridges (along the corona glandis or at the rim of the labia minora in women); by thickenings of the membrane at the tip of the glans (urethral chancre); or by a firm and circumscribed thickening of a limited part of the upper or lower lip of the mouth.

2. The *dry papule* is of commoner occurrence on the skin of the body elsewhere than that of the genital region, as of the arm after intentional or accidental inoculation. The chancre is then a pea- to lentil-sized, dry, scaling, and indurated papule or papulo-tubercle, with dirty-grayish scales at apex or base. It is at times seen over the pubes, near the anus, on the integument of the pendulous portion of the penis, in the groin, etc.

3. The *ulcer* is decidedly the rarer type of chancre, and may be said to result invariably from some accidental interference with the normal evolution of the process occurring at the site of inoculation, such as pus infection, admixture with the virus of "soft chancre" (*q.v.*) or improper treatment. Both shallow and deep ulcers may form, each with sloping edges, never exhibiting the clean-cut, sharply defined edge of the chancroid. These ulcers are at times represented by indurated fissures or cracks. The so-called "Hunterian chancre" is a huge crateriform excavation of a densely indurated mass of sclerosis. This sore, which Mr. Hunter supposed to be the sole precursor of syphilis, is merely an altered lesion of one of the types already described. Other chancres of unusual type and appearance have been described as "diphtheroid," "herpetiform," umbilicated, "silvery spots," diffuse infiltrations, indurated nodules, annular and encrusted lesions, all these terms describing merely accidental modifications of the lesion occurring always with the three invariable characteristics already enumerated.

The "mixed" chancre is that in which the virus of both syphilis and the chancroid are commingled in the production of a lesion which at first assumes the aspect of the chancroid without the lapse of the usual incubative period of the infecting chancre; and later, after that period has lapsed, takes on the usual characters of the initial sclerosis.

THE STAGE OF INVASION OF SYSTEMIC SYPHILIS.—After the appearance of a chancre, from forty to fifty days usually elapse before the appearance of the first syphilitic eruption. This period may be shortened to three weeks; and, in exceptional cases, prolonged to several months. There is strong reason to believe that it may be prolonged under the influence of mercury. In it the chancre commonly progresses from complete evolution to involution; and, when there has been ulceration of that lesion, to cicatrization. Usually, also, when ten or fifteen days only of this period have elapsed, the adenopathy connected with the chancre has appeared and reached its full development. With the chancre healing or cicatrized, and with one or several of the neighboring glands, possibly their lymphatics also, in a state of painless induration, the concluding three-fifths of this period is one of apparent inactivity of the disease. It has been called for that reason a second incubative period of the disease. In the view of the inexperienced, the subject of the disease at this time may be possibly regarded as in a condition of health. Careful examination, however, reveals usually the following significant symptoms:

(*a*) *The Chancre Features.*—If the chancre be examined it will be found, if recognized at all near the conclusion of the period, either ulcerated, cicatrized, represented by a sclerosis, or preparing for transformation to a lesion of secondary syphilis. Sometimes a deeply ulcerated and formidable chancre persists as such till the complete evolution of secondary syphilis; oftener, before the date of such evolution, a previous ulceration has resulted in a tender cicatrix surmounting one of the several grades of induration which characterize the primary lesion. In yet other cases, without any distinct ulceration, the characteristic sclerosis of the disease persists (upon the genital region, finger, lip, etc.), ranging in bulk from a parchment-like thickening to a large nut-sized semi-solid mass usually freely movable upon the tissues beneath. Careful search for this sclerosis in every suspected region should be made in all first examinations of a patient at this period. In yet other cases the chancre is represented by an erosive lesion capping any form of sclerosis which, participating in the process of systemic evolution of symptoms, soon exhibits an elevated floor which may be covered with a whitish pellicle resembling the surface of a mucous patch, and be thus in fact changed to a true granulating mucous patch, the so-called transformation of chancre *in situ*. In all or any of such events, just prior to the evolution of secondary syphilis, there is often a marked, pathological activity of some sort in the chancre-site, the sclerosis becoming larger, the declining maculo-papule more vivid, the ulcer deepening or reopening, or the superficial erosion becoming a smooth, granulating surface with an opalescent pellicle spread over its area.

(*b*) *The Lymphatic Glands and Vessels.*—With very few exceptions one or more, usually several, of the lymphatic ganglia nearest the site of the chancre are found enlarged and indurated in this invasion period. From the tenth day after the appearance of the primary lesion to the conclusion of the invasion stage (that is, the date of appearance of the first syphiloderm) these symptoms persist. In general, it may be said that the first half of this period is required for complete evolution of the local adenopathy which in the latter half may be somewhat less conspicuous, but which yet often, at the termination of this stage, exhibits the evidence of pathological activity described above. In some cases the glands become swollen, tumid, and tender at the onset of general symptoms. The induration of the glands may persist afterward for months, the duration of the syphilitic bubo depending somewhat upon the treatment pursued. Suppuration of these indurated glands is very rare. The lymphatic vessels in anatomical connection with such glands may also undergo this specific induration, and be represented by dense quill-sized cords, single or multiple, reaching from the site of the chancre to the single lymphatic gland or cluster of glands which are superficially involved.

Besides this persistent indurated condition of one or several of the glands near the chancre site, noticeable in the invasion stage of general syphilis, there is usually appreciable toward its conclusion a remarkable and often suddenly occurring engorgement of the superficial ganglia. This symptom is not of local but of systemic importance. It is related less to the chancre than to the general oncoming syphilis. It is an early and almost constant symptom of general infection, often, as just described, particularly conspicuous prior to the evolution of the first syphiloderm; at other times, not fully developed till such early symptoms have been declared, and in both cases usually persisting for some weeks after its appearance.

Reference is made to a tumid and engorged, very rarely indurated, often softish condition of the chain of lymphatic glands extending along the posterior border of the sterno-cleido-mastoid muscle, or of the post-auricular, suboccipital, epitrochlear, or submaxillary glands. These glands, usually so small as to be scarcely recognizable by the finger passed over the skin, may increase till they are of the size of a bean or a small nut, and are even conspicuous to the eye of the observer. The two glands beneath the occiput are often very significantly enlarged in this way, irrespective of the occurrence of any lesion upon the scalp or vertex. This general engorgement of certain special lymphatic ganglia is often symmetrical, the glands, for example, behind one ear, or over the mastoid process, corresponding in size and firmness to those of the other side of the body. Occasionally this engorgement of glands in special regions of the body is proportioned in extent to the syphilodermata developed in continuous regions, of the scalp, for example, where the suboccipital ganglia are affected.

(*c*) *State of the Blood.*—Syphilis, though popularly known as a "blood disease," is actually one in which but few alterations can be demonstrated in the blood. Investigators have, by repeatedly counting the number of red blood corpuscles, determined that these elements, in certain stages of syphilis, are reduced from fourteen to fifty per cent. in number. With this decrease in the red blood corpuscles, there is relative increase in the number of leucocytes. This change is characteristic of the early stage only; it is especially noticeable just prior to the evolution of the first syphiloderm. In the period under discussion the micro-organisms which produce the disease are multiplying, and by the avenues of all the vascular channels gaining access to distant parts of the body; even to regions where later a gummatous product may form.

The chloro anæmia which is the result of systemic intoxication in syphilis occurs from time to time in most well-marked cases of the disease. It may be an early or late symptom, and in grave and so-called galloping cases is throughout a marked feature of the malady. In tertiary and ulcerative types of syphilis, it may depend more upon the local symptoms than upon the general condition, and, in some cases, is without question a resultant of the long-continued inroads of the poison upon the general health. Justus has shown that in the early stages of syphilis a decrease of from ten to twenty per cent. occurs in the hæmoglobin blood-content twenty-four hours after mercurial inunction of the skin.

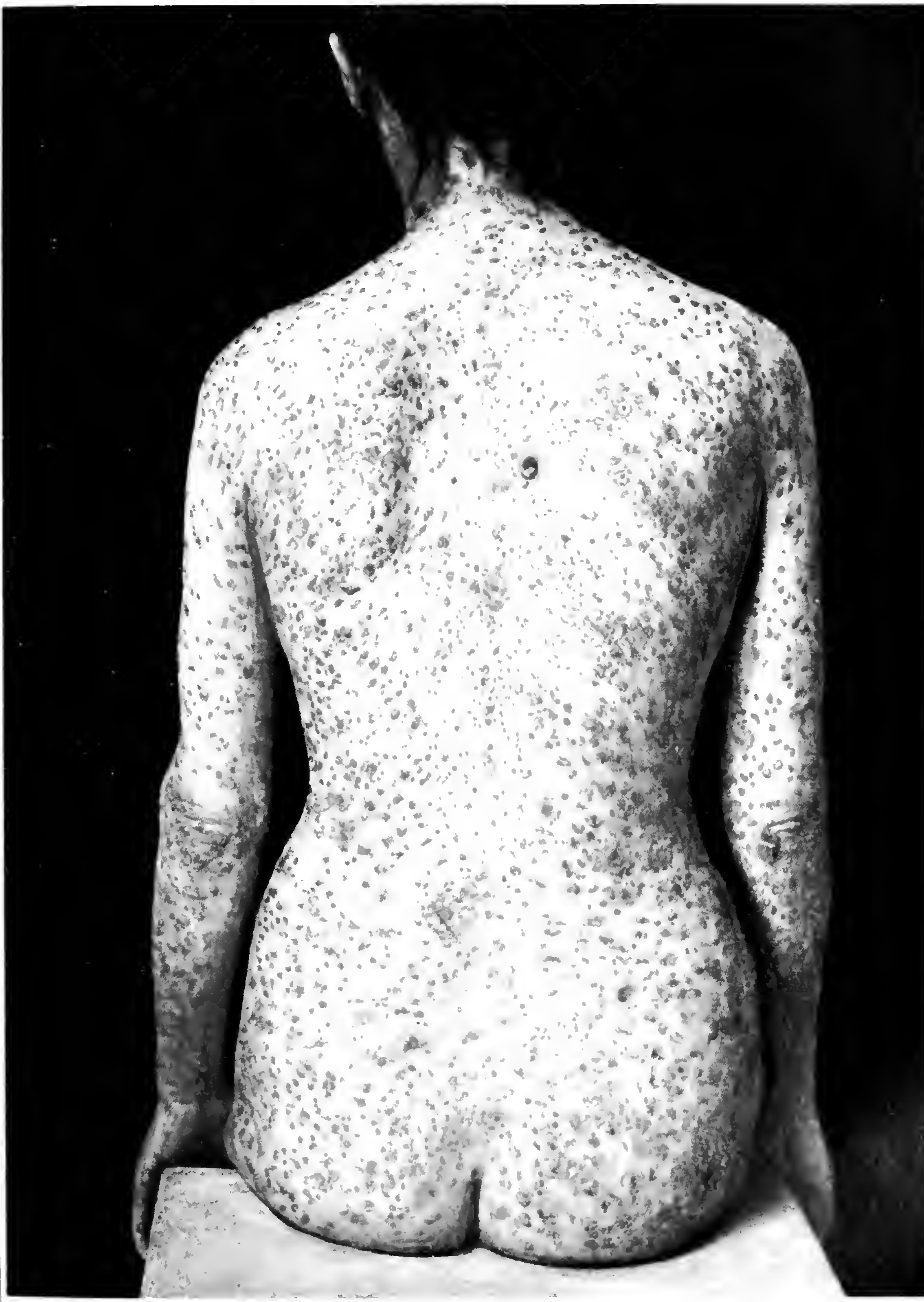
This chloro anæmic, anæmic, cachectic, or asthenic state is often conspicuous in the invasion period now under consideration, with mild or grave symptoms, particularly in persons of a naturally weak constitution, or in those prostrated by other previous disorders. Often, just before the appearance of the earliest syphiloderm the patient exhibits a pallor of the face, accompanied by a discolored, muddy, leaden, or saffron-like tint of the skin. With this there may be emaciation, weakness, and vague rheumatoid pains in different parts of the body (substernal, plantar, temporal, tibial, etc.). There is anorexia, and the patient will often describe his condition as one of "biliousness." In exceptional cases there is decided icterus, with yellowish conjunctivæ and urine of high specific gravity and heightened color. With this condition may be associated the ganglionic engorgement already described; the characteristic induration of the glands nearest the chancre; and the persistence of the initial sclerosis as a dense ridge, button, plaque, nodule, agglutination of tissue (digital chancre), or thin circumscribed sheet ("parchment" form of induration).

(*d*) *Syphilitic Fever.*—Recurrent, remittent, more or less persistent, and even intermittent elevations of temperature are of frequent occurrence in syphilitic subjects, more particularly in the early stages of the disease.

From one week to a fortnight before the first syphiloderm appears, with and without the icteroid, cachectic, or anæmic hue of the skin described above, the bodily temperature may rise to any point from 101° to 105° F., the lower figure representing the average of all cases where any such form is recognized by the physician, the higher temperatures often coinciding with a tolerably profuse first exanthem of syphilis. Usually this is a transitory symptom of the disease; but at times it persists for weeks. In cases, it is preceded by a sensation of chilliness or by distinct rigors. When remittent, the exacerbation is usually vespertine. There are commonly coincident thirst, malaise, *courbature*, and osteoscopic pains with headache and backache. In some cases, the febrile state is so insignificant as to attract no attention.

SYPHILODERMATA (Syphilides, Cutaneous lesions of syphilis).—The skin-symptoms of syphilis are numerous, widely different in type and career, and of the highest importance in the diagnosis of the disease. In any given case of syphilis, the greater number of skin lesions are displayed during the first two years after infection, that is, during the so-called secondary stage of the disease. They, however, occur often in grave forms in the late or tertiary period of syphilis.

General Characteristics of the Syphilodermata.—The skin-lesions of syphilis resemble the skin lesions of almost every non-syphilitic disorder, yet differ from the latter in certain special features. The study of these differences is essential to the recognition of the identity of the syphilitic exanthem. Their characteristics, generally considered, may be classed as follows: 1 Absence of subjective sensations. For the most part the syphilodermata are not accompanied by pruritus, or by sensations of burning, heat, pricking, etc. Notable exceptions to this rule may be found, but it is fairly constant of application, and due to the chronicity of the syphilitic exanthemata, their remarkable tendency to recurrence, and their striking amenability to treatment. 2. Career. The syphilodermata are rarely pyrexic; their course is essentially chronic; they are exceedingly liable to recur; and yet, as distinguished from the lesions of epithelioma and lepra, they are relatively rapid in evolution. They are greatly influenced by treatment, and are hence rarely seen when unmodified; but it is highly probable that all of them have, within variable limits, a cyclical career which would be pursued in most of the cases if no interfering agent modified their evolution. 3. Polymorphism. Multiformity of lesions—that is, the occurrence of multiple lesions of different elementary forms at one time upon the same person—is characteristic of several diseases of the skin, including syphilis. In the latter, papules, tubercles, pustules, ulcers, and maculæ may coexist upon the skin of an infected individual, who thus presents a striking contrast with the psoriatic patient, for example —the skin of the latter being often extensively covered with exclusively squamous lesions. 4. Color. The color of a cutaneous exanthem differs not only in different individuals of different color-type (blonde, brunette, African, etc.), but also in the same individual from year to year. This is true of the syphilodermata, the color of which exhibits the widest range of differences under different circumstances. Certain combinations, however, of the brown, the purple, and the duller hues of other colors are especially striking when seen in syphilodermata that are typical also in seat and configuration. The so-called characteristic color of the syphilodermata has been compared with that of raw ham and of coffee, shades which, when at all distinct, are highly suggestive. (See Plate LIII.) After complete involution of many of the syphilodermata, especially those seated on the lower limbs, the deeper pigmentations, suggesting chocolate, coffee, or ink in color, are often recognized. Most of these deeper tints are gradually and completely removed in the months or years that succeed complete involution of the lesion. 5. Contour. Many syphilitic lesions of the skin have a remarkable tendency to assume, wholly or in part, when grouped, a circular outline. This contour is often preserved when there has been both a grouping of elementary lesions and subsequent metamorphosis or degenera-



tion of the lesions thus grouped. In this way the figure of eight, the letter **S**, the dumb-bell, the kidney, and the horseshoe may be represented in outline by syphilitic papules in groups, ulcers, crusts, and even cicatrices. 6. Site. Any part of the skin of the human body may become the seat of a syphiloderm; and, indeed, the entire surface may be thus invaded, either by simultaneously evolved lesions or by rapid extension from one point to another. Syphilis may, however, affect for long periods of time a single region of the skin exclusively. This region may thus be preferred as the result of local irritation; for example, the palms of the syphilitic hand-worker, the uncleansed anal region of the syphilitic infant, and the mouth of the syphilitic tobacco-chewer. The so-called "corona veneris" is a group of dull-reddish, scaling papules on the forehead, which are peculiarly significant in male patients where the lining of the hat irritates the brow. 7. Amenability to Treatment. Mercury more particularly, and to a less extent the salts of potash after ingestion, are regarded by many practitioners as tests of the syphilitic character of any exanthem. There are few eruptions which amend under treatment of this character as readily as do the syphilodermata, but it is an error to conclude that the latter only are thus manageable. The great variability of the skin pictures in syphilis is largely due to modification by appropriate therapy. 8. Character of individual lesions. The scales of syphilis are rarely lustrous or nacreous; they are commonly small, dirty-gray, or darker in color, and rarely very abundant. Syphilitic papules are small or large, but often remarkable for a collarette of dirty, whitish scales surrounding their bases. The crusts of syphilis are apt to be dark-hued, in shades of deep yellowish, greenish, chocolate, and black, in consequence of the tendency of many syphilodermata to ulcerate and from the production in such ulcers of the pus and blood from which these colors are chiefly derived. The oyster-shell-like crust of rupia is wellnigh pathognomonic of syphilis. Syphilitic ulcers are prone to exhibit the circular outline, or traces of the reniform, figure of eight, letter **S**, and other shapes named above. The cicatrices left by such ulcers have necessarily a similar contour. They are, for the most part, smooth, supple, soft, and unattached. When recently formed, especially on the lower extremities, they are deeply pigmented in shades of chocolate and black. All, however, in time become white and lustrous, suggesting a thin sheet of mica when the centrifugal decoloration, which each very slowly undergoes, is complete.

THE MACULAR SYPHILODERM.—(*a*) *The Macular Syphiloderm due to Hyperæmia* (Erythematous syphilide; Syphilitic roseola; Exanthematous syphilide).—This is usually the earliest of the eruptions of secondary syphilis commonly appearing about forty-five days after the appearance of the chancre. It is developed in the form of symmetrically arranged, roundish, oval-shaped, or irregularly outlined, from the size of a split pea to that of a small coin, non-elevated, rosy, reddish-yellow, dusky red, or salmon-and-red maculæ, disappearing under pressure. Often at the outset this exanthem most resembles a slight mottling or marbling of the surface, and at times requires for its recognition careful observation on the part of the physician. It is probably more often unnoticed by the patient than any other symptom of syphilis, at times escaping observation entirely. It may be generalized, but is usually most conspicuous on the belly, loins, chest, and back. In well-marked cases the face (brow, temples, chin), back of the neck, and extremities, including the palms and soles, are conspicuously involved. It may be accompanied by the syphilitic febrile symptoms already described, substernal and other pains, engorgement of the cervical ganglia, mucous patches of the mouth, and other symptoms peculiar to this period. It may persist for a week and fade; or recur in fresh maculations. As the eruption survives, it is more persistent in color under the pressure of the finger. It is decidedly and promptly amenable to mercury. It is not to be confounded with the exanthematous fevers (the thermometer readily indicating the difference); nor with urticaria and the medicamentous rashes, which are more acute in type and accompanied by well-marked subjective sensations; nor with the yellowish patches of tinea versicolor, where a vegetable parasite is visible under the microscope. None of these affections exhibits the other signs of syphilis present in the person displaying the erythematous syphiloderm. The chief diagnostic danger, however, in this connection lies in ignoring, in certain cases, the special character of this indolent, scarcely appreciable exanthem, which rarely attracts attention by subjective annoyance, rather than in any difficulties in determining, after its discovery, to what special disease it is due.

(*b*) *The Macular Syphiloderm due to Pigmentation* (Pigmentary syphilide).—This exanthem occurs in an irregularly circular, ill-defined reticulum, of brownish or chocolate-shaded maculations, the color of which does not fade under the finger. Often there is unusual whiteness about the pigmentations, centrally or peripherally situated. Dr. Fox, of New York, has shown that after the central pigmentation develops there is a centripetal decolorization with deposit of pigment in excess in the interspaces of the original maculæ. The eruption is common about the neck and shoulders of blonde women. Illustrations of this condition in concentric circles of large pinhead-sized maculæ, alternating with rings of pigment, may be seen in Chinese subjects of syphilis. The lesions are obstinate under treatment, and are often included among the doubtful exanthemata of the disease. They are pigment anomalies, occurring in syphilis as in other diseases influencing the nervous centres.

THE PAPULAR SYPHILODERM.—The papule is the type of most of the syphilodermata. Many of the others are evolved from it; and it is probable that a large proportion of chancres and most mucous patches, condylomata, tubercles, and similar lesions are essentially papules which have been modified by the accidents of site, moisture, heat, etc. Syphilitic papules are circumscribed firm elevations of the surface, ranging in size from a millet-seed to a split pea. They may occur as the earliest cutaneous symptom of the disease in its earlier stage, or be developed from the macular syphiloderm described above. They may be small or large, pointed or flat, disseminated or in groups.

The Small Acuminate, Papular Syphiloderm ("Syphilitic lichen," Miliary papular syphilide).—This eruption appears in the form of pointed, firm, circumscribed papules the size of a pinhead or of a millet-seed, often copiously developed, with or without febrile symptoms, over the belly, chest, arms, back, and extremities, and usually in defined groups. The eruptive elements vary in color from rosy reddish to mulberry or purplish hues, differing widely in light and dark skins. Often the outer layer of the stratum corneum of the epidermis is slightly separated about the individual papule, which is thus surrounded by a faintly defined collar of scales. Often, also, when irritated they exhibit a minute vesicle, pustule, or scale at the apex. Where numerous, they are often symmetrical and very closely set together. Brownish-red blotches may follow their involution. The eruption may persist for months, and, with or without relapses, may appear in circular or semicircular groups, a ring of minute papules partly or wholly surrounding a confluent central patch.

The Large Acuminate, Papular Syphiloderm.—The small lesions described above may be, in special localities, developed to lenticular dimensions, retaining the conical apex. They may be seen on the back, shoulders, and chest as purplish-red rather than bright red papules, especially in the coarse skins of male patients. They may develop at the apex minute pustules, the involution of which leaves a small crust cap. They should not be confounded with iodic acne.

The Small Flat, Papular Syphiloderm.—This eruption is made up of roundish or oval, reddish to deep brownish, distinctly circumscribed and softish papules, from the size of a large pinhead to that of a split pea, and having a flat surface. They are often seen on the chest, face, buttocks, extremities, and palms and soles, and are frequently found near the mucous outlets, though decidedly less often grouped about the mouth and nose than are other lesions to be described later. They may be few, or developed in a copious exanthem. They may be covered with a thin seborrhœic crust, after the removal of which is exhibited one of the characteristic and almost indescribable color shades peculiar to syphilis, a lucent mixture of red, brown, and purple, suggesting the varnished section of a raw ham. They may be fringed or capped with scanty, dirty-yellowish scales. This eruption rarely occurs in cachectic subjects with a diphtheroid deposit over the papules, covering thus a granulating or superficially ulcerated surface.

Cicatrices seldom follow the involution of the syphiloderm under mercurial treatment. It commonly requires a week or ten days for complete development and, though occurring as an early syphiloderm, may relapse in any stage of the secondary period. Circinate groups, with an unchanged central area of integument, are rather more distinct in relapsing than in early forms of the exanthem. These are readily distinguished from psoriasis by the absence of the abundant nacreous scales of the latter disease, with a history of clearing, not of a primarily cleared centre.

The Large, Flat, Papular Syphiloderm.—This eruption appears in the form of distinctly circumscribed, vivid or purplish-red, flat or slightly globoid papules, discs, "buttons," or nodosities, from the size of a pea to that of a small coin, many of which distinctly exhibit the quality of color seen in a new copper penny. They may become scaly at the surface or the base, or become granular, moist, and secreting in these situations. They are insensitive, and rarely productive of pruritic sensations. The exanthem may be developed primarily, or be evolved from the macular lesions, or, very conspicuously and commonly, in the exanthematous period of syphilis, with a primary or relapsing and abundant crop of lesions in some special locality—the face (alæ of nose, forehead, mouth), palms, soles, axillæ, buttocks, and extremities. Upon the forehead these lesions may form the so-called corona veneris, glazed papules of coppery hue, arranged often in a line above the brows. They may develop an elevated rim and sunken centre; may ulcerate, especially in cachectic subjects or in localities subject to unusual moisture or irritation. Rarely gyrate and serpiginous lines of these papules are to be seen in special localities, *e.g.*, about the non-bearded lips and chin, or the axilla, where they may form rings. They are to be distinguished from isolated psoriatic patches, circinate in outline, (1) by their dull color, as distinguished from the more vivid hue of psoriasis; (2) by their scanty dirty-hued scales; (3) by the history and concomitant symptoms of syphilis.

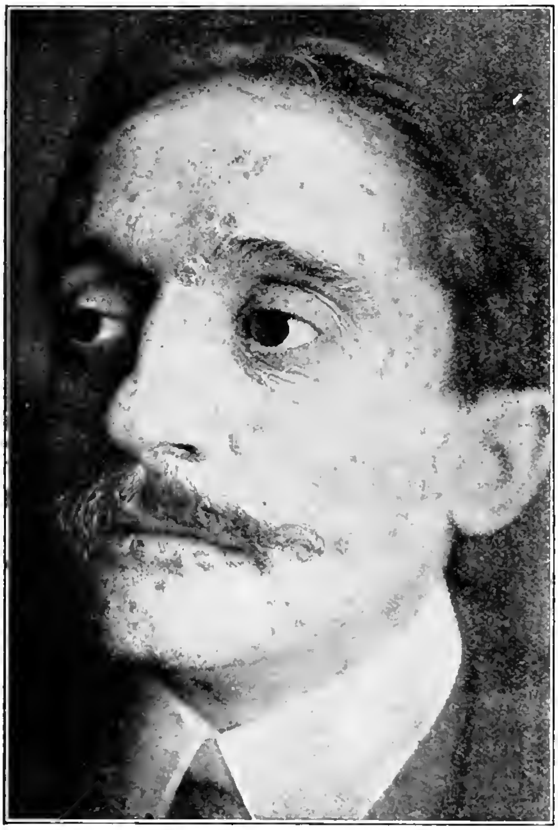


FIG. 4586.- Large Papulo-crustaceous Syphiloderm of the Face.

Syphilitic papules of all types may undergo any one of the following transformations, the features of which may often be recognized at one and the same time in the course of the disease:

1. The evolution of papules may, as a result of hyperplasia or vegetation, proceed to the production of the larger lesions recognized under various titles—warts, papillomata, condylomata, frambœsioid verrucæ, etc. In this way isolated or confluent, softish, warty growths, light or deep reddish in color, freely furnishing a secretion, often of nauseous odor, may cover large surfaces of the body or a single region only (scalp, anus, genitalia). These may be crusted from desiccation of the puriform mucus which smears them; in other cases ulceration ensues.

2. The evolution of the papules, as a result of the same processes in special situations, results in the production of broad, flat lesions. These are the results merely of an hypertrophic process occurring where mucous or cutaneous surfaces are in such close apposition that elevation of the lesion is restricted and lateral expansion only is possible. In this way are produced the condyloma, and the pinkish, whitish, and softish lesions known as the mucous patch of the skin, the vegetating mucous patch, *plaque muqueuse*, etc. They are well-defined, slightly raised, flattened discs, from the size of a bean to that of a large coin, their whitish color largely due to the muco-purulent secretion with which they are smeared, and which furnishes the characteristic, disgusting odor of these lesions. Heat, moisture, friction, perspiration, and neglect of the bath are fertile agents in their production in the axillæ, perineum, groins, the inner faces of the thighs, about the vulva, and elsewhere.

3. Papules may scale at apex or base, and the scaling become so significant a part of the process that the papular character of the lesion is almost disguised. In this way is produced the papulo-squamous syphiloderm. The scales are commonly scanty, desiccated, dirty gray in color, often attached, occasionally freely shed from the surface. Beneath them may be seen elevated papules having the so-called copper color, with the smooth, glazed surface of such lesions, or dull-red maculæ. Rarely the surface granulates.

PALMAR AND PLANTAR SYPHILODERMATA.—Syphilitic papules of the palmar and plantar surfaces are peculiar: (1) Because of the unusual thickness of the epidermis of the region affected; (2) because of the intermittent friction, contact, and exposure to which the organs are subjected. They may be early or late, transitory or peculiarly obstinate, and recurrent lesions. Careful inspection of the palms of the majority of patients exhibiting a copious macular exanthem will result in the detection of a few pea-sized discolored blotches in this region, which often are covered with a thin, slightly adherent scale. In greater approximation to the type of the average cutaneous papule, firm, circumscribed, dull-reddish, and distinctly elevated lesions, from the size of a large pinhead to that of a pea, are often seen in the same region. A variation from this type produces the dirty-whitish, corneous, epidermal masses embedded in the palms and soles like foreign bodies, and almost as readily separable. These are arrested forms of complete evolution of the syphilitic papule in the palms and soles. When progressing, unmodified by treatment, they become depressed and poorly defined in outline, coalesce so as to form circumscribed patches, from the size of a coin to that of an egg or larger, with newly developed outlying lesions. The next features are unquestionably impressed upon the patch by the traumatism and stretching of the infiltrated skin Scaling follows, centrally and at the periphery; fissures form in the lines of the furrows; ulcers develop, centrally situated, circular, oval, or stellate in outline. A purplish-floored ulcer is often seen here, its contour suggesting the fracture of a pane of glass. Recurrent and abortive attempts at reproduction of the palmar and plantar epithelium result in the formation of strata of ragged-edged epidermis, which irregularly fringe the deep losses of tissue. The entire palm or sole may be involved, and the process gradually sweep up to the wrist, instep, or ankle, and over the digits, affecting also the nails. The dorsal surfaces are occasionally involved, but always by extension from the palms or soles. Psoriasis limited to the palms and soles is of exceedingly rare occurrence; the specific lesions of this region are far more common, and are often accompanied by other unmistakable signs of syphilis with a history of infection. Squamous eczema is at times limited to the palms and soles, but, in the vast majority of all cases, affects the entire region, including the palmar faces of the digits, and is accompanied by itching. (See Plate LIV.)

THE PUSTULAR SYPHILODERM. — Pustules occur as early and late manifestations of syphilis, being, however, less frequently observed than the lesions just described. The purulent content may be sterile or contain the common pyogenic micro-organisms. The lesions are of the size of a pinhead to that of a bean, transitory or persistent, with mild or grave symptoms, and may originate as macules or papules, be isolated or grouped, scanty or abundant, and result in crusting, ulceration, and cicatrization. "Papulo-pustular," "pustulo-crustaceous," and similar terms are employed to indicate these mixed forms. Authors have also employed the phrases "acneform," "variola-form," "impetigo-form," "ecthymaform," etc., to designate the several varieties of the pustular syphilodermata. These terms are here purposely omitted, for the reason that the several diseases whose names are selected for comparative purposes are represented by lesions widely varying in the different stages of each disease, and exhibiting different features in different individuals. The phrases "syphilitic psoriasis," "syphilitic eczema," etc., are similarly discarded, as tending to contribute to the same confusion.

The Small, Acuminate, Pustular Syphilodermata.—The lesions of this class are of the size of a pinhead and larger, vivid or dull red, roundish, rapidly or slowly formed, and superficially seated, isolated, or wellnigh confluent pustules, which may be copiously developed in a general exanthem with syphilitic fever, or, more commonly, recognized in clusters about the regions where the pilo-sebaceous follicles are large and abundant. They may begin as macules or papules. The apex of each becomes yellowish-green as the pus forms, which may desiccate into minute crusts or may cover underlying ulcers of similar size. They assume at times circinate outlines. They are often seen on the scalp, face, neck, and trunk; rather less frequently on the extremities. Involution is often followed by rather persistent pigmentation; more rarely by minute atrophic scars.

The Large, Acuminate, Pustular Syphiloderm.—Yellowish-brown, conical pustules, of the size of a pea and larger, may develop slowly from the small lesions just described, or rapidly from maculo-papules. They are usually superficial in situation, become crusted at the apex, and, after the formation of the crust, may be depressed centrally Ulcers frequently form as the result of this process, the healing of which may leave small cicatrices. They form over the scalp, face, neck, shoulders, and extremities; and are usually the expression of either a graver form of syphilis or of a syphilis less judiciously managed than the lesions previously described

The Small, Flat, Pustular Syphiloderm.—This is a relatively frequent manifestation of syphilis, beginning by the development of circumscribed macules or maculopapules, which rapidly form flat, roundish pustules, the size of a pinhead and larger, superficial in situation. They are usually grouped, isolated, and at first not confluent; but their reddish and purplish areolæ become fused, and the whole is soon covered with a flattened, dirty-yellowish, and greenish crust, which commonly surpasses the limits of the patch. On the removal of the latter, a violaceous surface is seen, granulating, puriform, occasionally superficially eroded, possibly ulcerated. These lesions are often seen in and about the scalp, and about the lips, chin, beard, and trunk. In persons of weak constitution, and not properly treated, the face will occasionally be found almost completely covered by an irregularly crusted mask, formed in the manner described above, the pustulo-crustaceous lesions occasionally spreading in a serpiginous course, or forming the familiar rings, or segments of rings, seen in the grouped syphilodermata.

The Large, Flat Pustular Syphiloderm.—Pustules, the size of a bean and larger, deeply seated, or projected from the surface, may represent any of the forms described above, proceeding to full evolution, usually in cachectic subjects. They represent, also, the later periods of the so-called secondary stage of syphilis. Often they have dark red, deep, infiltrated bases with violaceous areolæ; and the pus finally desiccates into thick, bulky, greenish, or blackish crusts, firmly adherent to the edges of a foul-based, hemorrhagic, or pus-filled chamber beneath; or, after bursting, they leave open, sharply cut ulcers, with blood or pus freely formed from an exposed, eroded, sloughing surface. The ulcerative phase, with its crust, is indeed often the conspicuous feature of the process, the deep-seated pustular lesion which ushered in the mischief being thus speedily metamorphosed. These ulcers may be few or numerous, superficial or deep; and may be in outline circular, oval, semicircular, dumb-bell-shaped, etc. Their cicatrization commonly results in a typical syphilitic cicatrix.

RUPIA.—This term was at one time employed as the name of a distinct disease. It has long since lost any applicability to non-syphilitic disorders. Every rupia should to-day be recognized as syphilitic. Indeed, according to modern usage, the name merely describe certain peculiarities in the syphilitic crust. The explanation of its former temporary and unmerited elevation to the dignity of a disease supposed to have a separate entity is to be found in the fact that occasionally a patient will be extensively covered with rupioid crusts, who exhibits scarcely another symptom of syphilis.

The crusts thus named may be few and small, or large and generalized. First appear macules, then pustules, the contents of which desiccate into crusts of greenish, brownish, and blackish shades, covering and nicely fitted over underlying ulcers. The ulcer slowly spreads at the periphery, and its purulent and hemorrhagic secretions add by desiccation to the bulk of the crust. The additions are made beneath and laterally to the under surface and edges of the closely adjusted crust, which hence becomes a conical, stratified shell, usually with a slightly concave inferior surface, the whole often compared to an oyster shell. Each succeeding stratum of incrustation, from the conical apex of the crust to its base, represents, therefore, a somewhat larger ulcer and a somewhat more abundant secretion. There may be an outlying violaceous areola. The indolently spreading ulcers beneath correspond in size to the shells which cap them. They may be superficial or deep, but usually have a foul, purulent, or hemorrhagic floor, and punched out edges. Grave as is the condition of the patient who is extensively covered with the largest-sized rupioid lesions, the best of results may be anticipated under proper hygienic management and energetic treatment.

THE VESICULAR SYPHILODERM.—Vesicles are rarely the results of the syphilitic process in the skin. They usually point to an exudation more acute in type than that recognized in the indolently traversed cycle of syphilis. Occasionally miliary papules exhibit a vesicular apex containing a droplet of serum. Circinate and other groups of vesicles are described by French writers as of occurrence in this disease. Two explanations of the so-called vesicular lesions are at hand: first, the development of eczema, herpes, etc., in infected persons—phenomena not rarely observed by an expert; second, the occurrence of vesicular lesions provoked by extensively applied or internally ingested medicaments employed for the relief of the systemic disorder.

THE BULLOUS SYPHILODERM.—Discrete, roundish bullæ, from the size of a pea to that of a small egg, appear simultaneously or in crops upon the syphilitic skin, in consequence of a more or less circumscribed elevation of some portion of the epidermis by accumulation of a clear lactescent serum, pus, or blood. The contents usually desiccate into bulky, adhesive, stratified, greenish or dark colored crusts, which may cover granular, eroded, or ulcerative surfaces. Often they are surrounded by a violaceous halo. The ulcer, after removal of the crust, may spread in depth or area, or cicatrize; this according to the vigor of the patient and the treatment pursued. Lesions of this sort are rather more often recognized upon the extremities than elsewhere, in consequence of the greater distance of the latter from the centres of circulation. They are more often encountered in late

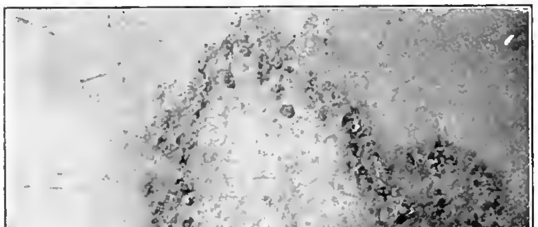


FIG. 4587.—Serpiginous Tuberculo-ulcerative Lesions of the Skin of the Back.

periods of the disease, and in cachectic subjects. They are for these reasons most often seen in the tender skin of the infant who is the victim of hereditary syphilis.

It should not be forgotten, when making a diagnosis of the bullous syphiloderm, that the iodide of potassium, in exceptional cases, is capable of producing such lesions in typical aspect when administered to the syphilitic as well as to the non-infected patient. American observers chiefly have called attention to this important fact, among them Drs. O'Reilly, Graham, Morrow, and the author.

THE TUBERCULAR SYPHILODERM.—Hyperplastic evolution of the papule, besides producing the aberrations from type already described, may also result in the formation of definitely circumscribed, deeply-seated, single or multiple, bright-reddish or livid, solid, cutaneous or more commonly subcutaneous, lesions, from the size of a pea to that of a small egg, known as tubercles. These are usually late syphilitic symptoms, which, in consequence of difference of involution, are divided into two classes.—the resolutive and the ulcerative.

The *resolutive tubercular syphilide* is characterized by slow evolution without marked subjective symptoms, disappearance after absorption of the plastic infiltration commonly involving the entire thickness of the derma, and the production, without previous ulceration, of an indelible scar. The lesions begin as superficial, reddish, and roundish gummatous nodules, the size of a pinhead, which, as they attain the larger dimensions named above, become flatter, smoother, more lustrous, and more deeply tinted. They are largely facial or cervical in situation, but may also spread over the trunk and extremities. They are often free from scales, except when seated upon the palms or soles, in which situations they may be covered with thick corneous plates beyond the borders of which can be recognized a violaceous halo. These lesions may be generally disseminated, or grouped in distinctly circumscribed patches, either circular in outline or exhibiting some modification of the latter (*e.g.*, the reniform, horseshoe-shaped figure, etc.). The former are the earlier; the latter the later, of occurrence.

When facial in situation, the tubercles may spread in a fan-shaped area over the forehead, or extend over the bridge of the nose to the cheeks, assuming the figure of a butterfly. The thinned, atrophic centre and elevated rim of the patch may then be significant.

An exaggerated grade of confluence and proliferation of these tubercles results in the hypertrophic, leontiasic, or vegetative syphiloderm. In these instances the nose, the chin, the ear, or some other part presents an enormous increase in bulk, with definitely distinguished lobules separated by furrows, the picture presented strongly resembling the elephantiasic condition. Again, a voluminous verrucous growth may spring from some portion of the scalp, and even in the end encroach upon a large part of that region, the warty mass freely projecting comb-like masses from the surface, smeared often with a puriform and offensive secretion (frambœsia syphilitica, papilloma syphilitica, etc.).

The *ulcerative tubercular* (*tuberculo-ulcerative*) *syphiloderm* is a somewhat later manifestation of the disease, or one which, developing as it does rarely within a few months after the evolution of the chancre, occurs in neglected, untreated, cachectic, or so-called "galloping," cases. Here also the lesions appear upon the face, trunk, and extremities, with the general characteristics already described, but more commonly in definite groups. Instead of undergoing, however, the atrophic changes observed in the resolutive form, a portion, rarely all, of the tubercles forming the patch, soften or become covered with a greenish or blackish crust from desiccation of the ichorous or sanguinolent liquid furnished by the breaking down of the gumma, beneath which an ulcer forms somewhat larger in size than the lesions from which it sprang. In this way the face may display over the chin, forehead, or cheeks a dense tumefaction composed of a group of closely agglomerated, livid papules, ulcers, and crusts, the size of a pea, or a distinctly outlined ring of such lesions disintegrating at the periphery and surrounding an atrophic, cicatricial, or even ulcerated central area. Gangrene and phagedena very rarely complicate these destructive processes. The ulcers which form are

of a typical syphilitic aspect, with pultaceous floor, steep, "clean-cut" edges, ichorous secretion, and serpiginous tendencies.

Mixed forms of commingled resolutive and ulcerative tubercles are not of rare occurrence. The following are

FIG. 4588.—Enlarged Portrait of Group of Lesions shown in Fig. 4587; showing Peripheral Extension by Multiple Circumscribed Ulcers.

common clinical pictures: A patient, from five to ten years after infection, has the forehead, nose, and cheeks fully covered with numerous, firm, smooth, shining nodules, the size of a pea, vivid and dull red in hue, occupying an infiltrated integument of the same general color. Some of the tubercles are slightly crust-capped, others are irregularly excavated as if wasting at such points. Between them are distinctly defined, atrophic, non-pigmented depressions from the size of a large pinhead to that of a pea resembling youngish scars. These are spread with some regularity between young and mature tubercles even at the scalp border and among the hairs over the tip of the nose and well over the cheeks. Uneven and verrucous patches may indeed occupy distant portions of the scalp where hairs have fallen from an atrophic area. Sometimes they undergo colloid degeneration. Attention is particularly directed to this complexus of nodules, crusts, atrophic discs, minute ulcers, and scanty pustules when occurring in this region, as it is a feature very rarely seen in any other disease than syphilis.

In most of these cases the changes wrought in the course of time after the employment of an appropriate therapy are marvellous. The violaceous tint disappears; the scars, if any have resulted, are transformed into thin superficial uncolored or dead-whitish inconspicuous blemishes; the natural fat of the panniculus adiposus is restored; and, even in middle life, after the fullest grade of evolution described above has been reached in the face of a woman, a fair degree of comeliness is restored.

Lupus vulgaris is distinguished from this condition by its onset at an earlier period of life, its far narrower limitations, its greater asymmetry, its profounder and more disfiguring scars, and its much more indolent career. The tubercles of lepra producing the characteristic leontiasic aspect of the face are far more chronic in evolution, more deeply pigmented and "varnished," less often ulcerated, crusted, and commingled with scars. The pearly, milium-like nodules of epithelioma are quite unlike the tinted tubercles of syphilis, are never so numerous, and the smooth-glazed, bright red, and scantily secreting floor of the epitheliomatous (rodent) ulcer never suggests the foul excavations of syphilis. Psoriasis is always scaly, never ulcerative in type, never crusted nor pustular. The most difficult cases for differential diagnosis are those of hypertrophic acne of the nose, with gaping orifices of sebaceous ducts whence comedo plugs may have been expressed, interspersed between dull reddish acne papules. Here the history of the case, the absence of scalp-lesions, the stricter limitation of the patch to the tip and alæ of the nose, the absence of a distinct ulcer, and the conspicuously smaller size of the scar-like depressions, usually furnish a clew to the distinction sought to be established.

The blastomycotic patch is almost invariably distinguished by its characteristic encircling border or wall, on the sound side of the integument sloping gradually to the level beneath, studded with exceedingly minute pin-

FIG. 4589.—Tubercular Syphiloderm of the Shoulders, showing Scars and Pigmentation.

point-sized abscesses, in the contents of which can readily be distinguished the double contoured organism with its lucent lenticular space within.

THE GUMMATOUS SYPHILODERM.—Single and multiple, isolated or massed nodules, from the size of a pea to that of an egg, or larger, originating simultaneously, but commonly invading the skin as they develop, occur in late, rarely in early, periods of syphilis, and are termed gummata in consequence of the gummy material they furnish when disintegrating. They are rarely numerous, often not more than from two to six affecting a single patient. As an exceptional fact, hundreds may be seen covering different regions of the body. They are peculiar to syphilis; in other words, they do not pursue, in the course of other affections, the same classical cycle of evolution and involution. Yet they are really syphilitic tumors, allied, on the one hand, to the hyperplastic process which produces the papule and tubercle, and, on the other, to the histological type of tumors in general. Pathologists have some ground for believing that the so-called gummous material of this lesion is to be recognized in the nodules that glue the iris to the capsule of the lens, and even in the neoplasm that constitutes the mass of the initial sclerosis.

FIG. 4590.—Gummatous Ulcer Simulating "Rodent Ulcer," near the Root of the Nose.

After development, gummata may for a long period of time be perceptible beneath the skin as smooth, circumscribed, insensitive, firm nodules, undergoing no change. Later, they become slightly painful; there is passive hyperæmia of the overlying skin; attachment between the skin and the tumor is effected; then follow, usually, fluctuation and evacuation (spontaneously or by surgical interference) of inspissated blood and pus, or of the contents of a true, circumscribed abscess. The gummatous mass constituting the tissue, bathed in pus and blood, is slowly or rapidly removed by this process, in the course of which is formed the gummatous ulcer. This has the circular outline, precipitous edge, sloughy floor, foul secretion, livid halo, and phagedenic tendencies already described as characteristic of the syphilitic ulcer in general, with this special added feature, that it is particularly deep. Its floor rests on subcutaneous tissues. It may involve fasciæ, periosteum, muscles, large vessels, bursæ, nerves, bones, tendons, and other important tissues. Its walls, carefully inspected, often exhibit the sharp and resisting edge of a dense aponeurosis, the glistening white border of a tendon, or the firm periosteum sheathing an osseous plate.

Occasionally gummata are lodged in, rather than beneath the skin, the firm, movable mass being then readily defined by palpation. Whether superficial or deep in situation, they may undergo complete resolution. When disintegrating by ulceration, they may go on to produce those extensive and formidable losses of tissue, complicated with erysipelas, pyæmia, etc., in the subjects of cachexia and alcoholism, which make syphilis, in some of its manifestations, a veritable scourge. Though occasionally numerous, not more than from six to eight are usually to be recognized in the person of a single patient. They are most frequently developed upon the lateral surfaces of the legs, and, next, proportionally after these, over other parts of the extremities, the face, scrotum, buttocks, neck, and the breasts of women. The importance of their recognition in the last-named situation, when the question of cancerous and other malignant tumors of this organ is presented for consideration, can scarcely be overestimated. The author has seen a gumma the size of a turkey's egg in the breast undergo complete involution under specific medication only.

The elephantiasic aspect of the face and legs of certain patients who are afflicted with extensive gummatous tumors and infiltrations of the cutaneous and subcutaneous tissue is a matter of great moment for the diagnostician. In almost every community there is some such patient, with a striking deformity, the nature of whose malady has been altogether unknown for years. In such cases there is often an obscure history, which, perhaps, the expert alone has been able correctly to interpret. The patient has been supposed to be the victim of "elephantiasis." The nose, lips, cheeks, and chin are possibly densely thickened, distorted, empurpled, and irregularly ridged and seamed with nodules, scars, and ulcers; or the leg is in the pachydermatous condition seen in the "Madura foot" and other diseases. It is a large, unwieldy organ, ridged, of cartilaginous hardness, furrowed, and covered with an integument looking like the

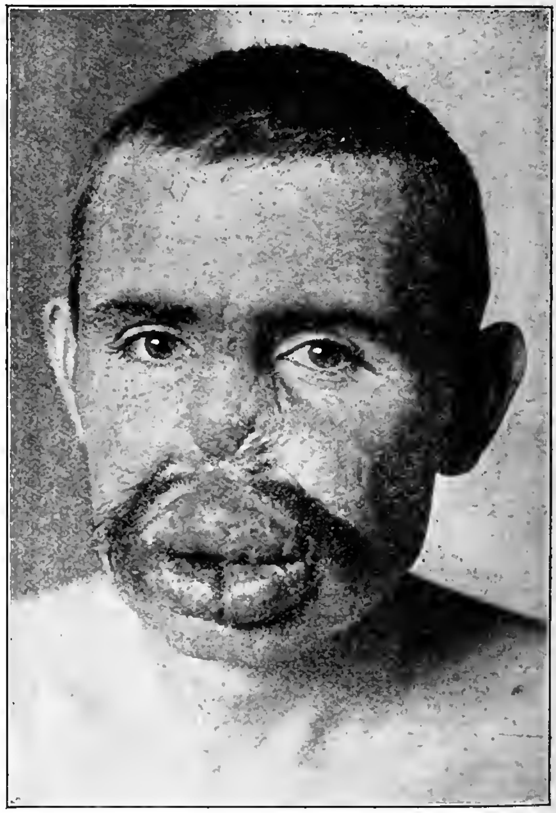


FIG. 4591.—Gummatous Changes in the Face Simulating Lupus Vulgaris, Resulting in Occlusion of the Nares.

bark of a tree. Careful inspection, however, always reveals in this mass the typical cicatrices of ancient gummatous ulcers, and the traces of new and old nodules buried in the hypertrophied and œdematous mass. Here, as in so many other of its formidable aspects, syphilis reveals its amenability to proper management. The changes that can be wrought by treatment in these apparently desperate cases are in a high degree satisfactory.

The Serpiginous Syphiloderm.—Though not distinguished by the name of an elementary lesion the preponderance of which might justify such a position, this syphiloderm has an individuality requiring separate consideration.

In its superficial forms the serpiginous syphiloderm is preceded by the appearance of small, pointed or flat syphilitic pustules, which form a circular or partially circular group of lesions in discs of the size of an egg and larger. These discs are soon covered with a yellowish, greenish, or blackish crust, which gradually clears from the centre, leaving there a granulating or smooth, reddish or normally tinted, atrophic or only superficially altered integument, surrounded by an entire or broken ring of attached crusts, beyond which is a livid halo. Underneath this latter is a superficial, centrifugally spreading ulcer, uniformly annular in contour, or here and there broken by bridges and islands of unaltered skin. Often this annular ulcer is seen to be composed of roundish excavations, the size of a pea and larger, arranged circle-wise, with confluent crusts. In other cases the crust is scarcely more than a narrow ring, no broader than the smallest penknife blade, which, as it spreads centrifugally, leaves cutaneous areas of former invasion the size of the palm and larger, pinkish-red or slightly pigmented in color, at times decidedly cicatriform, at other times texturally unaltered. In this way an entire buttock or limb, or the face, may be progressively involved.

The deep serpiginous syphiloderm generally spreads from a gumma or other late lesion of syphilis. A deep ulcer results, which attacks the subcutaneous tissues. The centre is soon represented by a tender or firm scar; the advancing edge by a thick, greenish or blackish, adherent crust, covering a deeply cut circular exulceration with punched-out walls and foul secretion. The dull, purplish areola of all similar lesions is visible at the periphery beyond its advancing edge. Its progress over the skin is decidedly more serpiginous than in the direction of the radii of a circle. Here and there a kidney-shaped or horseshoe-shaped edge exhibits a deeper excavation, or a more tenacious, bulkier, and darker crust. In yet another part of the same disc the ring may be represented by a partially cicatrized border, or by a wide bridge of unaffected skin. This is a late, exceedingly obstinate, and intractable form of syphilis, leaving generally a deforming scar. It is to be distinguished from lupus vulgaris (which is more often seen on the face) by its definite outline, its deep pustular, rather than nodular, elementary lesions, its sharply cut ulcerations, but, above all, by its relatively much more rapid progress.

Malignant Syphilodermata.—Syphilitic cutaneous and subcutaneous lesions are at times malignant in type, and then commonly precocious in occurrence and acute in course. They are described by Bazin and other French authors as "malignant precocious syphilides." The intensity and violence of the symptoms in these cases is in general due to the occurrence of the disease in cachectic subjects, those who are debilitated by age or previous or concurrent diseases, those deprived of the essentials of healthy living, viz., wholesome food and drink, hygienic environment, freedom from mental anxiety, and a proper adjustment of labor to bodily vigor.

In patients of this class the chancre is scarcely cicatrized before symptoms threatening malignancy appear. They are divided by most authorities into (*a*) the puro vesicular syphiloderm; (*b*) the tuberculo-ulcerative syphiloderm; (*c*) the gangrenous tuberculo-ulcerative syphiloderm. These names are mainly groups of symptom phrases, the lesions themselves exhibiting a wide variation indicated by both mild and grave characters.

The milder forms are really rupioid lesions following isolated or grouped pustules, which are rapidly followed by ulcers, thickly covered with laminated crusts. In certain cases, when the disease has progressed for long periods of time, the resulting keloid like scars are both extensive and disfiguring. (See Plate LV.) In a more accentuated form the malignancy of the outbreak is indicated by the development of blebs or lenticular tubercles, which hasten to break down into ulcers of characteristic syphilitic edge, secretion, floor, base, and areola, which attack the face, trunk, hands, or extremities. The graver

Fig. 4592.—Extensive Gummatous Ulceration of the Left Arm, with Production of Keloid in Cicatrized Portions.

forms are tubercular, ulcerative, and gangrenous. A group of nodules in or beneath the skin surrounds itself with significant purpuric points, supposed to indicate an endarteritis of the peripheral vascular elements. The whole rapidly or slowly becomes gangrenous, showing a dry, blackish eschar, which spreads at the periphery, and insidiously, as it encroaches upon the sound tissues in the vicinity. Sometimes a line of demarcation is formed, not between the gangrenous mass and the sound skin, but between the former and a thickened empurpled zone which surrounds it. When the slough is removed, a conical crateriform ulcer is exposed, having a fetid secretion, a sloughy floor, and markedly everted edges. The destructive process may progress till fatal results are produced, the patient succumbing to fever or marasmus and adynamia. But this is rare. Under the best treatment repair sets in, granulation is followed by cicatrization, and there is apparently complete restoration of the general health.

Cutaneous lesions and symptoms other than the forms described above are neither numerous nor important, but have been described by authors. Bronson, of New York, has described an erythanthema syphiliticum in which vesico-pustular and other lesions were grouped upon an erythematous base. Hemorrhagic effusions within the skin occur chiefly in patients who are the subjects of hæmophilia, and who have also contracted syphilis; in children afflicted with hereditary syphilis; in patients with paraplegia resulting from syphilitic involvement of the cord (purpura of the lower extremities); and as an accident of a number of secondary and tertiary lesions. The author has seen two such cases occurring in syphilitic disease of the cord. It should be remembered that the iodide of potassium, when administered for the relief of syphilis, may produce purpuric spots, especially over the lower extremities.

Lastly, eczema, psoriasis, the animal and vegetable parasitic affections of the skin, pruritus, and the various dermatites, all the forms of acne due to the ingestion of the iodic compounds, and other cutaneous disorders, affect the syphilitic as well as the non-syphilitic patient. Each of them exhibits its special peculiarities, apparently not at all or very slightly modified by the syphilitic infection, and is recognized in its identity as distinct from the manifestations of syphilis without great difficulty on the part of the diagnostician. This recognition is a matter often of the highest moment, as the anxiety and dread occasioned in many patients by the discovery of these intercurrent affections (to which the mass of mankind is subject) are out of all proportion to the real import of the symptoms presented in such cases.

Treatment of the Syphilodermata.—The internal treatment of the syphilodermata is that of syphilis in general, including the use of mercury, the iodide and other salts of potassium, iron, cod-liver oil, and a nutritive regimen.

Many of the lesions, however, require local treatment. The salves which are most effectively used with this end in view contain one of the salts of mercury. Among these may be named the ammonio-chloride, in the strength of from five grains to two drachms to the ounce (0.33 to 32.0); the red oxide, in the strength of from five to ten grains (0.33–0.66) to the same quantity; the ten or twenty per cent. oleate of mercury; the mild chloride, in the strength of from ten to thirty grains (0.66–2.0); mercurial ointment, in the strength of from half a drachm to a drachm (2.0–4.0) to the ounce; and the ointment of the nitrate of mercury in nearly the same strength. The bases of these salves may be vaseline, cold cream, lanolin, or simple cerate, a drachm (4.0) or more of glycerin being added to the ounce (32.0) of each when requisite to produce softness in the mass. Vaseline is preferably employed as a basis for salves to be applied over the scalp and hairy parts.

The tars also are often employed with advantage, including the oleum cadini and the oleum rusci (rectified or crude), in the strength of from half a drachm to a drachm to the ounce (2.0–4.0 to 32.0) of basis, adding an equal quantity of finely levigated prepared chalk to obtund the sharpness of the tar. These are excellent applications to palmar and plantar syphilodermata, when preceded by maceration of the affected surfaces for several minutes in water as hot as can be tolerated. Often the thick epidermal scales of these regions are best removed at the time of these macerations by the aid of a shampoo prepared by adding an ounce of glycerin to two or more ounces of the tinctura saponis viridis of the Pharmacopœia. After the shampooing with hot water, the hands or feet are dried, the salve well rubbed in, and gloves are drawn over the hands, or stockings over the feet. Other ingredients are often incorporated with such salves with excellent effect. Among them may be named salicylic acid, ten to twenty grains to the ounce (0.66–1.33 to 32.0); chrysarobin, pyrogallol, and ichthyol, in the same strength; zinc oxide and the subnitrate of bismuth, half a drachm to a drachm to the ounce (2.0–4.0 to 32.0); and the oleate of lead, in the form best known as Hebra's unguentum diachyli albi.

Powders occupy a most important place in the local management of the syphilodermata, more particularly those that are ulcerative in type. Among them may be named europhen, iodoform, iodol, aristol, hydronaphtol (one part to fifty of fuller's earth), boric and salicylic acids, calomel, starch, camphor, and lycopodium. Many of these are advantageously employed over such moist lesions as condylomata after they have been washed in a lotion of chlorinated soda or carbolic acid, so as to be not only deodorized but thoroughly cleansed.

Lotions of the kind just suggested are useful in the management of a number of the secreting syphilodermata. Others are compounded with the corrosive sublimate, one-half to one grain to the ounce (0.33–0.66 to 32.0) of bay rum, cologne water, or the rectified spirit of wine. Lotions containing tar, salicylic acid, carbolic acid, and boric acid (often in saturated solution) meet the indications of many cases.

For the purpose of stimulating or otherwise dressing mucous patches and indolent ulcers, solutions of the nitrate of silver, five grains to a drachm to the ounce (0.33–4.0 to 32.0), or crayons of the solid salt may be used; or even the strong caustic solutions, *e.g.*, of the hydrate of potassium twenty to sixty grains to the ounce (1.33–4.0 to 32.0), or of nitric acid. Solutions of corrosive sublimate in tincture of benzoin, or of myrrh, one to two grains to the ounce (0.066–0.033 to 32.0); benzol, creosote, and solutions of the permanganate of potassium and resorcin, one to five per cent., are also useful in many cases; the first two for destructive effects, the last as antiseptic dressings.

Many of the syphilodermata are effectively treated by the modern methods of radiotherapy (exposure to the *x*-ray). The duration and frequency of the exposures, together with the precautions needed to avoid the serious consequences of improper use of this effective and often proportionately dangerous agent, are governed by the rules formulated in experience acquired by treatment of non-syphilitic cutaneous affections by the same method. We have reserved the application of the rays to obstinate chronic engorgements of the skin, such as are occasionally recognized in the palmar and plantar syphilodermata; and to some of the persistent mucous and scaling patches of the lining membrane of the mouth.

The principles on which should be based the local treatment of the syphilodermata are those recognized in all similar non-specific affections of the skin. Of chief importance is the treatment of the disease itself, whether by internal medication, inunction, fumigation, or hypodermatic injection. To this, in most cases, the local treatment may be added with marked advantage. The scalp, hands, and feet may be often shampooed, and subsequently dressed with a salve or lotion. Pustules are to be opened, crusts removed, and small or large ulcerated surfaces cleansed, cauterized, or stimulated, and antiseptically dressed. Soap and water are as imperatively required for the syphilitic as for the non-syphilitic skin. Frequent applications of water as hot as can be tolerated are often required for the relief of pain, and the surgeon's knife is needed for opening softened gummata. In extensive syphilitic ulcerations an exceedingly valuable resource is the use of the continuous hot-water bath as employed in Vienna, the patient, if his ulcers can be in this way immersed in the water, remaining in it for hours, the bath being kept as hot as is grateful to the surface of the immersed skin. The bath is left only on occasions requiring evacuation of the contents of the bladder or of the rectum, or in order to secure sleep. Lastly, the mercurial, rubber, lead, and other surgical plasters, borated cotton, antiseptic lint, and wool (medicated with the mercuric iodide), prepared oakum, fuller's earth, and the other articles needed to make the dressings of modern surgery, are never more useful than in the management of multiple or extensive syphilitic ulcers.

Affections of the Hair, Hair Follicles, and Hairy Regions of the Skin.—A common manifestation of syphilis is a loss of hair, in excess of the physiological defluvium capillitii, resulting in alopecia. This

LATE SYPHILITIC ERUPTION (ULCERS) PRECEDED BY BULLAE, IN A CACHECTIC SUBJECT.

PHOTOGRAPH TAKEN A FEW DAYS BEFORE THE DEATH OF THE PATIENT.

(From the Collection of Photographs of Skin Diseases belonging to Dr. John A. Fordyce, of New York.)

may be an early or a late symptom, rapidly or slowly occurring, scarcely perceptible or greatly deforming, and transitory or resulting in permanent baldness.

The earliest form of alopecia may occur without local subjective or objective sensations, the symptoms being often limited to the loss of hair. It may again be accompanied by macular, pustular, papular, ulcerative, or crusted lesions of the regions affected. It may appear as early as the date of the first syphiloderm, and, indeed, may be the first significant or even the chief feature of general syphilis. In other cases it is conspicuous only after the third or later month of infection. It may affect any hairy region of the body, but is more commonly noticed on the scalp, beard, mustache, eyebrows, and lashes. Upon the scalp, it is probably much more common of occurrence than of observation, since it is often first recognized in men only after the hair is cut short.

The hair may appear to be merely thinned in syphilitic alopecia, when the pilary loss is actually conformed to type. The close-shaven head of the syphilitic, affected with the early form of alopecia, presents almost always the same appearance. The scalp is then seen to be covered with irregularly circular areas of baldness, symmetrically arranged as regards the two halves of the body, these areas varying in size from a split pea to a small coin. There is asymmetry, however, in the disposition of individual patches. The scalp thus affected may be apparently sound, or dry and lustreless, or, as described above, the seat of a syphilitic exanthem. When the hair is long, as in women, the striking disfigurement visible on the shaven scalp is scarcely apparent; in men whose hair has been cut moderately short the effect is that of a characteristic patchy irregularity, in which it is clear that the temple and occiput are as much affected as the vertex. The eyebrows, eyelashes, and mustache may be merely thinned, or suffer a loss in patches. The shaven beard may present an appearance nowise distinguishable from the condition of the same region when affected with alopecia areata.

The late forms of syphilitic alopecia are always due to destructive lesions of the cutaneous region covered with hairs; and the alopecia is hence usually the less important feature of the disease. Thus deep pustular, gummatous, ulcerative, and other like changes in the scalp are usually followed by an asymmetrical loss of hair, often limited to a single patch, where, after cicatrization, the resulting alopecia is remediless.

The early form of alopecia is unquestionably chiefly due to defective nutrition of the hairs in the hair follicles, and, as alopecia areata is probably due to the same immediate cause (the remote cause being essentially different), it follows that the shaven scalp presents almost the same appearance in two selected cases of the two diseases. The bulbs of the fallen hairs are seen under the microscope to be distorted and misshapen in early syphilitic alopecia, and the hairs themselves are usually dry and lustreless. The pathology of the late forms of alopecia in syphilis is that of the syphilitic process to be studied in the tissues generally. Usually a degenerating gummatous infiltration eventually encroaches upon and destroys the hair follicle. Syphilitic alopecia is to be distinguished from all physiological losses of hair by its sudden occurrence in persons of the age in which syphilis is most commonly encountered, its asymmetry, and its involvement of the temples and occiput equally with the vertex. A history of infection can usually be obtained, and other symptoms can often be discovered. Seborrhœa capitis, or alopecia furfuracea, is distinguished by its fatty or dry scales, and its failure to remove the hairs in distinct areas. The patches of alopecia areata strongly resemble those of early syphilitic baldness in the shaven head; the loss, however, in the former disease is more sudden, and recovery is marked by the appearance of whitish or grayish downy hairs, which is not often the case in restoration after syphilitic alopecia. The internal treatment is largely that of the secondary symptoms of the disease. The local treatment should consist of daily shampooings with hot water and the Sarg fluid soap; or, when mere stimulation is required, by the aid of the tincture of green soap. After such shampooing the scalp may be anointed with scented lanolin or vaseline, or with an oleaginous lotion made by adding two drachms (8.0) each of the oil of sweet almonds and glycerin to an ounce (32.0) each of the spirit of rosemary and alcohol, and two ounces (64.0) of cologne water.

Affections of the Nails, Matrix and Bed of the Nails, and Adjacent Parts.—The term onychia is applied to the changes which are first apparent in the nail; and paronychia to those which only secondarily affect the nail and primarily the matrix, nail-bed, or cutaneous folds by which the nail substance is surrounded. It is probable that the distinction is purely artificial, both forms being preceded by alterations of tissue exterior to the nail substance proper. These appendages of the skin are frequently affected in syphilis, both during the secondary and during the tertiary stages, and the resulting lesions may be transitory or persistent, and mild or grave in character. The course of these changes is usually chronic.

In the most frequent form of onychia (*onyxis craquelée*—dry or friable form) a portion or the whole of one or several of the nails may become dry, lustreless, grayish-yellow in color, friable, rugous, irregularly thickened, traversed by furrows in one or more directions, or singularly disfigured by numerous minute pockets, from which the crumbling nail substance has fallen or been removed by washing and scrubbing. The nails are usually tilted up at the free border and separated from their beds. Careful examination will often reveal a ridge of thickened epidermis at the sides or attached border of the nail, which may be normal in appearance or dull purplish in color and scaling; or, on pressure, a few drops of thin, ill-conditioned pus may escape from beneath it. This form is said to be more common in women. Under treatment these phenomena may disappear, and the distorted nail be pushed forward and replaced by a healthy new one. In other cases one or several of the nails are insidiously loosened from bed, matrix, or nail-fold, and are shed without the occurrence of any appreciable change in the surrounding parts, precisely as the hairs fall in many cases of syphilitic alopecia. Sometimes, even when attached at its border, the nail is seen to be completely separated over its entire area from the bed beneath. When the nail, on the other hand, is affected with an onychauxis, it may increase to three or four times its normal bulk, a condition described by some writers as hypertrophic onychia.

Paronychia may affect the whole or a part of the nail, and be dry or ulcerative in type. In the former case a dull-purplish ridge of cutaneous tissue, in the vicinity of the nail-fold and including it, becomes indolently thickened, scaling, and fissured. Superficial ulceration may follow, with purulent or hemorrhagic secretion and crust formation, the ulcer spreading slightly beneath the nail at one point, the substance of that organ having already exhibited the changes due to impaired innervation. The characteristic feature of this complication is a finger with its distal phalanx having a bulbous appearance, its partially altered, dirty-looking nail tilted upward or to one side, and a dry, scaling, or indolently granulating surface exhibited in the exposed part of the bed.

Ulcerative paronychia is characterized by a shallow or deep ulceration extending at the central or lateral parts of the nail-fold, matrix, or bed, bathed with a sanguinolent, thin, or ill-conditioned pus. It may begin with the dry lesions described above, or with the development of marginally seated papules or pustules. The nail may, as a result, be in lateral deviation from the axis of the phalanx, or partially or wholly loosened from its attachments. In this state it may present any of the changes seen in syphilitic onychia. The nail-bed, when thus exposed, is usually tumid, covered with a thin, puriform secretion, granulating, or the seat of an irregular, firm, and whitish, epithelial investment. Thin layers of new nail substance speedily form over this surface if proper treatment be instituted; and, even in the cases in which a distorted nail at first covers the bulbous phalanx and its purplish, tumid nail-fold, the restoration is eventually complete. In some cases the ulcer first forms beneath a crust under the free edge of the nail, and thence, when not properly managed, spreads irregularly over the matrix, the nail becoming loose and undergoing the changes already described. Care should be taken in the diagnosis of such cases to exclude trichophytosis unguium (where the parasite is recognizable under the microscope); eczema and psoriasis (in which there is no history of syphilis and none of its other symptoms); digital chancres (in which the nails are not chiefly involved); and ordinary forms of paronychia (which commonly spare the nail-bed and matrix).

The treatment is largely internal; locally the white precipitate salve [one scruple to the ounce (1.33 to 32.0)] may be applied on rags. Ulcers may be dressed with pencillings of the nitrate of silver, followed with iodoform or iodol in powder.

The Relations of the Syphilodermata to the Process of Systemic Intoxication and to the Accidents of Environment.—The view was once generally held, and is still largely entertained, that the several eruptions observed in the course of evolution of syphilis are due solely to the constitutional malady. This position, viewed in the light of modern science, is seen to be untenable. The eruptions minutely described and definitely catalogued in the treatises upon this subject can, without difficulty, be assigned etiologically to several categories.

In the first are grouped syphilodermata due solely, so far as can be ascertained by our present methods, to the influence of the toxin of the disease. These eruptions constitute probably the smaller number of all with which the physician needs to be familiar.

In a second category are to be recognized the syphilodermata due wholly to externally operating causes, the accidents of environment. Some eruptions should be here included, in which manifestly the pyogenic staphylococci are the efficient factors in the production of the lesions, some of them resulting from inoculation, others from auto-inoculation. It is quite noticeable of the pustular syphilodermata that they are nowhere seen so abundantly and in such typical expression as among the filthy, the impoverished, and the neglected. They are decidedly among the rarer complications of the evolution of the disease among the cleanly, the well fed, and the comfortably clad. Specific treatment being for the time abandoned, the pustular syphilodermata as a rule respond rapidly to the treatment indicated by the existence of such lesions, viz., bathing, disinfection, asepsis, proper clothing, and shelter of the body. Some of the pustulo-crustaceous and bullous lesions acknowledge similar causes. It is an error to dissociate syphilis in all cases from the category of the filth-diseases. The worst varieties of the malady, without any question, are to be found in the lowest class of patients in the out-departments of public charities, where attacks are daily made upon the unwashed skin by micro-organisms, animal and vegetable parasites, the "flora dermatologica" of Unna, and the finger-nails of the sufferers.

In a third class are to be named the eruptive phenomena, due without question to the operation of an internal cause, but brought into existence, or encouraged, or precipitated, by externally operating accidents. This includes an enormous number of all the syphilodermata, and there are few that may not acknowledge influences of the sort to which attention is here directed. The mouth of the tobacco-chewer and smoker is often freed from mucous patches when relieved of the irritation thus aroused; the anus of the infant is no longer surrounded by a group of condylomata when its surface is properly cleansed and disinfected; the palmar plaques of the toiler with material or tool cease to ulcerate and begin to heal when labor is suspended, or the hands, when thus engaged, are protected from injurious contacts.

In a fourth class are to be placed a small number of supposed syphilodermata, due to causes operating internally, and to be attributed only in part to the infective process. Here should be described all the medicamentous eruptions, due to the iodine compounds administered for relief of the disease, chiefly the acneiform lesions (acne artificialis, acne varioliformis). With these should be enumerated eruptions of the class represented by the pigmentary syphiloderm which refuses to succumb to the action of the remedies commonly effective in syphilis, and which is in reality a pigmentary disorder only very indirectly associated with the toxic condition of the system.

In a fifth class are represented a number of the cutaneous pictures of syphilis, due to the commingling of syphilodermata with simpler dermatoses. Chief among these is the combination of syphilis and seborrhœa seen so often about the nose, the brow, and over the scalp of the subjects of the two disorders.

The Behavior of the Syphilodermata in the Presence of Other Infective Processes.—The knowledge had respecting the relation of syphilis to other diseases was of the vaguest character prior to the date of an exact appreciation of the etiological importance of micro-organisms in disease. The mutual antagonisms of the latter in several of the infective processes are made apparent in many of the morbid conditions presented in syphilis. Erysipelas may affect the skin which is the seat of syphilodermata, but then the result, far from suggesting a complexus of two disorders with a confused picture of each, is a typical erysipelas having an issue which leaves the skin, after relief of the later infection, free from the lesions first occupying the ground. Similarly, in observation of a series of cases of typhoid fever occurring at the moment of an abundant eruption of syphilodermata of an early type, the cutaneous symptoms wholly disappear with all other traces of syphilis, only to return, usually in milder expression, after the conclusion of weeks or months of illness and protracted convalescence, when the bodily weight is again nearly approaching its normal standard.

Syphiloma of the Subcutaneous Glands (Gummatous involvement of the lymphatics, so-called "tertiary bubo").—In those periods of syphilis, when gummatous material is deposited in any of the bodily tissues, the subcutaneous glands may suffer. This complication of the disease is more common than is generally supposed, and, when the glands of the neck are involved, presents a condition which is often mistaken for tuberculosis.

The subjects of the disease are not always in what has been termed the "late" stages of the disease. They are often the recently infected, even within a few months of the date of that accident, and, as a rule, are of the type formerly described as strumous. They are usually individuals of weak constitution, under normal weight, and poorly nourished, or severely taxed in daily toil. The glands are recognized as round and oval, dense and at times elastic swellings, involving one or a group of several glands ("pleiades" of French writers), which may pursue a gradual course terminating in disintegration, or undergo resorption of the deposit in any stage of development. The glands are at first in a purely irritative condition, thus probably resenting the entrance of either bacilli or toxins of the same in their meshes; later, there is a well-marked cell proliferation with degeneration of the central pulp of the gland, pus formation, and exit of the same, either spontaneously or by means of surgical interference; in other subjects caseation results, the cell proliferation decreases *pari passu* with increase of the intercellular tissue, and fatty metamorphosis eventually takes place.

The glands most frequently involved are, first, those of the neck (submaxillary, infraclavicular); next, those of the inguinal regions; lastly, the axillary, cubital, and popliteal.

The tumors vary in size from small nuts to large eggs, are both painful and tender, and soften when about to break down at or about the central point of the mass. They are exceedingly indolent, and even when converted into an abscess have little or no tendency to burst, but retain for weeks at a time, even longer, their pulpy and ill-conditioned contents. They are at first covered by a movable and normally colored integument; later this becomes dark-hued and livid. When spontaneously bursting, the rent of the gland capsule reveals a discolored grayish-yellow or darker admixture of thin pus and detritus of tissue, a healthy-looking wound being produced after scraping, which in well-managed cases proceeds without delay to repair. The scars left in either event strongly resemble those resulting from the similar process in tuberculous involvement of the lymphatic glands.

Actinomycosis should always be differentiated by the aid of the microscope; tuberculosis, if not by the same means, at least by the relative rapidity of evolution of the syphilitic process; for though at times but a few months are required for the entire career of the syphilitic lesion, the tuberculous are commonly far slower of career and soften centrally only after long delay. The lymphoma of syphilis rarely requires a twelvemonth for its completed curriculum. Carcinoma of the regions named is exceedingly rare; sarcoma is even more rare of occurrence.

The more lately devised methods of treatment in syphilis have not yet supplanted the older and approved devices, nor do they contain the promise of so doing. Tommasoli has employed intramuscular injections of a fluid obtained by keeping the blood of lambs for twenty-four hours on ice, separating thus the serum. From 2 to 8 c.c. of the latter are injected for a dozen or more times. The lesions of syphilis are reported to have rapidly and permanently disappeared under this treatment; and the reactive effects from these injections were in no case severe.

Wellander, of Stockholm, has employed for injections a mixture of the acetate of thymol mercury, gr. 1.5 in liquid paraffin, injected every fourth day till six or seven injections have been made. Indurations and abscesses at the site of the operation were minimized in number and severity; the reactionary effects were reported mild, and the symptoms of the disease yielded with varying but satisfactory promptness, some relapses occurring.

The other mercurial salts lately employed besides hydrargyrum thymolicum (thymolaceticum) are salicylicum, succinimidicum, alaninicum benzoatum, oxycyanatum, formamidatum. The basis employed by Schadek is an emulsion of gum arabic. The oxycyanide is used in injections of one-quarter of one per cent. The benzoate is employed in solution as follows:

Hydrarg. benzoat..................	0.30
Sod. chlorid........................	0.10
Aq. destillat........................	40.00

The succinimidicum is used also in one-per-cent. solutions.

Moncorvo and Ferreira report the treatment of a large number of young children affected with syphilis by hypodermatic injection, the corrosive sublimate being preferred by them for this purpose. The doses were exceedingly well tolerated by the children, who exhibited but little tendency to the after-occurrence of stomatitis, salivation, or intestinal colic.

Affections of the Eyes.—The *bones* composing the orbit may be involved in ostitis or periostitis, with degenerative results in the form of caries or necrosis. In this way may be lighted up an intra-orbital cellulitis resulting in abscess. Nodes also occur within the orbit, and may be followed by serious consequences when productive of pressure effects. The lachrymal passages also may be involved in obscure catarrhal changes, associated with pharyngeal lesions. Mucous and subcutaneous tissue, periosteum, and bone may be eventually implicated, with the result of producing lachrymation, epiphora, abscess, and eventually fistulæ. The treatment is by division of the canaliculi and dilatation of the canal by probes. The parts may then be treated with weak injections of the nitrate of silver, or, what is fully as valuable, two- to five per cent. solutions of resorcin. When the canal is pervious to the probe, the trouble is usually due to changes in the periosteum of the nasal process of the superior maxillary bone. The frequent application of water, as hot as can be borne, to the affected parts, if required in connection with the application of fomentations, will often give relief in these cases when energetic constitutional measures are adopted. Bumstead and Taylor report syphilitic changes in the lachrymal gland sufficient to produce a species of ptosis, and also gummata of the caruncles.

The *eyelids* may be severely and extensively involved in syphilis. They may be the seat of chancres, as also of papules, pustules, ulcers, and resulting cicatrices dragging the lids into ectropion. Syphilitic ulcerations attack the canthi and free edges of the lids, encroaching also upon the mucous surfaces. The author has seen both upper lids symmetrically involved in ragged ulcerations of the edge resembling the work of a punch. Degenerating gummata of these regions often leave disfiguring cicatrices. The palpebral conjunctiva is often the seat of mucous patches. Subcutaneous indolent nodules, the size of a hemp-seed to that of a pea, occasionally form in the lid, and they may obstinately persist when treated. The tarsus is reported also by several observers to have been involved in a tarsitis syphilitica, which is at first productive of tumefaction of the lids, and later of changes in the cartilage itself. The fasciæ and tendons of the ocular muscles are also liable to s philitic changes, which may result in thickening, in abscess, or in fistula. All syphilitic lesions of the eyelids are to be distinguished from chancres of the lid, accidents not of very rare occurrence in the large cities. In these cases there is great tumefaction, brawny, empurpled thickening (of the inner canthus usually, the part most apt to be rubbed by the finger that transports the infective secretion), and a specific induration of the preauricular or submaxillary gland—far more commonly the former.

The *conjunctiva* may be the seat of mucous patches, circumscribed macules, papules, tubercles, and gummata. These are, however, rare. The ocular conjunctiva is spared most of the lesions of syphilis, save when it becomes engorged with blood as a consequence of iritis.

The *cornea*, when participating in syphilitic changes, is usually recognized in the victim of inherited disease. There is found, first, slight pericorneal vascularization, in the diffuse form, with one or several centrally situated or marginal opalescent points showing in the cornea. These increase till the whole or a great part of the cornea is involved, producing thus a characteristic opacity limited to the field of the keratitis. With the keratitis of inherited syphilis are often seen the alterations in the color, size, and shape of the permanent incisor teeth, first described by Mr. Jonathan Hutchinson, who regards the permanent upper central incisors as the test-teeth. These are usually vertically and transversely shortened and thinned, with a crescentic notch at the free border, its convexity regarding the root of the tooth. This notching, most conspicuous in childhood, becomes partially obliterated by attrition in later life. The teeth are also often convergent, occasionally separated; in other cases "pegged," and again discolored in shades of a dull brown.

The punctate form of keratitis is seen both in acquired and in late inherited syphilis. Intracorneal puncta, the size of a pinhead, are then visible, careful observation of which reveals the lack of lustre or grayish shade of color of corneal opacities in general.

The *sclera* may be involved (1) in an episcleritis beginning with pericorneal hyperæmic macules of a dull-reddish hue, with few if any subjective sensations. A circumscribed portion of the sclera may then appear thickened, and in some cases radii of engorged conjunctival vessels indicate an extension of the hyperæmia to the overlying membrane. In extreme cases the cornea, sclera, iris, and lens are involved in a common inflammatory process; cases which the writer believes originate for the most part in an iritis. (2) An interstitial, or parenchymatous, scleritis may present the features of an inflammation of the organ, or of a gummatous deposit, or of infiltration within its substance, which, following the rule in similar involvement of other organs, may undergo resolution, or degenerate into an ulcer with irregular edges, and softish, grayish floor. When the cornea also is implicated, one sees a characteristic conical area of corneal opacity, its base resting upon the involved sclera, its apex projected forward to the centre of the cornea.

Iritis.—More than one-half of cases of iritis are of syphilitic origin, the proportion ranging between sixty and eighty per cent. of all cases. It is not only a common complication of the disease, but, as regards the loss of vision, one of the most disastrous. The symptoms of specific and non-specific inflammation of the iris are, taken *per se*, indistinguishable. Three forms are to be recognized: simple plastic, serous, and parenchymatous. The two first named belong to the earlier period of the disease; the last is due to a gummatous infiltration of the organ. The disease is commonly unilateral in situation at the outset, but in fifty per cent. of all cases ultimately attacks the other eye. It occurs most frequently at the average age of the syphilitic subject—that is, in early adult life; and is much more frequent in men, by reason of the greater exposure of the eyes of the male to the accidents incidental to the trades and occupations of life. Iritis is decidedly more frequent when special conditions in the environment of the patient favor the occurrence of the disease, as, for example, when the eye is exposed to the radiation of light from newly fallen snow in winter. Simple plastic iritis is the condition in which there is, first, hyperæmia and later a plastic exudate from some portion of the iris with proliferation of the connective-tissue elements. It may be so slight in its symptoms as to escape detection, and be then accompanied by mild photophobia and vascular injection. In other cases the symptoms are marked and distressing. There is distinctly pericorneal vascularization, sometimes subconjunctival œdema. The large, mobile, tortuous, brick-red conjunctival vessels contrast strongly with the straighter radii of delicate pinkish underlying vessels visible in the sclerotic zone and limited largely to it. Both planes of injection aid in giving a distinctly reddish color to the eye, which is evidently in a state of inflammation. The affected iris is peculiarly dull-hued, its color, as compared with its unaltered fellow, being changed in various shades according to the color natural to the organ in health. It is sluggish to the light, and often its structure is indistinguishable to the eye of the careful observer, because covered with a delicate stratum of the plastic exudate. The latter may extend also over the anterior capsule and give the pupil a cloudy appearance. The aqueous humor also may become turbid. In consequence of these changes the free border of the iris is often agglutinated, in various degrees, at one or several points, to the anterior face of the capsule of the lens, so that when its muscles contract the pupillary outline becomes irregular, being changed from the figure of a circle to that of an interrupted curve, or to semilunar, trefoil, figure-of-eight, or scallop shapes.

Serous iritis is characterized by the exudation of a serous fluid, with hypersecretion of a cloudy aqueous humor, which precipitates a deposit in the form of a delicate, opaque, punctate, or diffuse film on the posterior face of the cornea, the anterior face of the lens, and the membrane of Descemet. There is increased intra-ocular tension, the pupil is immobile and dilated, and the iris is changed in hue. There is less injection of the sclerotic zone than in the plastic form of iritis. Glaucoma may eventually result, from participation of the ciliary body and choroid in the process.

Parenchymatous, gummatous, or suppurative iritis affects the stroma of the organ, the cellular and vascular elements of which then proliferate, causing a regular or irregular increase in its dimensions. The attachments which form between the lens and iris are firm and unyielding. Tubercles, nodules, or "condylomata" (gummata), become visible as light- or dark-colored, circumscribed elevations on the surface of the iris, marginal or not in situation, sometimes vascularized as they persist, and attesting the unicity of the syphilitic process in all tissues of the body. Pus may form in the anterior chamber, especially in cachectic subjects.

The diagnosis of these disorders is not difficult, since their association with a syphiloderm, often papular, and the history of the case, usually corroborate the suspicion aroused by the lachrymation, pain, photophobia, and circumcorneal vascularization. The treatment is by the administration of mercury and the iodide of potassium internally, pushed until the system is controlled by these drugs; and by the instillation into the eye of the sulphate of atropine in solution (gr. ij. ad fl. ℥ i. [0.133–32]). In exceptional cases vesication over the temple may be employed with advantage, or a leech or two may be affixed near the ear. Opium hypodermatically, or cocaine locally, may be required to relieve pain. The oleate of mercury and morphine also may be applied by inunction over the brow, even where the mydriatic is employed. The eyes should be disused and protected against light (by a darkened chamber or shaded glasses). Paracentesis of the cornea and iridectomy may be required in severe cases at the hands of the ophthalmic surgeon.

A form of iritis has been observed in the first half-year of life of infants, mostly of the female sex, affected with inherited syphilis. It is both unilateral and bilateral, and accompanied by few of the marked subjective symptoms of the disease experienced by adults, but is far more liable to result in pupillary occlusion.

The *lens* is affected in syphilis chiefly by extension to it of inflammation of the delicate organs with which it sustains anatomical relations. Cyclitis, or inflammation of the ciliary body, is for the most part similarly excited by an iritis or choroiditis of the same eye. Very rarely, indeed, a gummatous exudation occurs primarily in its substance, and then commonly the iris is secondarily involved, with characteristic symptoms.

Choroiditis and Retinitis.—Plastic, serous, and parenchymatous inflammations of the retina and choroid are described by authors, the distinction between which forms, as also between inflammations of the two organs, is difficult to establish. The objective symptoms of these disorders, as recognized by the aid of the ophthalmoscope, may be described as increased vascularity, ecchymosis, opacity, œdema, and appearance in the fundus of the eye of whitish or yellowish spots. Often the pigment of the choroid atrophies, permitting in one or more places a view of the sclera through its tissue. Blackish areolæ may surround these irregularly bordered macules. In other cases the choroid presents the appearance of maceration; or again, circumscribed nodules (gummata) project above the general level. When there are distinct retinal changes, the point of entrance of the optic nerve is usually pinkish or reddish in shade, œdematous, and surrounded by distended and conspicuous vessels; or it is hidden from view by plastic deposits upon its surface, or by a fog in the vitreous humor.

The *optic nerve*, when affected with syphilis, is usually involved after extension to it of a retinitis or choroiditis. It is with great rarity primarily infiltrated with a gummatous product. The same is true of the vitreous, which is usually implicated only after syphilitic changes in its investing membranes.

Paralysis of the nerves of the eye is as nearly pathognomonic of syphilis as is iritis, from fifty to sixty per cent. of all cases occurring in syphilitic subjects. Many of these are early phenomena of cerebral syphilis, and hence amblyopia, failure of co-ordination of the ocular movements, and visual disturbances of every kind should be closely investigated at all times when occurring in the victim of syphilis. Paralysis of the third pair of cerebral nerves, the oculomotorius, is characterized by ptosis of the upper lid, external strabismus, and inability to move the globe upward, downward, or inward. Accommodation is wholly or partially lost, and the pupil is dilated. Paralysis of the sixth pair, the abducens, is, on the other hand, characterized by internal strabismus, amblyopia on the outer side of the vertical axis of the eye, and inability to move the globe outward. Paralysis of the fourth pair, the patheticus, is characterized by amblyopia for all objects lying below the equator of the globe of the eye, and by the fact that the patient is obliged to make an effort to correct the visual impressions of objects below that equator by the inclination of the head.

These paralyses may occur singly or in combination; and, with or without them, may be recognized monocular mydriasis, which, albeit occasionally associated with grave cerebral syphilis, the author has seen persist for years without impairment of co-ordination or other ocular symptom. Unquestionably these paralyses may be due at times to gummatous and other syphilitic changes in the membranes, periosteum, and bones within the cranial vault. Convergent strabismus is readily distinguished from paralysis of the sixth pair by the relief of the squint in the former case when the sound eye is covered. The treatment of these paralyses by the usual method of managing constitutional syphilis is, for the most part, encouraging. Tenotomy may be occasionally required.

The Eye in Inherited Syphilis.—In congenital diseases the lids, conjunctivæ, cornea, iris, choroid, retina, and optic nerve, may, one or all, be affected with specific inflammatory changes, or, more commonly, by gummatous deposits resulting in degeneration and ulceration. Grave ocular troubles in early life, especially if coexisting with persistent alterations of the subcutaneous structures, periosteum, or bone, should generally awaken the suspicion of syphilitic disease.

[For affections of the ear in syphilis consult the exhaustive article on this subject in Vol. III. (page 674)].

Affections of the Respiratory Tract.—*The Nose.*—The lining membrane of the nares may be the seat of macules, papules, erosions, mucous patches, and ulcerations, with catarrhal symptoms, the discharge from the nares becoming serous, purulent, or hemorrhagic. Inspissated masses of these secretions smeared with an offensive discharge are at times expelled. Gummata form in the same region, the degeneration of which leads to ulcerative changes in cartilage, periosteum, and bone. This order of sequence may be reversed, the gummatous infiltration first occurring in the osseous structure. The septum, floor, Eustachian tube, pharynx, roof of the mouth, antrum, and even the cerebral meninges, may be attacked by extension of the disease from one point to another. When the bridge of the nose is in this way undermined, a characteristic and highly disfiguring flattening occurs, which is rarely seen in any other disorder save syphilis, traumatism excepted. Cartilaginous destruction is productive of flattening of the tip of the nose. The practically remediless nature of these deformities renders the treatment of all nasal disorders in syphilis a matter of the highest consequence. When the antrum of Highmore is affected, there is a peculiar tumefaction, unaccompanied by coloration or change in the skin, of one side of the face, the treatment of which may require removal of a tooth, penetration of the floor of the antrum, and the wearing of an obturator for a time. When the Eustachian tube is involved, the drum membrane may be perforated and a purulent otitis media follow. Many of these changes, whether vegetative, erosive, or ulcerative in type, are accompanied by fetid ozæna, nasal phonation, and partial or total loss of the olfactory sense. Sometimes osseous fragments, varying in size from a hemp-seed to a finger nail, are discharged from the nares, the detritus of the carious process as it affects the nasal, turbinated, or other bones. Eburnation and thickening of the bones *in situ* may also result. The internal treatment of these cases is by mercury, iodide of potassium, the mineral acids, and ferruginous tonics. Locally, the treatment may be successfully conducted by the aid of mercurial fumigation, but the use of a cleansing douche, followed by lotions containing the bichloride of mercury, resorcin, iodized phenol, potassium chlorate, or boric acid, may be preferable.

The Larynx.—The vocal cords, arytenoid and glosso-epiglottic folds, and all parts of the mucous, submucous, cartilaginous, and osseous tissues of the larynx, may become the seat of syphilitic changes. Diffuse circumscribed erythema, mucous patches, papules, "condylomata," vegetations, erosions, and gummata may be followed by superficial or deep ulcerations, circumscribed or extensive infiltrations, and cicatrices, the contracture of which may induce grave and dangerous laryngeal stenosis. Pain, cough, changes in the volume or pitch of the voice, dyspnœa and dysphagia, are not at first noticeable. The supervention of œdema may gradually or rapidly usher in a serious condition. Later, when stenosis of the larynx (the more frequent of the ultimate results) is induced by cicatricial contraction, or (more rarely) by vegetations, false membranes, gummata, or nodes, the voice may be reduced to a whisper, or there may be complete aphonia, dysphagia to a slight extent, or dyspnœa even to a grade demanding tracheotomy for the preservation of life. The mucous membrane of the larynx is affected also with a chronic form of infiltration, which results in a characteristic induration of the important submucous tissues of the larynx, distinguishable from œdema by its firmness and density. The deeper ulcerations of this organ resulting from degenerating gummata, circumscribed or diffuse in extent, commonly spread from similar lesions in the pharynx, resulting ultimately in destruction of the epiglottis, leaving often in such cases a single wide and ragged laryngo-pharyngeal chasm; or involving the cords, aryteno-epiglottic ligaments, and deeper structures. When the cartilage is involved, crepitation is said to be perceptible after the occurrence of perichondritis; and sequestra have been removed when caries or necrosis has attacked the ossified cartilage. Syphilitic aphonia, obscure as to its immediate cause, as well as paralyses whether of one or both sides, is not to be confounded with syphilitic aphasia. Tuberculosis can now be satisfactorily differentiated from these affections by the modern methods of recognizing the bacillus of that disorder, as well as by the other signs of phthisis and the absence of a history of syphilis and its concomitant symptoms.

The trachea may become the seat of lesions similar to those recognized in the larynx; but the absence here of the delicate mechanism required for phonation explains why they are rarer, less conspicuous, and less complicated. The larynx, trachea, and bronchi are usually simultaneously or successively involved, the trachea alone very rarely. All the lesions of mucous surfaces in syphilis, all the vegetations, infiltrations, and degenerations, may here be noted, including extratracheal abscesses from perforation. Stenosis from cicatricial contraction may here also induce fatal results. The internal treatment of laryngeal and tracheal syphilis is that of the disease in general. Locally, the parts may be wiped with solutions of boric acid, benzoin tincture, eucalyptol, or dusted with iodoform, or tannin in fine powder, reduced if desired. The galvano-cautery is best employed in the surgical management of membranoid occlusions, which are, it should be remembered, quite uninfluenced by large doses of the potassic iodide. The last named drug is indeed, in some cases, credited with producing a form of laryngeal œdema. Dilatation with bougies has not won for itself much favor in the management of these cases. The use of tobacco, both by smoking and by chewing, is to be interdicted in all cases.

The bronchi may become the seat of the syphilitic changes described in connection with the larynx and trachea. Few cases, however, have been carefully studied, though stenosis following ulceration has been recognized post mortem.

The lungs may be the seat of a syphilitic infiltration affecting usually one side of the chest only, and then the upper, middle, or lower lobe. The pulmonary tissue becomes so dense in these cases as to be impermeable to the air; and yellowish points are visible here and there in the relatively small patch of consolidation, due to the irritation of the parenchyma by the sclerotic nodule.

These sclerosed portions of the lung by their contraction induce either stenosis or ectasia of the normal canals and chambers in the vicinage. Under the microscope the sclerosis is seen to be made up of bundles of firm connective tissue, between which appear stellate, fusiform, and roundish cells, with a granular detritus. The vessels of the part are first engorged with blood, and later choked with the stasis of their contents.

Pulmonary gummata, or circumscribed syphilomata, of the lung rarely form at the apices of these organs, but are found in all other parts. They are grayish, semi-solid masses, varying from the size of a pea to that of an egg, set in the pulmonary parenchyma, surrounded always by an opalescent, fibrous, basket like capsule, and as they grow older they often exhibit one or more yellowish points in their mass where caseation has begun. Softening progresses from centre to periphery, and the contents may find exit by the portal of a neighboring bronchus with a secreting cavity left behind; or resorption may occur with the result of leaving in the lung tissue a fibrous mass, having a cheesy centre. These conditions may be found in one lung: gummata forming in cavities originally resulting from lesions that have degenerated, mingled with fibrous sequelæ of resorption, and contracting cicatrices. Often the pleura and bronchi are either involved in the same process or exhibit the irritating effects of the pulmonary neoplasms. Microscopically, the centre of these gummata is found to be made up of granular connective tissue, in process of degeneration, and highly refractive granules. The fibrous tissue is concentrically wrapped about them, the cellular elements nearest the core having undergone in part fatty metamorphosis. Still more externally lie irregular masses representing a small-celled infiltration, which in places blocks up the alveoli. The lesions are encircled by peripherally distributed connective tissue with clearly defined limits. The result, as regards the lung tissue, is, according to Councilman, a pneumonia with fibrinous exudation, accompanied by fibrous thickening of the alveolar walls, the whole undergoing caseation. When the action of the virus is intense, necrosis of tissue occurs before there is time for the development of the protecting connective tissue.

The analogy between tuberculosis and syphilis of the lung is shown by the fact that in both processes a caseous pneumonia results; but in the former instance the inflammatory process is the direct result of the presence and irritative effects of tubercle bacilli; in the latter, the primary process is an atrophy of the alveolar walls, most probably due to a hyaline degeneration of the capillaries.

The diagnostic differences, as given by Delafield, are, in syphilitic disease of the lung, dyspnœa on inspiration; a varying degree of supra- and infraclavicular retraction; on percussion, marked dulness over the affected parts; on auscultation, prolonged and high-pitched respiratory murmur, with a pause between it and a prolonged and almost equally high-pitched expiratory murmur. Sibilant, sonorous, crepitant, and subcrepitant râles are often wanting; vocal fremitus on coughing is increased. The symptoms of these lung changes of syphilis are largely those of non-specific inflammatory disorders, viz., bronchial catarrh with expectoration of muco pus; diminution of sonority in percussion; limitation of the respiratory area in affected parts of the lung; dry and moist râles; prolonged expiration, and dyspnœa. Cases of severe hemorrhage in patients affected with syphilitic pulmonary sclerosis may go on to complete recovery after appropriate therapy. In the event of degenerating gummata of the lung, the symptoms are those of pulmonary caverns, whatever be the cause, hollow gurgling râles, pectoriloquy, raucous voice, etc. The diagnosis is established by the history of syphilis and by any concomitant symptoms present; by the relative immunity of the pulmonary apex; by the smaller number and larger size of gummata, as contrasted with miliary tubercles; and by the absence of the bacilli of tuberculosis, of the signs of hydatid cysts, and of neoplasms of other diseases. The treatment is that of syphilis in general, with such remedies as are specially indicated by the pulmonary symptoms present.

Affections of the Digestive Tract.—*The Mouth.*—As the lining membrane of the mouth is more often exposed to the eye of the practitioner than any other mucous surface in the body, the symptoms which it exhibits in the victim of syphilis may be regarded as representative of mucous lesions in general. They are all properly in alignment with the cutaneous lesions, the modifying influences being chiefly heat, moisture, and motion; the latter incidental to the performance of the important functions of the mucous cavities. Thus the buccal cavity is often the seat of diffuse or circumscribed erythema, in dull red shades, faucial or palatal in situation, with defined or irregular outlines, accompanied by infiltration, œdema, and often by erosions. These may be multiple, pea-sized patches, or a single sheet of diffuse blush. The former, after maceration, may, by either a vegetative or a degenerative process, form papules, mucous patches, or ulcers. In malignant cases a dull-red erythema often precedes the gangrenous crateriform ulcer which opens, almost as at a stroke, the oral and nasal cavities by a communicating chasm.

Mucous Patches (Mucous tubercles, Plaques muqueuses, Moist papules, etc.).—The larger number of these lesions appear in the mouth and about the anus, though they are to be seen near all the mucous outlets of the body. They are far more common and more severe in the mouths of men than in those of women, on account of the tobacco habits of the former. They are early and late lesions of syphilis, and are represented in the symptoms of relatively few diseases not syphilitic. They consist of roundish, oval, or irregularly shaped discs, or longer, narrow, indefinitely outlined bands of a delicate rosy hue; grayish or opalescent in color; often granular and elevated about a millimetre above the general level of the surface where they appear. Many of them seem to be covered with a delicate pellicle. When of a pinkish or reddish shade, they represent merely a stage of hyperæmia of the membrane; when opalescent, as if pencilled by the silver crayon, a stage of maceration of the previously infiltrated epidermis; when granular, a stage of attempted repair, the loosened pellicle having been removed by friction or otherwise, and the surface beneath forming a new epithelial envelope. They may form upon a chancre when undergoing its so-called "transformation *in situ*," already described. When located in quasi-mucous situations, viz., those portions of the skin in the vicinity of the mucous outlets subjected to friction and kept moist and warm (inner faces of the thighs, inside of the toes, etc.), they may vegetate and produce the condyloma, a lesion frequently seen about the anus and genital region, more particularly in syphilitic women of filthy habits. These are usually circumscribed, multiple, roundish, or irregularly shaped, wart-like elevations, smeared with a whitish mucus, highly contagious, and of especially disgusting odor when seated about the ano-genital orifices. In the same situation they are remarkable for the production of a sensation of itching, rarely awakened by other syphilitic lesions. Occasionally they are dry. They are, as a matter of fact, merely papular lesions, flattened by apposition of the surfaces between which they are developed, or vegetating, as the clefts in these same surfaces permit of such a growth, secreting because moist and macerated, and itching because irritated by the same agencies. When exposed, as about the bearded lips and nares, they are dryer, and browner, or duller red in hue. They occur in and about all the mucous outlets, and affect all mucous surfaces, with a marked predilection for the neighborhood of the muco-cutaneous borders. They are common in both infantile and inherited syphilis. They may become cracked, eroded, and superficially or very deeply ulcerated. Their excessive proliferation may produce enormous masses of secreting, wart-like, softish growths, described by authors as frambœsioid condylomatous syphilodermata.

The mucous patches of the mouth are less elevated and more opalescent than others, and appear upon the inside of the lips and cheeks, gums, uvula, palate, tonsils, and pharynx. They should never be confounded with the transitory, minute, usually distinctly circular, aphthous ulcerations to be seen in healthy adults after a fit of indigestion; nor with the persistent, much firmer, leathery discs, or striated or ribbon-like streaks, described as psoriasis linguæ, leukoplakia buccalis, etc., which, as is now well known, may be the earliest epitheliomatous transformation of a mucous membrane; nor with lichen planus of the mouth; nor, lastly, with the so-called "smokers' patches" (plaques des fumeurs, etc.), which many cases, it can scarcely be questioned, represent buccal lesions in a veteran of syphilis.

The tongue may display a wide variety in the lesions of syphilis. In the order of gravity may be named: Multiple, macular lesions, the size of a pinhead, abundantly spread over its upper surface; mucous patches in all forms, particularly over the edges and tip, often forming where the organ is rasped by the rough edge of a carious molar tooth; flat, circular papules, the size of a bean and larger, elevated a millimetre or two above the general level; circumscribed and diffuse, superficial or deep (parenchymatous) scleroses, usually developed upon the upper surface of the organ and near its mesian line, characterized by irregular increase of bulk and almost cartilaginous density, which may result in resorption and atrophy or ulceration; and, lastly, superficial or parenchymatous gummata, submucous or muscular in site, occasionally single, often multiple, which also may disappear by resorption or degenerate by ulceration. One of the remarkable features of disintegrating syphilitic, as distinguished from other neoplasms, of the tongue is the relatively slight damage apparent after completion of repair. These all are to be distinguished from epitheliomata, which are more voluminous, more hemorrhagic, less deeply excavated, more irregular in mass, and more painful; as also from colloid lingual tumors (so-called "hygroma" of English authors), with the appearance of vesicles on the upper surface and enormous asymmetrical increase in the bulk of the organ in childhood; and, lastly, from tuberculosis of the organ, rare of occurrence, to be recognized only by its histological characters.

The *maxillary bones* may undergo necrosis as a result of syphilis. The most common site of the accident is the central part of the dome of the hard palate. There is first a dull-red erythematous swelling of the membrane and submucous tissue, which in severe cases may seem to give way like wet paper, leaving a conical perforation through which communication is opened between the oral and nasal cavities; in other cases an abscess forms and bursts, after which the bone is laid bare and exfoliates in larger or smaller masses from time to time. Necrosis of the alveolar processes usually occurs in the upper law. Gummata of the soft palate often form insidiously, are circumscribed or diffuse; at first firm, later softish, tumors, varying from the size of a pea to that of a small nut, or in patches of thickening. Absorption or ulceration may result, and the latter often rapidly, in consequence of the lax and unsupported tissues involved; the process in grave cases opens (by destruction in whole or in part of the uvula, pillars of the fauces, and velum) a wide chasm between the fauces and the posterior nares. Interference with the Eustachian tube often produces temporary deafness. The voice is disagreeably nasal, deglutition is often difficult in the erect posture (patients with extensive tissue-loss will often assume unusual postures, by which they can even succeed in swallowing liquids without the passage of the latter into the nose), and the pain in general is quite disproportionate to the severity of the damage. Marvellous are the reparative results when, as is usually the case under sound management, repair ensues. The remaining fragments of the velum palati contract adhesions to the posterior pharyngeal wall, the chasm contracts, and the expert can trace the picture of the mischief that has occurred when inspecting only the narrow and distorted chink left after contracture is complete.

Fournier only has reported a case of syphilitic involvement of the sublingual gland.

The *pharynx* may become the seat of macules, papules, mucous patches, gummata, and ulcers, which in many cases are formidable. The latter may spread from the posterior nares and extend downward into the œsophagus, or backward, so as to produce destructive effects upon the periosteum of the vertebræ and the structures they protect. Occasionally, patients long neglected or badly treated, exhibit gigantic caverns, including what were once the nasal, buccal, and pharyngeal cavities, the whole lined with a granulating or secreting and ulcerated membrane. Even in those extreme cases in which one is disposed to wonder even at the prolongation of life, repair ensues and emphasizes the striking, almost pathognomonic, distinction between the damages inflicted by syphilis and many other destructive diseases.

The *œsophagus* is said to be very rarely the seat of syphilitic lesions which, after ulceration, may produce stricture, either spasmodic or organic, resulting in serious danger to life.

The *treatment* of all these lesions is practically the same. Internally, mercury and the iodide of potassium are essential, the latter often in the largest permissible doses, to save important organs. Care of the patient's nutrition is in most cases imperative. Locally, the nitrate of silver, sulphate of copper, chlorate of potash, tannin, resorcin, acid nitrate of mercury, nitric acid, and tincture of iodine may be employed in strength varying according to the requirements of each case—the first named in solid stick or solution of a strength of from five to sixty grains to the ounce (0.33–4.0 to 32.0). By spraying, pencilliog, dusting, washing, and gargling, these preparations may be used, with the greatest advantage, a number of times throughout the course of the day. The following are excellent formulæ for gargles:

℞ Potass. chlorat............... ʒ i. (4.0)
Mel. despum.,
Myrrh. tinct...............āā fl ℥ ss. (16.0)
Aq. des.................ad fl ℥ iv. (128.0)
M. S. Gargle. Use diluted as required.

℞ Potass. chlorat.................. ʒ i. (4.0)
Infus. lini...................... O i. (500.0)
[Bumstead and Taylor.]

℞ Acid. carbolici................ ʒ i. (4.0)
Glycerin,
Spts. vin. rectif............āā fl ʒ ij. (8.0)
Iodin. tinct.................. fl ʒ ss. (2.0)
Aq. dest..................ad fl ℥ i. (32.0)
M. Five to fifteen drops in a third of a tumbler of water for gargle or lotion.

The toothbrush, in all cases, is to be regularly employed twice daily; if the patient is unaccustomed to its use the mouth should be well cleansed and the gums rubbed with a bit of soft muslin on the finger, dipped in water to which a few drops of the tincture of myrrh and cinchona have been added. Tobacco is to be, in every form, absolutely interdicted; and all very hot and very cold, and irritating articles of diet are to be excluded (*e.g.*, hot coffee, ice cream, vinegar, spirits, spices, etc.).

The stomach and intestinal canal may become the seat of syphilitic lesions of the type seen upon the other mucous surfaces. Huet, Cornil, Klebs, and others report gummata of this part of the digestive tract; Leudet, Virchow, and Fauvel describe diffuse infiltrations of portions of the tube; Engel, Fioupe, Cullerier, and others, perforating ulcers (probably due to gummata) as also scleroses resulting in contracture, even productive of irritation sufficient to light up a peritonitis near a stricture of the colon. It should not be forgotten that a long list of functional disorders of the alimentary canal might be enumerated as of occurrence in the syphilitic subject, which are often due to the toxic influence of the disease (cachexia, etc.); to the effect of certain of the medicaments ingested or externally applied for its relief; and to improper alimentation or hygiene.

The rectum may become the seat of a series of important changes due to syphilis. Women are more liable to be thus affected than men in the proportion of eight to one, a preponderance which has been referred to the anatomical differences between the sexes, to the physiological fluxes of women, previous pregnancies, and to unnatural or excessive coitus. Chancroids, occurring as they do frequently about the anus of women, may result in induration of the submucous tissues, accompanied by purulent and sanguinolent discharges, constipation, or looseness of the bowels, and painful defecation. This condition is to be carefully distinguished from syphilitic stricture of the rectum.

The syphilitic affections of the rectum may, perhaps, include the category of syphilitic lesions of mucous surfaces in general. The most important, however, are those characterized by ulceration or gummatous changes. The former may extend from without inward, from the perianal region to an inch or more within the sphincter; or may begin by one or several points of ulceration in the latter situation. The so-called "ano-rectal syphiloma" is a cylindriform, gummatous, non-ulcerated infiltration of the entire circumference of the ano-rectal walls, capable of producing stricture by transformation into fibrous tissue. It is, however, an error to suppose that stricture of the rectum not due to chancroids, but syphilitic in character, always conforms in type to the syphiloma. The author has treated a middle-aged woman, whose husband and two children are victims of severe syphilis, and whose left lower extremity is extensively seamed with perfectly typical syphilitic cicatrices. There are in this case four abscesses in the nates, communicating by fistulous sinuses with the bowel and vagina, the syphilitic stricture of the rectum being represented by a sharply defined, thin, annular coarctation of the rectal wall, with a submucous gummatous infiltration strictly limited to the ring of the coarctation. It is evident that only in exceptional cases, probably during the period before contracture has set in, can internal medication accomplish practical results in these cases. Dilatation or division of the stricture by the knife or galvano-cautery is usually required, with free opening of all abscesses and sinuses, and observance of strictest antiseptic precautions with bichloride dressing. Often the production of an artificial anus in the abdominal wall is imperative. The future is, however, often unpromising for these cases, many women who are the victims of the disorder having their health profoundly impaired by previous suffering and disease.

The liver, like the intestinal canal, may suffer, when invaded, from functional disorders, which may depend upon slight structural changes participating in the process which results in the cutaneous exanthem. The icterus probably originating in this way, which may somewhat precede or accompany the first syphiloderm, has already been described. It may be accompanied by hepatic congestion and by symptoms of malaise, hebetude, cephalalgia, and even slight pyrexia. The late forms of syphilitic involvement of the liver are well marked. General, more commonly partial, interstitial hepatitis, affecting chiefly the capsular and ligamentous attachments of the organ, produces a distortion of the gland by contracture of fibrous bundles which, springing from these attachments, penetrate the hepatic parenchyma and divide it into uneven lobulations and irregular masses separated by furrows. There is at first increase, and later diminution, in the bulk of the organ, with the usual symptoms of cirrhosis. Hepatic gummata are of more frequent occurrence, and in "galloping" cases may be seen within six months after infection. They are usually grouped in clusters of from six to a dozen lesions, varying in size from a large pinhead to a small nut. Centrally they contain roundish cells and granules in a delicate connective-tissue reticulum, surrounded by a fibrous envelope, and embedded in dense hepatic tissue. The symptoms in mild cases are probably scarcely sufficient to indicate the nature of the affection. In others, disturbance of the alimentary canal (icterus, constipation, dysentery); pain in various degrees, limited to the hepatic region or radiating from it; and, very rarely, morbid changes perceptible on palpation of the enlarged, or previously enlarged and subsequently shrunken, organ, may first point to the precise nature of the trouble.

Gummata of the liver are to be distinguished from hydatid cysts; carcinoma (of advanced years); hepatic abscess (in persons who have been long resident in tropical countries); tubercles (usually softer, more cheesy, more purulent in the centre); and the rare forms of sarcoma of the liver. The prognosis of hepatic syphilis is usually not grave.

Amyloid degeneration of the liver may be the result of syphilis as of other diseases. There is increase in the bulk of the waxy-looking organ, the hepatic cells becoming enlarged after involvement of the swollen hepatic capillaries. Often there are coincident amyloid changes in the heart and spleen. The symptoms of hepatic gummata are as obscure in many cases as in syphilitic cirrhosis. There may be ascites, hemorrhage from the portal vein, and dyspnœa. The treatment is largely that of syphilis in general.

The spleen often enlarges in those early periods of syphilis when the lymphatic glands tumefy. Commonly the enlargement subsides as the disease progresses or is modified by treatment. Syphilomata of the spleen (gummata) are rarely observed, but have been recognized in both circumscribed and diffuse forms. Splenic gummata are yellowish, softish nodules, from the size of a pinhead to that of a small nut, set in a dense splenic tissue of unusual dryness. In diffuse forms, the organ appears to be in part hypertrophied and dark brown in color. Later, islets of grayish sclerosed tissue become apparent in this mass, the involution of which leaves cicatriform depressions. Rarely a perisplenitis may be lighted up by these changes, leading to the formation of whitish patches of almost cartilaginous density. The clinical symptoms of syphilis of the spleen are obscure.

The pancreas is said to be occasionally the seat of changes supposed to represent the circumscribed and diffuse syphilomata recognized in the liver and spleen.

Affections of the Circulatory Organs.—*Myocarditis*, recognized chiefly in post-mortem examinations, may be a late complication of syphilis, which affects men more often than women in the proportion of six to one. Softish, yellowish gummata, from the size of a nut to that of an egg, as well as circumscribed and diffuse sclerosis, have been recognized in the ventricular walls and auricles of both sides. Plastic or fibrous metamorphosis of the muscular tissue about any of these lesions may occur. Whitish diffuse infiltrations, firm, or of the consistence of a sarcoma, with round-celled infiltrations and vegetations, may affect the endocardium or muscular tissue; and the same changes in the pericardium may result in partial or total obliteration of its sac. These commonly originate in subendocardial or subpericardial gummata. Wagner, Lancereaux, and a few others have reported gummata limited to these serous membranes. The symptoms excited by these changes are dyspnœa, palpitation, cyanosis, præcordial distress, and angina pectoris. The prognosis is naturally grave, since all the identified instances of this affection were recognized in the bodies of the dead. It is reasonable, however, to suppose that syphilis here, as elsewhere, exhibits its usual amenability to treatment in the case of patients with symptoms not diagnosticated in life.

Arteries and Veins.—The femoral, jugular, saphena, and other veins may be affected with a phlebitis due usually to the pressure exercised by a gummatous tumor in the vicinity. A sclerous phlebitis, in which the intima was first attacked, has also been recognized post mortem.

The capillaries and arteries also may be primarily or secondarily involved. In the latter case the result is commonly due to compressive or destructive effects exerted by syphilitic processes upon adjacent organs. Syphilitic endarteritis, however, is much more common; and investigation by Virchow, Heubner, and others has revealed its pathology with sufficient clearness. The lesions are more commonly observed in the smaller cerebral arteries, but the carotids and other vessels are occasionally involved. The definite limitation of the disease to a single patch is declared by the rapid appearance of whitish, opaque nodules, the size of a millet-seed, composed of small, roundish, or spindle-shaped cells, which may be agglomerated into a firm, fibrous mass, from the size of a pea to that of a nut, obliterating the lumen of the invaded artery by thickening of all its investing coats, and producing eventually either rupture or an atrophic or cicatriform relic of its existence. This infarction is remarkable for the indirect results which it produces, including cephalalgic, aphasic, paretic, paraplegic, and even comatose symptoms.

The Genito-urinary Organs.—Symptoms of syphilis are disclosed in the genito-urinary tract of patients of both sexes, early and late in the course of the disease.

The penis may become, in one part or another, the seat of circumscribed syphilitic infiltrations and gummata.

Lesions of this nature may be subcutaneous, or there may be nut-sized masses deeply lodged in the substance of the corpora cavernosa, or in the submucous tissue of the urethra. Some of the lesions discovered post mortem, and described as "chancres of the deep urethra," are really tertiary ulcers resulting from broken-down gummata of the prostatic or membranous urethra. Jullien figures a cavern of the cutaneous surface of the penis originating in this way in one of Langlebert's patients. Tubercles of syphilitic origin may be developed near the furrow at the base of the glans.

Each part of the *testicles* may be affected with syphilis.

The epididymis, when involved, may display either an early or a late form of syphilitic epididymitis.

The early form, first described by Dron, in 1863, may be observed at any time between the third and thirtieth months after infection. The disorder bears no relation to gonorrhœal epididymitis. The globus major, or head, of the organ, much more rarely the globus minor, is attacked and either insidiously or acutely affected, producing a roundish or squarish, circumscribed tumor, from the size of a bean to that of a small nut, which has been compared to a "monkey-nut screwed to the testicle." One or both organs may be involved, successively or simultaneously, and the globus minor may be attacked later. The affection is amenable to treatment, and commonly disappears without unfortunate sequelæ.

The late form is often connected with gummatous changes in the testis proper, but very rarely arises independently of the latter. Here also the globus major is more often attacked; and resolution, as is the case with deposits in the testis proper, may be followed by atrophic changes.

Syphilitic *orchitis*, sarcocele, or albuginitis, may be a relatively early or late symptom of syphilis, involving one or both organs simultaneously or in succession. In these cases, the body of the testicle is involved, often without the production of pain, in a smooth, uniform, and firm swelling, which may be due in part to enlargement of the testicle, and in part to a moderate grade of hydrocele concealing the irregularities perceptible later in the body of the organ. In other cases, this body can be recognized by palpation as the seat of one or several masses, from the size of a pea to that of a small nut, which may be at first isolated and circumscribed, but later become fused into a solid, resisting mass having the general shape of the testicle, but often three or four times larger. Under energetic treatment, resolution of these masses is accomplished; but obliteration of the vasa deferentia and atrophy, or fatty, fibrous, cartilaginous, amylaceous, even osseous metamorphosis of the parenchymatous tissue of the gland may follow the absorption of the neoplasm. In this way the testicle may be, after completion of this cycle of changes, represented by merely a bean-sized mass of fibrous tissue. Suppuration and ulceration of the tunics almost never result, though a few authors have reported a resulting "fungus of the testicle."

Pathologically studied, the glands are found to be the seat of vascularization and proliferation of connective tissue, resulting in the production of fibrous trabeculæ traversing the organ in various directions, but always attached to its thickened investments, resulting by contracture in compression and atrophy of the secreting cells of the tubules. In other cases, true, grayish or yellowish gummata are found in the testis, single or multiple, diffuse or circumscribed, from the size of a pinhead to that of a pigeon's egg, environed by fibrous capsular coats. These commonly disappear by absorption; even in the rare cases of disintegration and the formation of "fungus of the testis," recovery ensues under proper treatment.

All syphilitic lesions of the epididymis and testis are to be distinguished from the gonorrhœal, the cancerous, the sarcomatous, and the tuberculous. The blennorrhagic affections of the epididymis are acute in type, painful, attack the tail of the organ by preference, and are usually preceded by an unequivocal history of urethritis and discharge. The neoplasms of cancer and sarcoma in the testicle, more often occurring in subjects of advanced age as contrasted with the younger victims of syphilis, are usually accompanied by inguinal adenopathy, severe pain, systemic cachexia, extensive damage to the parts affected, and proneness to disintegration. Tuberculosis is more common in young men virgin of all venereal antecedents, usually with tuberculosis of the prostate gland and marked dysuria. The bacillus tuberculosis may be recognized in the secretion obtained by "milking" the prostate. The treatment internally is by the potassium iodide and mercury. Locally, suspension of the organ is to be recommended; hot fomentations for relief of pain when such exists; and applications of salves containing lead, mercury, belladonna, or opium. The oleate of mercury and morphine, mercurial plaster, white precipitate salve, or the compound iodine ointment may be applied. Strapping, as employed for relief of gonorrhœal epididymitis, may be practised with advantage in some cases. The prognosis is not unfavorable as regards the health of the patient; but, after double syphilitic orchitis, the patient may have complete aspermatism. The *prostate gland, vasa deferentia, common ejaculatory ducts*, and *vesiculæ seminales* are all the seat at times of syphilitic changes, the characters of which are not known.

In women the *labium majus*, usually one, occasionally both, may be the seat of gummatous changes due to syphilis. These may be late and unique manifestations of the disease. Often nothing can be gathered in cases of this sort as to the history of syphilis, a not uncommon experience in the infected of that sex. The organ is found, when examined, to be wholly or in part the seat of a dense, smooth or irregularly lobulated, vertically disposed tumor, very closely resembling in size and external appearance a scrotum containing a testicle affected with syphilitic orchitis. Syphilitic gumma of the vulva is usually an exceedingly indolent affection, lasting for long periods of time, rarely occurring at the outset till three or four years have elapsed since infection. It is often diagnosticated as "elephantiasis" of the labium. Disintegration of the mass by ulceration is rare.

The syphiloma of the vagina is similar to the lesion described above in the date of its occurrence, its exceedingly indolent career, and its existence for months without a single coincident symptom of syphilis to substantiate the diagnosis. Many of these cases have been recorded, treated, described, and even illustrated as "lupus of the vulva," or "of the vagina," which disorder is even rarer than this exceedingly rare manifestation of syphilis. When recognized, the vagina is converted into a thickened cylinder of tissue infiltrated with gummatous material, which greatly restricts the distensibility of the vaginal walls. In some of these cases the finger can with great difficulty be introduced into a channel through which viable infants have been ushered into the world. Irregular projections of the inextensible vaginal membrane, club-shaped, knobbed, granular, eroded, or ulcerated, represent points where the larger submucous gummata are undergoing extreme development or ulcerating. These lesions break down more frequently and more disastrously than do the gummatous metamorphoses of the labia. Occasionally the ostium vaginæ is converted into a vast gummatous ulcer, invading the vestibulum and even the urethra. In severe cases the rectum participates in the change.

The neck and body of the *uterus* exhibit more rarely and to a much less marked degree similar changes; induration, tumefaction, erosion, and ulceration of the mucous lining are reported by authors.

The Fallopian Tubes and Ovaries.—Lancereaux and Lecorché, respectively, have reported instances of diffuse and gummatous changes in the ovaries. In the case reported by the first-named author, there were two egg-sized tumors with long diameters parallel with the broad ligament. Bouchard and Lepine, quoted by Jullien, describe a single case of syphilitic salpingitis.

The kidneys undergo changes both in early and in late syphilis. The phosphates and chlorides may be unchanged in the urine; urea may be quantitatively in excess, and albumin occur in quantities as great as in Bright's disease. Severe albuminuria following syphilitic changes in the kidney and even extensive anasarca following may be satisfactorily relieved by treatment. Glycosuria has appeared and disappeared under precisely similar circumstances in syphilitic subjects. By some authors, these several conditions are claimed to be the results simply of the cachexia which may affect syphilitic as well as non-syphilitic patients, producing thus the amyloid, waxy, and other metamorphoses recognized in other cases. Without denying the possibility of such accidents, the striking fact remains that some of these cases bear the special imprint of syphilis in that, after the exhibition of alarming symptoms, a complete, rapid, and permanent recovery may ensue after energetic treatment by mercury and, more often, by the iodide of potassium.

Syphilitic sclerosis and gummata of the kidney are late lesions of syphilis, and of rare occurrence, the last named being decidedly the rarer of the two accidents. In the diffuse form of syphilitic nephritis there is usually a cycle of vascularization and tumefaction of the cortical portion, followed by interstitial proliferation, attachment of capsule to cortex, and formation of irregular, small, or large nodules and projections from the surface, the exterior gross appearances of which suggest the similar lobulations of the syphilitic testicle. In some places these undergo lardaceous, amyloid, and other degenerative changes resulting in cicatrices. Precisely as the seminiferous tubules of the testicle are choked and eventually reduced to atrophy, the glomeruli and uriniferous tubules of the kidney may be compressed, their channels obliterated, and their functions arrested. Here and there, on section, yellowish points or streaks of fatty metamorphosis are visible upon a granular surface; or the totality of the organ may be changed to a dead-whitish color.

Gummata of the kidney are developed in both the cortical and the pyramidal portions. They are single or multiple, grayish or whitish, definitely circumscribed masses, from the size of a pinhead to that of a pigeon's egg, with a whitish or reddened and vascular, fibrous envelope like a capsule. The centre is firm or cheesy, according to the age of the gumma; and the body of the lesion is made up of elements derived by proliferation from the connective tissue of the renal stroma. The subjects of these several complications of syphilis may suffer from vague pains, changes in the eye, peritoneum, pleura, and nervous centres, as well as ascites, anasarca, lumbar pain, hæmaturia, and albuminuria. The prognosis is decidedly less grave than in non-specific renal affections of similar type.

The Nervous System.—Affections of the nervous system may be early or late symptoms of syphilis, and are commonly the results of morbid changes in contiguous structures, such as bone, vessel, or investing membrane. They are much more common in men, chiefly because of the greater tax levied upon that sex in the demand for physical and mental strain.

The literature of nervous syphilis, most of which has been contributed during the last twenty years, has been both voluminous and valuable. In the following paragraphs it will be possible merely to trace the outlines of the important advances which have been made in this special field. The clinical pictures presented may be briefly named as follows:

Headache, insomnia, and irregular performance of functions of many of the organs of the body (eye, ear, heart, muscle, liver), dependent upon nervous disturbance, are not infrequent in the early periods of syphilis. The headache of this stage of the disease is often persistent and obstinate. It may be frontal, temporal, or occipital in situation, and of the moderate grade from which few infected subjects are wholly exempt, or severe, with intense nocturnal exacerbation, eliciting groans from the sufferer. This distressing complication of the disease may endure for only a few days, or last for weeks or months, proving eventually a mere precursory symptom of cerebral syphilis. Without question these symptoms are often recurrences or exaggerations of morbid states existing previous to infection by the subjects of hysteria, alcoholism, other cerebral affections, and epilepsy. Mild nervous manifestations may be recognized, including anæsthesia, analgesia, circumscribed hyperidrosis, and hypertrichosis, and cutaneous sensations of coolness, heat, formication, and tingling. Many of these features are such that the pathological changes on which they depend are necessarily unknown, or can be estimated only by reasoning from analogy. The supposed cerebral syphilis *sine materia* has for its basis only the non-recognition of structural changes where autopsies were made after the exhibition of well-marked nervous symptoms. In such cases, the possibility that the actual physical basis of the morbid phenomena was simply not discovered cannot properly be ignored.

When a patient is actually affected with *cerebral syphilis*, the unmistakable features of the accident, as indicated above, often follow the milder symptoms. The headache, which was at first simply annoying or tolerable, sets in with paroxysms of distress which make the patient dread the hours of the night as a period of torture. Constant or intermittent grinding, boring, or hammering sensations are referred to the whole or any one of the regions of the head described above. The patient becomes eloquent in declaring that the head feels as if it were screwed in a vice, riveted with iron bands, hammered upon an anvil, etc. Under treatment even this condition may yield in a few days, or, defying all skill (a rare complication), go on to the extreme conditions described later. At times definitely circumscribed regions of tenderness may be appreciated by both patient and physician, the latter by the pain evoked in percussion of the cranial vault. Insomnia, vertigo, intellectual hebetude, apathy, melancholia, and other morbid mental states, photophobia, and marked cachexia are the usual concomitants of this state. When the disorder progresses uninterruptedly to full evolution, the patient becomes weaker, takes to the bed day and night, may exhibit some mild ataxic or paretic symptoms, usually goes into delirium, and presents the picture of one affected with utterly hopeless cerebral disease. Yet here, as so often in the history of this singular malady, he is really far from such a hopeless state, and thus furnishes the diagnostician with a clew to the syphilitic origin of the disease. Such a patient, properly treated, may rise from his bed, regain his flesh, return to his occupation, and live out his natural days, so far as regards the disorder under consideration.

Many odd features may be presented in the course of this complication. There are patients thus affected who present singular hallucinations; yet others suffer from vague terrors, dreading self-destruction or attacks from enemies.

Chorea, or at least choreic symptoms, may be recognized in some patients of this class. Spasmodic contractions may affect one or a group of muscles, either before or after the occurrence of paralytic symptoms, or independently of the latter. There may be slight, severe, transitory, remittent, or constant contractions of muscles of the head or extremities. A persistent, rhythmical swaying of the head from side to side may last during the hours of wakefulness for a fortnight.

Aphasia, partial or complete, continuous or intermittent, often of sudden onset, may be the sole symptom of nervous syphilis, or occur before or after some of its grave complications.

Paralysis, sensory or motor, partial or complete, usually succeeds a prodromal stage in which the patient has complained of obstinately persistent headache or some other premonitory symptom of cerebral disorder. The paralyses of the motor muscles of the eye belonging to this group of disorders have been already described. In a similar way the nerves of special sense, not only those of vision and hearing, but also those of olfaction and gustation, are totally or partially deprived of sensitiveness to external impressions.

Hemiplegia, occurring suddenly in a patient under fifty years of age, is, in the great majority of all cases, of syphilitic origin. It may be of early or late, sudden or gradual occurrence, and constitute a mere paresis of a group of muscles on one side, or, much more rarely, a complete motor paralysis of one-half of the body. It is usually preceded by cephalalgia, vertigo, lassitude, and neuralgia, with anæsthesia or tingling of the parts about to be affected, or mild choreic, rarely convulsive, seizures. Usually, after well-marked prodromal symptoms have been exhibited for some days or weeks, the patient awakes from sleep to find himself more or less unable to move one or both limbs of one side; or the attack comes on in the hours of the day, the patient falling to the ground in a state of partial unconsciousness. The leg only is most commonly affected; at times it is followed by involvement of the arm. Rarely the arm alone is affected. The bladder and rectum may participate in the resulting symptoms by loss of power to expel their contents. Alternate paralysis of the facial muscles is occasionally noted, *e.g.*, the right leg and the left side of the face. There may be dilatation of the pupil of the eye on the sound or affected side, with or without ptosis and involvement of the oculomotorius. With these symptoms are occasionally associated total genital impotence, which may even survive the paralytic symptoms in the extremities, muscular tremors, and contractures. Sensory disturbances are few; rarely there is complete sensorimotor loss. The affection is commonly attributed to an obliterating endarteritis. The prognosis in most cases is favorable as respects the preservation of life, but restoration of the function of the paralyzed organ is rarely complete.

Epilepsy is simulated in syphilis, under the influence of which epileptiform seizures occur. They are far rarer than hemiplegic complications. With or without premonitory sensations comparable to those experienced in the aura, both the *grand mal* and *petit mal* are represented in syphilitic seizures. There is, in the first case, the usual precursory severe cephalalgia, followed by distressing sensations in the extremities or about the heart, or singular creeping sensations of chilliness. Jullien insists that during these attacks the patient, even if unable to speak or to move, never wholly loses consciousness and never utters the cry, an important diagnostic distinction.

The patient may fall as if shot, and exhibit tonic, followed by clonic, convulsions during a portion of the time, but rarely throughout the whole period occupied by a seizure. These convulsive movements do not notably affect all of the muscles of the body. The patient may foam at the mouth and bite the tongue or lips, though often, with marked convulsive seizures, these symptoms are absent. The intervals between these crises may be but a few hours, or days, or several weeks. They tend to multiply with each recurrence, and may result in dementia.

The *petit mal*, or mild form, is betrayed in tremors, spasms of the muscles, for example, of a single limb, or of the neck, or of one shoulder; dyspnœa, dysphagia, or vertigo. Other patients experience sudden loss of memory, or imperception of environment, confusion of ideation, and incoherence of speech.

Paraplegia is, in more than fifty per cent. of all cases occurring in male patients under forty years of age, of syphilitic origin. Over ninety per cent. of cases of syphilitic paraplegia occur in males. There may be precedent cephalalgia of extreme violence, rachialgia, neuralgia, convulsive seizures of the muscles of the lower extremities, and hyperæsthesia or anæsthesia of the cutaneous surface. The paraplegia may be partial or complete, and sudden or gradual as to occurrence, but, as Althaus indicates, is unaccompanied by loss of consciousness, the patient often "assisting" at the invasion. It is apt to terminate in complete loss of power of both lower extremities, with and without sensory disturbances, partial paralysis of rectum and bladder, and complete impotence, lasting often for years. One side of the body may be involved after the other; or the same side may be again affected after an interval of months has elapsed. Paralysis of cranial nerves, mental hebetude, mydriasis, and other signs of syphilis of the nervous system may be present, but are often absent; and when the paraplegia is complete this may be the sole objective symptom of the infective disease.

Tabes is an affection the precise etiological relations of which have been the subject of no little careful study and discussion. By Fournier the disorder is classed with a group of morbid conditions named by him the "parasyphilitic affections." It is now fairly well established that between seventy-five and eighty per cent. of cases of locomotor ataxia occurs in syphilitic subjects, chiefly male patients; and the symptomatology, pathology, diagnosis, and prognosis of this affection, as detailed in the treatises devoted to the subject, belong to the domain of syphilis. None the less it is to be admitted that, in the minority of cases represented by the percentages given above, the disease occurs with classical features in persons who have never contracted syphilis; and further that, as in the other affections of the group described as "parasyphilitic," there is little if any amenability to antisyphilitic treatment. In the syphilitic affections of the cord, the well-defined sclerosis of the posterior columns which is characteristic of progressive spinal ataxia is not readily recognized.

Syphilis rarely selects a definitely limited portion of the cord for its manifestations, but involves here and there a patch in the columns, near which can commonly be recognized altered vessels or investing membranes where the morbid process originated.

General paralysis of the insane ("*Délire des grandeurs*") is to-day by most modern authors placed in the category of affections described by Fournier as "parasyphilitic." It occurs in the victims of former syphilis, in almost the same proportion as does tabes; and, like that disorder, is singularly uninfluenced by antisyphilitic treatment. Due weight can be given to the argument that these are "parasyphilitic" rather than syphilitic disorders (by reason of their admitted failure to respond to energetic treatment of a syphilitic involvement) when attention is drawn to the significant fact that a group of other admittedly syphilitic changes are to the same slight degree influenced by an appropriate therapy; as for example, the pigmentary syphiloderm, monolateral mydriasis, hemianopsia, etc., all syphilitic in origin.

Jullien calls attention to the fact that the syphilitic patient supposed to have general paralysis is really ill (cachectic, anæmic, or adynamic), while the "real fool," on the contrary, exhibiting moral decrepitude, stupid facial expression, and perturbed cerebration, appears to be otherwise in good physical health. The former, moreover, is apt to display one or more of the syphilitic paralyses following a characteristic vertigo, hemicrania, or a cephalalgia, or some one of the ocular or aural complications of syphilis, in brief, at capriciously selected points where nervous symptoms are displayed. This also is associated with a milder exaltation of ideas and a more rapid evolution of symptoms.

Other symptoms of nervous syphilis are exhibited in gastro-intestinal derangements (vomiting, etc.), in functional disturbances of the kidneys and bladder, and in disorders of other viscera.

Coma, preceded by cephalalgia, anæsthesia, mental hebetude, or aphasic symptoms, may occur during sleep or result from sudden diurnal accidents. The patient is usually found lying listless, or apparently asleep, pallid, expressionless, and not suffering pain. He may be roused to take food or drink, to thrust out the tongue, or even momentarily to recognize a friend or answer a question. The pupils are usually contracted, insensitive to the light, and covered by the lids. The globes are shrunken in the orbits. Sensibility and reflex excitability are either wholly preserved, impaired, or lost. The pulse and respiration are retarded in frequency, the temperature is subnormal, and the excretions are passed unconsciously.

The pathology of these several complications of syphilis is explained chiefly in post-mortem examinations.

The cranial and other bones, when involved in an ostitis or periostitis (diffuse, circumscribed, gummatous), may produce nodes capable of explaining etiologically several of the groups of symptoms described above by pressure effects, including inflammation and even destruction of the parts invaded. Nodes of the internal tables of the cranial vault or of the vertebræ may thus be responsible for mental, paretic, paralytic, convulsive, neuralgic, and ataxic symptoms of the most varied character. Well-defined cranial nodes in the outer table also of the skull are, as the result of sympathetic influences, capable of producing many of the milder symptoms of nervous syphilis.

The meninges of the brain (dura mater, arachnoid, pia mater) are subject to the same involvement. They may be changed by pressure of a node, and be agglutinated to it; or may be separately involved in diffuse or circumscribed, single or multiple thickenings, due to proliferation and vascularization of the tissues (pachymeningitis). The lesions may be symmetrical or asymmetrical, and involve the brain more often than the cord. These changes are capable in various degrees of producing cephalalgia; and at times a distinct area of meningeal surface may be recognized as the seat of the severe headache of syphilis, with intense nocturnal exacerbation, by pressure or percussion with the finger over a limited region of the skull—a manœuvre which decidedly increases the pain.

The brain and medulla are always involved as a sequence of changes either in the bones, meninges, or vessels in anatomical relation with those organs. The softening which results may be either of the red or white forms of *ramollissement* recognized in non-syphilitic cerebral disease. Gummata of the brain may be single, or usually multiple, occasionally exceedingly numerous, circumscribed or diffuse, superficial or deep tumors, from the size of a millet-seed to that of a small egg. They most often exist as superficial lesions in direct association with gummatous changes in the meninges. They have a well-defined yellowish or whitish cheesy centre, with a firm, sclerotic, peripheral mass set in vascularized and greatly softened nervous tissue. Evidences of simple inflammation in the brain substance, excited by the irritating presence of the neoplasm, are usually to be recognized, and are described by Jullien as distinctive marks of a cerebral syphiloma, inasmuch as the brain substance tolerates with greater ease the softer nodules of tuberculosis. The deep-set lesions are much rarer, but are recognized, for example, in the substance of one ventricle, in the optic thalamus, the corpus striatum, or the white substance of the cord.

The arterial changes, responsible for so many of the nervous complications of syphilis, are of frequent occurrence, and may be primary or consecutive in order—that is, they may be the original and immediate cause of cerebral disease or the sequence of changes induced by a neighboring gumma or pachymeningitis. Heubner, Greenfield, Hutchinson, Dowse, Dreschfeld, and others have chiefly contributed to the present knowledge of this interesting subject. The small arteries are most often attacked, symmetrically at times as regards the two halves of the brain, in distinctly limited areas, where whitish points or nodules become visible to the naked eye. Longitudinal section of vessels thus implicated reveals an obliteration wholly or in part of the lumen of the vascular tube, due to thickening of the inner coat; the middle, clearly defined, being scarcely affected (endarteritis obliterans). The adventitia is doubled or trebled in volume, its cells under the microscope being exhibited as long, parallel, fusiform elements. The obliteration of the lumen, however, is chiefly due to a cellular proliferation between the endothelial lining of the vessel and the fenestrated membrane, resembling a granuloma in appearance. Externally and internally are flattened or fusiform cells, arranged more or less regularly in parallel lines, between which are more irregularly and loosely packed larger cells, mingled with minute fibres of elastic tissue and the vasa vasorum. The endothelium is then finally separated from the membrana fenestrata, and projects into the lumen of the vessel as a vegetation, occasionally forming a second fenestrated membrane on the sides of the vessel wall. In this way complete stenosis of the tube is eventually produced—an accident rare in atheroma, in which the cellular proliferation is more indolent, more generalized, more disposed to terminate by calcification, and never results in complete obliteration. These accidents are often the causes of the severe headache, vertigo, chorea, epilepsy, and other of the nervous phenomena noted above.

It is by the production of thrombosis or cerebral ischæmia that the arterial stenosis operates to induce the derangement.

A syphilitic periarteritis is described by a few authors (Charcot, Rabot, Bumstead and Taylor), in which circumscribed, lenticular, whitish masses of irregular shape result from an endarteritis affecting the external coats of the vessel, with proliferation also of the media and internal coat. The internal elastic tissue is reported intact, with round-celled infiltration of the muscular layer, and multiplication and dilatation of the vasa vasorum.

The cerebro-spinal nerves may suffer compression by an osseous or meningeal lesion of syphilis sufficient to produce a series of symptoms ranging from formication, hyperæsthesia, and moderate numbness to complete anæsthesia, analgesia (rare), or paralysis. The derangements of vision induced by syphilitic changes in the optic nerves supplying the muscles that move the globe of the eye have been already considered. In a similar way, the olfactory, sympathetic, and other nerves may be implicated. Petrow, in the cases examined by him in which the sympathetic nervous trunks were involved, recognized a pigmentation of the cellular protoplasm, attributed to the deposit of hæmatin in the nervous cells. The endothelial elements were proliferating and surrounded by polygonal nucleated cells, some undergoing colloid metamorphosis. These nervous elements were compressed by an hyperplastic connective-tissue growth, undergoing later sclerosis, and eventually starving the nervous elements into atrophy. The membranous envelope of the latter, after undergoing hypertrophy, may be the seat of fatty metamorphosis.

The treatment of the nervous complications of syphilis is that of the disease in general. The credit of employing large and progressively larger doses of the iodide of potassium in all serious emergencies, with brilliant results, is largely due to American practitioners. The best and simplest way of attaining the end is to administer drop doses of a saturated aqueous solution of the potassic or sodic iodide in a gobletful of water or milk every four hours, beginning with a relatively small dose, five to ten drops (0.33–0.66), and pushing on by increasing one drop each dose until the end in view is reached. By this means one ounce and a half (48.00) of the iodide may be given in twenty-four hours, with happy effect; and still larger doses have been reached by others. The pepsin, pancreatin, or takadiastase solutions may be employed at times with great advantage as vehicles for the administration of the salt. The rule should be to stop the increase at once on the supervention of any toxic effects or marked symptoms of physical protest against the large dose; to then hold at a given point, or to reduce the dose to a point of complete toleration, and to recognize the fact that after the extreme point of toleration has been fully reached, perhaps slightly surpassed, and for a moderate length of time held, further medication of this sort, in the absence of the definite and brilliant results usually attained by its adoption, is useless and in cases harmful. In the absence of such desired results, mercury in full doses (*e.g.*, calomel gr. $\frac{1}{10}$ [0.0066] every hour or two in any serious emergency) may prove of inestimable value.

The prognosis in syphilis of the nervous system, even in the face of apparently desperate peril, is far more favorable than in the case of nervous symptoms of similar import occurring in those who are not the victims of that disease.

Muscles, Tendons, and Articulations.—Muscular contracture is described by a number of authors as a syphilitic accident occurring slowly or rapidly, and producing fixed flexion or extension of any movable part to which the tendon of the muscle is attached, the latter, on palpation, being recognized as a rigid and inflexible cord. The joints are not in such cases involved. One or several muscles may be attacked, the biceps being that most commonly affected, the forearm being then flexed at an acute angle upon the arm. The involved muscle may and may not be then the seat of pain and tenderness. A tetaniform involvement also of a much larger number of muscles is described as of occurrence in syphilis.

In the diffuse form of myositis occurring in syphilis, there is diffuse swelling of the whole or a part of a muscle, some redness and œdema of the overlying skin, and pain when the muscular fibres contract. Gummata of the muscles are small, at first firm, later softish, usually globular masses, from the size of a nut to that of an egg, of insidious development, and often, when in process of disintegration, attached to the skin and undergoing the cycle of changes already described in connection with the ulcer resulting from subcutaneous gummata. It is believed that the sheaths of the muscle-bundles are first involved in these changes. They undergo, in some instances, osseous and cartilaginous metamorphoses instead of disintegrating.

The tendons, tendinous sheaths, and aponeuroses may become in syphilis the seat of flattish, triangular, circumscribed, and usually painless tumors, due to effusion in the serous sacs; or to projecting gummata which may break down and ulcerate, leaving a cicatrix the contracture of which may subsequently interfere with the function of the muscle to which such a tendon or aponeurosis is attached. Diffuse gummatous thickenings also affect the fasciæ and aponeuroses, more particularly those of the lower extremities.

In gummatous syphilis the bursæ are not rarely affected, more particularly those of the patella and of the tibial tuberosity. They begin as single, painless or slightly painful, firm, elastic, or softish gummata, from the size of a nut to that of an egg, which are apt to involve the skin eventually, and to be obstinate under treatment.

Syphilitic rheumatism (arthralgia, pseudo rheumatism) may be an acute, more often a subacute, polyarthritis with tender and painful points about the articulations, preceded often for days by arthritic pains, as distinguished from simple rheumatism. This complication is remarkable for the failure of acuity in the symptoms, the relative painlessness of the affected joints, the absence of articular swellings (*arthritis sine materia*), and the nocturnal exacerbation of the pain. Hydrarthrosis, most commonly symmetrical and of the knee joints, though also mono-articular, is both an early and a late symptom of syphilis, and is chiefly remarkable for the extent to which the joints may be distended with synovial fluid, and be yet sufficiently free from pain to permit of performance of their function. It often recurs and disappears for several weeks at a time. The so-called "syphilitic white swelling" is due to fibrous thickenings and subsynovial, gummatous infiltrations in and about the joint. These synovial effusions chiefly occur in the subjects of cachexia, or male patients of fragile constitution.

The fingers and toes may be the seat of early and late syphilitic lesions, and in both acquired and inherited syphilis. To Dr. R. W. Taylor's researches we are indebted for a knowledge of this interesting subject, to which merely a brief reference can be made in these pages.

The affection is more common in hereditary than in acquired disease. In the former the disease may begin in the subcutaneous connective and fibrous articular tissues, or primarily in the osseous and periosteal tissues, and consecutively invade the other structures named. The digit affected, either in one or in several phalanges, enlarges insidiously, becomes dense, painful, inflexible, with attached overlying and purplish-red skin. Sometimes an articular hydrarthrosis can be detected; again, one or more of the symptoms resulting from gummatous infiltration. These gummatous deposit. are circumscribed or diffuse, and not prone to ulcerative degeneration. Specific dactylitic osteomyelitis, periostitis, or osteoperiostitis may be a slow, rapid, or relapsing accident, producing in full evolution a balloon- or acorn-shaped, globular, or pyrform swelling, involving one or several phalanges of a single digit, usually the proximal, and more often those of the fingers than of the toes. As sequelæ, may be enumerated inflammatory changes with abscesses discharging a caseous matter, crepitation from roughness of the articular faces of the cartilages, the formation of sinuses, hydrarthrosis, and osseous atrophy after resorption of the gummatous deposit, leaving the shaft of the phalanx more slender and fragile than before. In other yet more marked cases the phalanx is reduced by shrinkage till the finger is shortened one-third or one-fourth of its length. The resulting deformity is conspicuous, and almost peculiar to the special disease under consideration.

Cartilages and bones are attacked in both early and late forms of the disease. The most common form of bone disease is an osteoperiostitis characterized by inflammatory phenomena, vascularization, and exudation, diffuse or circumscribed, of the area of contact of the osseous and periosteal surfaces. The result is declared in the formation of well-defined, rarely poorly circumscribed nodosities in various degrees sensitive, and usually the seat of a characteristic pain, intensely, often intolerably, aggravated at night after retiring to bed. Absorption may result or, much more rarely, degeneration and exfoliation of a thin lamella of bone. In other cases an exostosis results from a plastic effusion between the periosteum and bone, usually circumscribed and flattish, globoid, annular, sessile, or pedunculated, which may undergo eburnation and exhibit compact or cancellated tissue in its structure. When the bone has been infiltrated with a gummatous material which degenerates, it is usually the epiphysis which is the seat of the disorder, though the medulla (osteomyelitis) and bony substance, or even periosteum and bone, may be involved. Ulceration may then leave a roundish cavity, from the size of a pea to that of a nut, possibly communicating with the medullary canal, filled with a bright yellowish pulp; the faces of the cartilages become the seat of salient granulations and depressions (scars?), the size of millet-seeds. At times the diaphysis of the bone is first attacked and the epiphysis secondarily. Often the synovial membrane remains intact.

The "dry caries" or "inflammatory atrophy" of Virchow is a change beginning with vascularization, but unaccompanied by suppuration or ulceration, in which the osseous substance is found wanting in stellate or foveolated pits which may enlarge in the line of furrows representing the Haversian canals. These parts are surrounded by hyperostosis. These and similar depressions in the osseous substances, when osteoid growth has ceased centrally and is actively progressing at the periphery, may be regarded as syphilitic cicatrices of bone. The meninges, periosteum, and integument may participate in the formation of such cicatrices, resulting finally in the production of a uniform, thin, contractured, whitish or grayish fibrous tissue, unprovided with vessels.

The various bones of the skeleton are in different degrees subject to the several changes described above. The vault of the cranium is particularly liable, in both external and internal tables, to exhibit single or multiple, circumscribed osseous changes, as also are the sternum, the clavicle, the ribs, and particularly the tibiæ. The substernal and similar pains, noted so frequently as precocious phenomena in the early periods of the disease, are probably associated with transitory osteoperiosteal hyperæmia. In the later periods the nodes that form, whether inflammatory or gummatous in type, are characterized by the same severe nocturnal exaggeration of the pain they excite and by marked localized tenderness. Some of the consequences resulting from the pressure induced by intracranial nodes have been described in the paragraphs devoted to the phenomena of nervous syphilis. Gummata of the frontal and temporal bones, forming firm projecting tumors, are at times so conspicuous as to produce marked deformity. Other bones besides those named, *e.g.*, the radius, ulna, femur, maxillary, and, indeed, any part of the skeleton, may become the seat of these lesions. The treatment is that of syphilis in general, more particularly in its advanced stage. The remarkable effect of the potassic iodide upon many of these lesions is one of the demonstrations, which even the most sceptical are compelled to accept, of the signal efficacy of an ingested drug upon a neoplasm defying local therapy. The dose is to be pushed, to secure marked relief, to any required point precisely as indicated above in the management of nervous symptoms. Indeed, as will be gathered from what has preceded, the same treatment is often urgently demanded in the same patient, at the same moment, for relief of grave nervous complications depending solely upon syphilitic osseous disease. Locally, the mercurial ointments, plasters, and oleates, with occasional use of anodynes, fill an important part.

HEREDITARY SYPHILIS.—This form of the disease, the only one not known to originate by an initial sclerosis, is also termed congenital and infantile syphilis. The syphilis of infants, acquired by accidental or intentional transmission after birth, is practically that of acquired syphilis of adults, the differences being chiefly due to the tender skin of the young patient and its extreme liability to nutritional disorders.

Hereditary syphilis is the disease transmitted by inheritance from one or both progenitors to a second generation. Evidences of such transmission to the third generation are extremely rare. The more active the disease in the progenitors, the greater the chances of infection of the offspring.

In inherited, no less than in acquired, syphilis pathologists have recognized micro-organisms which have been claimed to be effective in the evolution of the disease. Doutrelepont, Kassowitz, Hochsinger, Kalisko, and Chatzen have both detected and failed to detect streptococci in the viscera of children affected with hereditary lues, as also in the skin, mucous surfaces, bones, and liver. In some instances the lymph-channels have been found choked with micro organisms of this kind, which fact has suggested to Chatzen that the cachexia of some patients in this category was a streptococcic septicæmia.

Relative Influence of the Parents in the Transmission of the Disease.—The father alone, when the victim of active constitutional syphilis, is capable of transmitting the disease to his child without infection of the mother. It is probable that he does not possess this power before the disease is actively displayed in his own person by constitutional symptoms. It is certain that this power is greatly weakened while he is under the influence of mercury; is weakened and regained during the respective periods of repose and activity so commonly observed in the disease; and is finally extinguished by time. It remains to be admitted that the cases in which the father alone is thus responsible for syphilis in the second generation are far fewer than those in which the mother alone is thus responsible; and that the power of such transmissibility is positively denied to the father by the followers of Cullerier, Oewre, and others.

The mother alone, the father being unaffected, may transmit syphilis to the child, if she be the victim of active constitutional disease. If conception occur later than the twentieth day after the appearance of the earliest syphiloderm, the product of such conception is almost certainly doomed to destruction, abortion of the ovum commonly following from the third to the seventh month. The woman, however profoundly syphilitic, may abort or miscarry in consequence of the cachectic state to which she is reduced by syphilis, and may thus throw off, as in any cachectic condition, the unaffected germ. Again, the child may escape entirely by the operation of that inscrutable law which ever and again protects the offspring from the vices and errors of the parents. Lastly, in a series of pregnancies, abortions may be followed by miscarriages; the latter by stillbirths at term; then by viable infants exhibiting symptoms of syphilis before the fourth month of life; and, lastly, by the birth of children in whom syphilis can never be recognized, the power of transmission being weakened till it is wholly lost in the process of time.

If the mother be affected after conception, it is possible that she cannot convey her disease to the child. She may abort or miscarry in consequence of the anæmia induced by her own disease, but it is improbable that, either in the first or latter half of pregnancy (both periods have been claimed as those of special danger), the virus can be transmitted through the utero-placental circulation. Cases have been cited in support of both views as to the possibility and impossibility of such transmission, the cases cited in support of the affirmative view being in the main defective, by reason of failure to demonstrate both perfect immunity of the father and positive syphilis of the child.

A healthy mother may bear a syphilitic child. On this point also there has been much division of authority. The larger number of all mothers who bear syphilitic children are themselves unquestionably syphilitic. But the possibility that a syphilitic child may be infected by inheritance from the father alone, the mother remaining sound (precisely as is the case when the child is sound and the mother infected), is demonstrated by numerous records. In this country the facts set forth abroad by Kassowitz and others have been substantiated by reported cases. The well-known law of Colles is urged in support of such transmission. That law formulates a well-known clinical fact, viz., that the mother of a syphilitic child is never infected at the breast by her offspring—the secretions of whose diseased mouth are infective for all healthy persons. A few exceptions are reported to this law, so few and so inconclusive as rather more fully to establish its general applicability. It is probable that the system of the mother, after the bearing of such children, is so modified as to render her incapable of receiving the disease. If the sound child be infected at the moment of birth by direct contact with recently developed, secreting lesions existing upon any part of the external genitals of the mother (an accident reported in a few cases), the result is acquired infantile, and not inherited, syphilis.

The clinical symptoms of hereditary syphilis are first the death of ovum or fœtus. These products of conception are then ushered into the world either undistinguishable from the dead products of pregnancies where no syphilis has interfered; or macerated, the epidermis being readily separable from the corium, which is deeply congested, or, for the reason first named, raised into bullæ, and the viscera in various ways are profoundly altered. In a second list are to be classed still-births, and the birth of children surviving but a brief time. These may be apparently unaffected by disease; or covered, in various degrees, with bullous lesions produced by passive exudation of fluids elevating the loosened epidermis from the corium; or they suffer from visceral changes. In a third category may be named children who survive for various periods to maturity. One-third of all are thought, however, to perish without attaining that development. Many perish before the second month; those who survive commonly exhibit the symptoms of inherited syphilis in the same period, even if no signs are apparent at birth. Hereditary syphilis is rarely deferred in its manifestations after the fourth month. Cases reported as of late inherited syphilis, where the first symptoms of that disease were manifested at the period of puberty, for example, are regarded by most experts with suspicion.

The placenta may be the seat of a diffuse or circumscribed gummatous infiltration. The two may concur. In such cases the syphiloma is characterized as usual by the firm, external, fibrous, grayish-tinted layers surrounding a softer, yellowish central mass. Hydramnios is also counted among the possible syphilitic changes of pregnancy.

The skin of the victim of inherited syphilis is subject to many changes, resembling, for the most part, those recognized in the acquired form of the disease. It is commonly seen to be either flaccid and wrinkled, or tightly stretched over the bones as if deprived of its panniculus adiposus. In this way the characteristic little-old-man and little-old-woman appearance of the syphilitic infant is produced. The skin has, moreover, a not less constant and characteristic sallow, yellowish, earthy hue. Manifestly the nutrition is profoundly impaired, and the child exhibits a series of symptoms, such as vomiting, diarrhœa, etc., which indicate that not the skin alone but other organs are participating in the disease. As a matter of practical moment, it is well for the practitioner to remember that a healthy-looking, well-nourished child, six months and more of age, without pulmonary or gastro-intestinal disorder and no signs of disease save a suspicious-looking eruption upon the skin, is probably *not* the victim of inherited syphilis.

The macular or erythematous rash (roseola) appears usually over the belly, face, neck, palms, extremities, and other parts, in the form of roundish or oval-shaped macules, from the size of a split pea to that of a finger nail, of characteristic copper-and-reddish shade, soon refusing to yield under pressure, often seen as the earliest cutaneous symptom of the disease. The spots may enlarge by multiplication or coalescence; may, in cases, become elevated or covered with scales; or may undergo fissure.

Papules, mucous plaques, mucous patches (of the skin and mucous membranes), and condylomata lata are all phases of one and the same process of proliferation in hereditary syphilis. The most common of all is the occurrence of flattened papules or patches in the nasal cavity, furnishing a serous discharge which rapidly becomes purulent or hemorrhagic in type, and which by desiccation soon blocks up with crusts the nasal passages. As a consequence a characteristic "snuffles" follows, the child abandoning the nipple to get breath, and even in sleep respiring with a suspicious snore. Specific coryzas of this sort may progress to ulceration or osseous necrosis. Similar roundish or oval-shaped patches, or (after confluence) large sheets of involved mucous surface, may be recognized in the mouth, furnishing a highly contagious secretion. In this way the tongue, lips, gums, and fauces may be involved, and the child may be rendered incapable of seizing the nipple with the mouth. At the angles of the mouth, also, on the muco-cutaneous surface, flat papules, condylomata, or secreting patches may conceal the natural outlines of the parts, be extensively crust-covered, or even superficially or deeply ulcerated.

Over the general surface of the body, small or large, flat or, more rarely, acuminate papules, copper-colored and reddish in hue, smooth or scaling, symmetrical, and generalized or limited to a single region, may be conspicuous. They may coalesce, furnish a patch of infiltration, and even extensively ulcerate. The most frequent manifestations of this type, next to the nasal lesions accompanied by "snuffles," are the condylomata about the anus, from the size of a pea to that of an egg and larger, flattened, whitish or reddish lesions, secreting, elevated, and distinctly circumscribed.

Vesicles, isolated or confluent, conical or flattened, from the size of a pinhead to that of a split pea, may also spring from macules or papules, rest upon a brownish and reddish base, and be filled with serum or a seropurulent fluid. They are rare lesions. Pustules, from the size of a pinhead to that of a split pea, are more often seen, with and without a previous or concurrent evolution of vesicles or papules; often as a metamorphosis of the latter. The skin thus affected is commonly infiltrated, purplish, and covered with brownish or greenish crusts. Beneath these may be simply excoriation or ulceration. The genital region, face, scalp, and lower extremities may be involved; rarely the entire surface of the body. The scarring which results is not conspicuous.

Bullæ are grave and unfortunately common symptoms of inherited syphilis. They may, as indicated above, be conspicuous at birth, single or multiple as to number; or develop later as wine-colored, circumscribed patches of integument; first pea-sized, later as large as an egg, an orange, or a cocoanut, filled with serous, lactescent, or hemorrhagic contents. The palms and soles are frequently involved. The areola is violaceous, often infiltrated and raised. The brownish crusts cover ulcers with a foul, hemorrhagic, or diphtheritic floor. Death usually ensues, when the eruption is at all generalized, in the course of a few days. Furuncles beginning as circumscribed cutaneous or subcutaneous and indolent nodules, from the size of a pea to that of a nut, may be in some cases so numerous as to constitute a characteristic and even symmetrical eruption. They may, after a typical suppuration, discharge a core by sloughing, or break down into conical ulcers of crateriform shape.

Tubercles and gummata may observe almost the same cycle. They also begin as roundish or irregularly knobbed, usually subcutaneous nodules, which break down, furnish an irritating, semipurulent, or serous discharge, and finally result in ulcers of the typical aspect already described as of occurrence in the acquired forms of syphilis. These ulcers may also follow the less circumscribed gummatous infiltrations of the skin and subcutaneous tissues.

Many of the grave cases resulting in profound destruction of tissue about the face (eyes, nose, lips, jaws, etc.), illustrated in the works of the best authors on the subject of hereditary syphilis, originate in gummata, the ulcerative processes in or beneath the skin, spreading thence to muscles, fascia, periosteum, and bone.

The *larynx, trachea,* and *neighboring parts* may be, in early inherited disease, the seat of ulcerations resulting in the production of stenosis, cicatrization, and bridles stretched between adjacent walls, so as to interfere with the function of the organ implicated. The late forms are described by Fournier as diffuse hyperplastic, circumscribed gummatous, and sclero-gummatous—the last named a combination of other forms. These may be serious in consequence of the results recognized in acquired disease, viz., production of (chiefly laryngeal) dyspnœa, glottic spasm, acute œdema, and sudden death. Sclerosed masses, subsequently exhibiting a central yellowish softening, have been recognized by Lebert and others in the lungs of children dead of inherited syphilis. These are believed to be gummata.

The mucous lining of the *alimentary canal* may be the seat of changes similar to those observed in the exposed mucous surfaces of the subjects of the disease. Circumscribed hyperæmia and even indurated hyperplastic, as well as ulcerative, patches have been recognized about the solitary and agminated glands. The liver may be, after the occurrence of specific changes in the walls of its vessels, hypertrophied, dense, and resisting; or the seat of pedunculated tumors, or of diffuse or circumscribed parenchymatous gummata. These may be miliary or nut-sized, and surrounded by the usual fibroplastic envelope. The spleen is probably always involved in the child affected with inherited syphilis. It may be the seat of a partial or general perisplenitis, capsular or subcapsular in situation; is always greatly increased in size and weight; and may undergo later, under treatment, reduction to its normal size, or, in other cases, lardaceous metamorphosis. The increase in size and weight which has been noticed in the pancreas is different, in that it seems to be accompanied by a sclerosis due to hypertrophy of the interstitial connective tissue.

The *suprarenal capsules* may be involved in a partial or complete pericapsulitis, as also in a parenchymatous deposit of miliary gummata. Fatty, colloid, and gelatiniform degeneration may be observed as a result of these morbid changes in both capsule and substance proper. The *kidney* has been found enlarged and also containing one or many miliary, whitish or yellowish, circumscribed gummata, or diffuse infiltrations. The origin of these lesions has been traced to proliferative changes in the connective-tissue stroma of the organ. Here, too, colloid and fatty degeneration has ensued—in rare cases, ulcerative destruction. More often than is generally taught there is serious involvement of one or both *testes* in male patients, the disorder beginning with an indolent tumefaction of the testis proper (the epididymis being usually spared), smooth, lobulated, and accompanied or not by moderate hydrocele and scrotal engorgement. Fournier calls attention to the discovery, in patients exhibiting tardy symptoms of inherited disease, of small, densely indurated testicles, either arrested in development or the fruit of the gummatous changes wrought in earlier periods of the disease. It is possible that the ovaries may be similarly involved (Panot).

The *hair* and *nails* are affected in hereditary as in acquired syphilis, chiefly after involvement of the tissues on which they depend for nutrition and support. In this way patches of alopecia become visible in the scalp. The nails are surrounded by a ring of purplish infiltration, or papulo-pustules, degenerating into ulcers, undermine the matrix and possibly finish with loss of the nail and formation of a cicatrix. The deformity of the distal phalanx in these cases is strikingly characteristic, presenting as it does a livid club-like enlargement, often both tender and painful, bearing, usually on one side only, a semilunar ulcer with sero-purulent secretion, foul base, and distorted or displaced nail. The nail-substance in these cases may be friable, eroded, "worm-eaten" in appearance, frayed, or laterally ridged and furrowed.

The changes so strikingly characteristic of inherited syphilis in the *eye* (keratitis, etc.), *ear* (remediless deafness of late inherited syphilis), and *teeth* (Hutchinson's changes) have already been described. A group of symptoms less classical and constant are puriform dépôts in the *thymus gland*, supposed to be abscesses (Dubois); glandular abscesses due to the irritation of neighboring cutaneous lesions (*e.g.*, in the neck, when associated with scalp or mouth disease); hæmophilia, or hemorrhagic symptoms appreciable at birth or soon after, in the cutaneous or mucous surfaces, probably due in greater measure to the cachexia of the disease than to specific changes; stenosis of veins and arteries (perhaps associated with gummatous changes in the vascular wall similar to those occurring in the endarteritis obliterans of acquired syphilis); and fusiform swellings of the synovial sheaths over the metacarpal bones.

The affections of the *bones* in hereditary syphilis have been exhaustively studied by Wegner, Waldeyer, Parrot, Taylor, Fournier, and others. They are among the most common of all the symptoms of the disease, being next in order to the ocular changes. Many of the phenomena long ascribed to rickets are to-day referred to inherited syphilis. Osteochondritis usually affects the diaphyso-epiphyseal extremity of the forearm, leg, arm, or thigh, but all the bones may be involved in the newly born infant, and this as the sole manifestation of the disease, or in conjunction with skin and other lesions. A partial or complete annular swelling, smooth, irregular, or ridged, is then found, of insidious or rapid development, encircling the extremity of the bone (distal extremity of ulna, sternal extremity of clavicle). There may be articular effusions in the contiguous joint. The swelling may disappear under treatment, or degenerate by ulceration as in gummata, resulting in loosening, separation, or destruction of the epiphysis or cartilage; or ultimately result in death by exhaustion. The bone may be shortened as a result, or invested with a thickened periosteum. The pathological changes may be described briefly as due to proliferation of the cartilage cells, with mamelonation of the epiphyseal surface and calcification of the osteoid processes. Periosteal and perichondrial thickenings follow, conjointly with retarded osteogenesis at some points.

Osteoperiostitis is a later bone-symptom of inherited syphilis, affecting predominantly the tibia, but also the ulna, radius, cranial, and other bones, often more than one bone in one subject of the disease, and then at times symmetrically. The hyperostosis resulting may distort the tibia so as to produce the so-called "sabre-blade" deformity, its voluminous mass forming a curve, with an anterior or lateral convexity, painful, tender, and indolent of development; or it may result in characteristic multiple cranial hyperostoses of the temporal and frontal regions. All these forms may result in necrosis, ulceration of bone, and formation of fistulous tracts through which sequestra may be removed.

In gummatous osteomyelitis the medullary canal, after degeneration of a gummatous infiltration, may be the seat of a cheesy tissue here and there enclosing solid masses, surrounded by layers of newly formed bone.

The syphilitic dactylitis of inherited resembles that of acquired disease, the swellings attacking sowly or rapidly, with or without pain, one or more of the proximal phalanges, or metacarpal or metatarsal bones. In all these bone-lesions the joints may participate secondarily, or the synovial membrane or fibrous capsule may be first to induce a hydrarthrosis or tumefaction, which may go on to degenerative changes involving cartilage and bone, or be averted at any stage by treatment.

The nervous system, in inherited syphilis, is chiefly involved after the occurrence of structural changes in the meninges and other neighboring parts. Fibrous and gummatous thickenings and infiltrations, diffuse and circumscribed, may implicate one or more of the meningeal layers, agglutinating them to each other or to the nervous structures they enclose. Periostitis of the surfaces in contact with these membranes, intracephalic scleroses and gummata, and occlusions of the lumen of the cerebral vessels, may here, as in acquired disease, be followed by a long series of nervous symptoms, dilatation of the pupil, facial paralysis, paraplegia, hemiplegia, epileptiform seizures, hydrocephalus, idiocy, and various grades of failure of intellectual development and vigor. Fournier, in describing the late forms of this complication, lays stress upon the occurrence of severe and persistent cephalalgias, similar to those so frequently recognized in acquired syphilis of the nervous system, as also upon the frequency of urinary incontinence. The same author believes that there is an heredito-syphilitic tabes, and possibly also a sclerosis *en plaques*. The paralyses resulting from compression or other changes in the nervous trunk chiefly involve the ocular muscles.

The *treatment* of the mother affected with syphilis, and pregnant or nursing a syphilitic infant, is usually indicated. Mercurial inunction of the infant by smearing its flannel roller with oleates and salves is an efficient means of introducing the metal when it is required. Calomel, or the gray powder, may be given, one grain to one-twentieth of either (0.066 to 0.0033) rubbed up with sugar of milk, and placed upon the tongue of the infant, three or four times daily. The dose can be nicely adjusted to the requirements of each case. The bichloride may be substituted in combination with syrup of licorice or of ginger. Ten drops may be given of a two ounce (64.0) solution, containing from one-fourth to one grain (0.0160 to 0.066) of the sublimate to the ounce (32.0). Inunction is, however, preferable for the majority of cases, with the administration of cod liver oil by the mouth. When mercury and the iodide of potassium are both indicated (more particularly in the management of osseous lesions), the several combinations known as the syrup of Gibert are useful, *e.g.*:

℞ Hydrarg. biniodid............. gr. i. (0.066)
Potass. iodid.................. ℥ ss. (16.0)
Syr. glycyrrhiz. (vel zingiber.),
Aq. dest.....................āā ℥ ij. (64.0)
M.

Of this solution the infant under the fourth month can take from five to ten drops in water, the larger dose being gradually reached. Similarly, in all portentous cases, the iodide of potassium may be administered in drop doses of a saturated solution to the point required to produce any desired effect, as already described in the treatment of acquired nervous syphilis. In all cases the diet and hygiene are highly important. The heredito-syphilitic child should be at the breast of the mother (and at the breast of none other), if it can be thus properly nourished. The local management of the mouth, of the ano-genital region, and of all syphilodermata is important, and to be conducted on principles heretofore indicated. Tonics are often useful. The prognosis is grave in all severe cases. In viable children, free from visceral complications, much can be accomplished by treatment.

TREATMENT OF SYPHILIS.—The chief point of importance in syphilis is the non-medicinal management of the patient, without a proper knowledge of which the most skilful use of drugs is ineffective. This introduces to the wide field of diet, hygiene, and occupation of mind and body. The diet should be nutritious, and should exclude alcohol in all forms not specifically directed by the practitioner, with a view to securing its valuable tonic (not stimulating) effects. Tobacco in every form is best discarded, as having an injurious effect upon the nutrition in general, as well as upon the mucous surface of the mouth, which constitutes such a fertile field for the development of mucous patches. The body should be sponged daily with cool or tepid (often with salt) water, and then briskly scrubbed until warm, when the general surface not the seat of syphilodermata permits such a course. The skin should be properly protected by warm underwear. In the case of syphilitic patients sexual indulgence should be prohibited. Most patients are better for regular and systematic attention to their usual occupation, though the latter should not unduly tax the mental or physical powers. The bowels should be evacuated daily. Exercise in the open air and due regulation of the hours of sleep should not be forgotten. In many cases, where the purse of the patient will permit, the recreation of travel, a sojourn at the seashore, or a change from an inhospitable to a mild climate, are valuable steps toward recovery.

In a small percentage of cases the expectant or tonic treatment of syphilis, conducted largely by the measures described above, aided by the use of tonics (ferruginous, bitter, acid), suffices for what seems to be a cure. Indeed, no observer of large experience can deny that cases of exceedingly mild and benignant syphilis are often untreated and exhibit no recurrence.

The immense preponderance of cases, however, is on the other side of this slender border-line of safety; and the danger of an expectant course, for most patients, is sufficiently grave to furnish the basis of serious charges against the practitioner who habitually pursues it.

Mercury is to-day, as for nearly four hundred years past, the most efficient of drugs in the treatment of syphilis. It is given by the mouth in the form of the protiodide, biniodide, bichloride, calomel, gray powder, blue mass, tannate, or other combinations of the metal. The protiodide is deservedly popular with American physicians, and may be given in one-fifth of a grain (1 cgm.) granules, pellets, or discs. It is usual to begin with one after each meal, and to increase gradually till some constitutional effect is produced, such as looseness of the bowels, slightly increased flow of saliva, or moderate abdominal pain, after which the dose is reduced. Keyes suggests at this point a "tonic" dose—one which can be tolerated for months at a time without inconvenience, and reached by the reduction of the dose described above. For speedy effect, calomel is employed in doses of one-tenth of a grain (0.0066) every hour; and for slower effect, less often. It is well administered in powder rubbed up with sugar of milk. The mercurial pill has the advantage of being readily combined with iron, as *e.g.*:

℞. Pil. hydrarg................. ℈ ij. (2.66)
Mass. Vallet (pil. ferri subcarb.) ℈ ss. (0.66)
Nux vom. ext................ gr. iv. (0.24)
M. Ft. pil., No. xx. S.: One after meals.

The dried ferric sulphate, quinine, ergotine, and aloes may each, when indicated, be incorporated in these or similar pills.

The bichloride is often best combined with iron in some such acid solution as:

℞ Hydrarg. bichlorid...gr. i.-ij. (0.066-0.133.)
Ferri tinct. mur.,
Acid. mur. dil.....āā ʒ ij.-iv. (8.0-16.)
Syr. zingiber. (vel. sarzæ)..............f ℥ ij. (32.0.)
Aq. dest............ad f ℥ vi. (192.0.)
M. S.: A teaspoonful in a glassful of water after each meal. To this the sulphate of strychnine in medicinal doses may often be advantageously added.

Solutions of the bichloride effected with the aid of alcohol or with an equal quantity of the muriate of ammonium are also useful.

The biniodide is usually administered by decomposing corrosive sublimate with the potassic iodide, and dissolving the precipitate in an excess of the same salt, *e.g.*:

℞ Hydrarg. bichlorid........... gr. i. (0.066.)
Potass. iodid.................. ʒ ij. (8.0.)
Aq. dest...................... ℥ iij. (96.0.)
M. S.: A teaspoonful in water after meals.

The Gibert formula, modified variously by almost every author, is nearly as follows:

℞ Hydrarg. biniodid.............gr. i. (0.06.)
Potass. iodid..................... ʒ i. (4 0.)
Aq. dest......................... ʒ i. (4.0.)
M. Filtra, deinde adde syrup. aurant. cort.................... ʒ vi. (192.0.)
S.: One to two teaspoonfuls in water after eating.

Combinations of mercury and the potassic iodide are employed chiefly in the so-called "mixed" treatment of syphilis; in lesions that are transitional in type between the graver and milder forms; and also in many precarious or rebellious symptoms in the earlier stages of the malady. Pills of the bichloride and biniodide are usually objectionable on account of their tendency to the production of irritative effects, but are in some cases given with advantage. From one-sixteenth to one fortieth of a grain of either (0.004 to 0.0016) may thus be administered after meals.

Mercury is of great service when applied by vapor in fumigation. This method is generally, in the larger cities of the country, relegated to the bath-houses, but by the aid of a chair, a blanket, and the Schering (formalin) lamp, it can be employed at the residence of any patient. From one to three drachms (4.0-12.0) of calomel, cinnabar, or the gray oxide, or two or more of them in combination, are used for the production of the vapor when placed on the metallic plate of the lamp. Steam is furnished by water boiling in the chamber designed for that purpose, and the naked and sweating skin of the patient wrapped in the blanket and seated over the lamp, is thus subjected two or three times a week to the fumes of the mercury.

The uncleanly, but very effective, method of introducing mercury by inunction is popular abroad, but used in this country chiefly by experts, in hospitals, and at certain Springs enjoying repute for the relief of this disorder. Equal parts of the twenty-per-cent. mercuric oleate and scented vaseline, or the ordinary mercurial ointment, made with lanolin oil, may be used, one drachm (4.0) or more being rubbed at night before retiring into different portions of the skin (selecting a new region each night), and removed by a bath in the morning.

Hypodermatic injections of mercury in various forms are popular upon the continent of Europe, but are much less frequently employed in England and America. They are rapidly effective when used. They have been the subject of much favorable and adverse criticism, and are both praised and decried by leading syphilographers. They are subject to the disadvantage of requiring a physician for the administration of each dose, and are therefore better suited to hospital than to private practice. The following formulæ have been employed: Calomel, gr. iss. to iij. (0.10 to 0.2), rubbed up with about twenty-four minims (1.5) of pure glycerin (Scarenzio); corrosive sublimate, four grains to the ounce (0.266 to 32.0) of distilled water; fifteen minims (1.00) to be injected every two or three days (Lewin). These solutions have been modified by incorporating with them one-tenth of a grain (0.0066) of the acetate or of the sulphate of morphine to relieve pain; and the chloride of sodium, four parts to one of the bichloride, to render the solution less irritating. As these subcutaneous injections are liable to be followed by abscesses, attempts have been made in the direction of securing a soluble albuminate or peptonate of mercury, all of which have proved unsatisfactory. Solutions of the bicyanide, biniodide, nitrate, and formidate of mercury have also been recommended. None of these devices has yet rivalled in popularity the solutions of corrosive sublimate in distilled water.

When mercury produces its happiest effects in syphilis, by any mode of administration, the symptoms diminish or disappear, and the patient actually gains in weight. Even when improperly employed, mercury is not (always) responsible for many of the results popularly ascribed to its influence. These are chiefly syphilitic symptoms of patients misinformed as to the nature of their disorder. The statistics collated by the physicians of the great Russian mercury mines, of disease observed among the workers in the metal, include none of the symptoms popularly ascribed to the influence of this metal in syphilitic patients—mouth-patches, rheumatism, eruptive symptoms, etc. They are all in the direction of salivation, and, in grave cases, of maxillary necrosis. Tenderness of the gums, moderate fetor of the breath, slight increase in the salivary flow, noticeable indentation of the sides of the tongue by the molar teeth, and tumefaction of the mucous membrane—these are the first signs of a toxic effect, which may increase, if the drug be further pushed, to the extreme of complete salivation, with loosening and even falling out of the teeth. In the modern treatment of syphilis no such effects are desired, and are rarely attained. The milder of these manifestations readily disappear under appropriate therapy: tepid gargles of milk, flaxseed tea, or sweetened or demulcent water, containing one drachm (4.0) of potassium chlorate to the pint (500.0) of vehicle; a liquid and nutritious diet; abstinence from iced, alcoholic, spiced, acetous, and hot articles of food and drink; suspension of the mercurial; laxatives sufficient to secure complete evacuation of the bowels; and often the ferruginous and other tonics, preferably in solution.

Iodine and its compounds are useful in combination with mercury and without such union. They are more available for gummatous symptoms, but may be often employed with the greatest advantage in the milder symptoms of the disease. The articles of the class most used are iodine, iodipin, iodoform, and the iodides of lithium, sodium, starch, and potassium. No one of these is equal in value to the iodide of potassium; none enjoys to the same degree the confidence of the profession. It may be given alone or with mercury by the mouth; or it may be given by the mouth when mercury is employed by inunction or fumigation; or it may be given in alternation with one or more of the courses named.

It is always best administered in solution, gr. iij. to xx. (0.20 to 1.33), given in distilled water, milk, or any other vehicle preferred, such as cinnamon water, or one of the various syrups employed as vehicles. The method of administering the iodide of potassium in largest dose, gradually reached, from one drachm to an ounce (4.0 to 32.0) in the twenty-four hours, has been fully described in the paragraphs devoted to nervous syphilis. Employed with all due precautions, and administered with large draughts of pure water, it furnishes one of the most brilliantly effective of the measures at hand in the grave emergencies of the disease. When its morbid effects are produced, these may become apparent after the exhibition of the smaller doses. Among them may be named severe coryza, with œdema of the lids, lips, and glottis; salivation; gastrointestinal distress and tenderness; and a series of cutaneous eruptions. In the order of frequency the latter are acneiform papulo-pustules, furuncular lesions, purpura, tubercles, erythematous macules, bullæ, and eczemaform patches.

An enormous number of medicinal articles, beside those named, have been used in the treatment of syphilis. Some are indispensable in the management of most cases; some have a doubtful effect; many are absolutely worthless. In the first class may be named the ferruginous tonics; the mineral acids (only given simultaneously with the mercuric bichloride); cod-liver oil; quinine and the vegetable bitters; alcohol, judiciously administered; and, in particular, the fluid extract of erythroxylon coca, first warmly recommended by Taylor in the management of syphilis, and fully indorsed by the writer, who has employed it with advantage in many cases. In the second class may be named sarsaparilla (probably having no other than a purely "stomachic" value); the "McDade formula" (equal parts of the fluid extracts of smilax, sarsaparilla, stillingia sylvatica, kappa minor, and phytolacca decandra, with one-half of one part of the tincture of xanthoxylum carolinianum), and Zittman's decoction (probably efficient chiefly for the mercury it contains). In the last class may be named nitric acid, gold, thuya, cascara, berberis aquifolium, and the mass of proprietary preparations, many of which, though advertised as "purely vegetable" compounds, depend for a short-lived popularity upon the mercury or iodine which they contain. None of the mineral springs, in this country or abroad, which enjoy a reputation in the treatment of syphilis supplies a water which can be demonstrated to possess a therapeutic value outside of the climatic, hygienic, and, indeed, medicinal effects obtained by residence and treatment by physicians in the districts where such springs are found. The waters of the well-known Hot Springs of Arkansas, in this country, have never yet been shown to possess any medicinal virtue; and the number of syphilitic patients who annually resort thither and reap some advantage from such a course are, for the most part, those who have been treated there by physicians with mercury or the iodine compounds. The so-called process of "syphilization" has not survived its brief period of notoriety. It was based upon a confusion respecting the nature of the syphilitic and the non-syphilitic sore, and is now a curiosity in the literature of medicine.

No limit can be set to the length of time which should be assigned for the treatment of the disease. The average patient requires careful observation and treatment for from two to four years. Many require this for a far longer period. Mild cases may require less. No guarantee of future immunity can be given any patient on the conclusion of treatment, though probably seventy-five per cent. of all the infected have no symptoms of returning disease after proper treatment by a competent physician. Two years of immunity from all symptoms should elapse after the conclusion of treatment, before a patient of either sex should be permitted marriage with a non-infected person, though in the case of women who have not reached the menopause and are regularly menstruating, this period may be somewhat shortened. Two years of immunity is required by some of the larger insurance companies before accepting life-risks of the infected. Syphilis, however, is, as a matter of fact, one of the most readily managed and promising of all diseases that affect the human race. As distinguished from them all, its prognosis in general may be pronounced good. It may often disfigure, but it rarely destroys, its victims. As against the frequent fatality in pneumonia, variola, typhoid fever, or erysipelas, its statistics include an overwhelming preponderance of infected subjects in whose later years it figures only among those indelible reminiscences which teach the sternest lessons of life.

James Nevins Hyde.

BIBLIOGRAPHY.

The literature of syphilis has accumulated to such an enormous extent that a full bibliography, in the limits assigned to this article, would be impossible. Appended is a brief but selected list of titles, embracing a few of the older classics of syphilitic literature and some of the modern standard treatises devoted to the subject:

Astruc, John: A Treatise of the Venereal Diseases, London, 1737.
Boeck, W.: Erfahrungen über Syph., Stuttgart, 1875:
Boerhaave, H.: De lué vener, 1762.
Desprès, A.: Traité théorique et prat. de la syph., Paris, 1879.
Dowse: Brain and its Diseases, London, 1879.
Fournier, A.: La syph. hérédit. Tardive, Paris, 1886.—Syph. et mariage, Paris, 1890.—L'Hérédité syphilitique, Paris, 1891.—Traitement de la syph., Paris, 1899. Les Affections Parasyphilitiques, Paris, 1900.
Hutchinson, J.: Syphilis, London, 1887.
Hyde, James N., and Montgomery, F. H.: Diseases of the Skin, New York, 1901.
Jullien, L.: Traité prat. des maladies vénér., Paris, 1899.
Keyes: Venereal Diseases, New York, 1891.
Lancereaux, E.: Traité hist. et prat. de la syph., Paris, 1873.
von Lesser: Encycl. der Haut. und Geschlechtskrankheiten, 1900.
Lang, E.: Vorlesungen über Pathol. u. Therap. der Syph., 1896.
Morrow, P. A.: System of Genito-urinary Diseases, Syphilology and Dermatology, New York, 1893.
Mansurrow, U.: Die Tertiär. Syph. Gehirn. Geschlkht. und deren Behandlung, Wien, 1877.
Mauriac, C.: Traitement de la syph., Paris, 1896.
Neisser: Ziemssen's Handbuch, Heft i., Leipzig, 1883.
Neuman: Spec. Path. et Therap. v. Nothnagel; Syphili. 1899, Festschrift, Wien, 1900.
Rollet, J.: Traité des maladies vénériennes, Paris, 1866.
Keyes, E. L.: Genito-urinary Diseases, with Syphilis, New York, 1888.
Zeissl, M.: Lehrbuch der venerisch. Krankheiten, 1902.

SYRINGOMYELIA. See *Spinal-Cord Diseases; Syringomyelia.*

TÆNIÆ. See *Cestoda* and *Anthelmintics.*

TALIPES. See *Foot, etc.*

TALLEY'S SPRINGS.—Mecklenburg County, Virginia.

POST-OFFICE,—Palmer's Springs.

Talley's Springs are located seventy-five miles southeast of Petersburg, and within eight miles of the Atlantic and Danville Railroad on the north, and eleven miles of the Seaboard Air-line on the south. The situation is in a beautiful valley, the surface being clothed in a magnificent growth of original oak. The country is moderately hilly in character, and the climate very genial and salubrious. The springs have never been developed, but the waters have been resorted to by residents of the district for many years, and numerous cases are cited which illustrate their beneficial effects. A partial analysis has shown the presence of lithia, sulphur, and iron. A strong odor of sulphuretted hydrogen pervades the neighborhood. The water is said to have a wonderful preservative power. We are informed by Mr. G. W. Davis, the owner, that a small green log which has lain in the spring between thirty and forty years is still perfectly sound. It is stated that the advantages of these strong waters and the many attractive features of the neighborhood will soon be turned to good effect and a desirable summer resort established. Palmer's Springs, which also possess a local reputation, are two miles away.

James K. Crook.

TAMARIND.—(*Tamarindus*, U. S., P., B. P.; *Pulpa Tamarindorum Cruda*, P. G.; *Tamarinier*, Cod. Med.) The preserved pulp of the fruit of *Tamarindus Indica* (fam. *Leguminosæ*). The tamarind is a large, handsome, widely spreading, locust-like tree, with rough, dark-gray

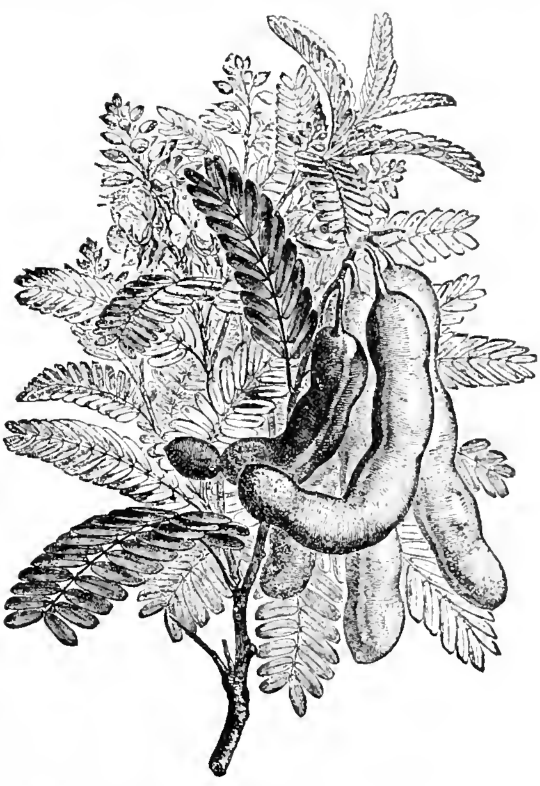


FIG. 4593.—Tamarindus Indica. Flowering branch with fruit. (Baillon.)

bark, and rather small, cassia-like, abruptly pinnate leaves. The fruit is a flattened, curved, solid "pod," from three to six or more inches long; smooth, yellowish-brown externally, with a brittle shell, and a firm acid pulp surrounding the seeds. The pulp contains a skeleton of fibrous bundles running lengthwise over the seeds. The tamarind tree grows now in all tropical countries, and is, besides, extensively cultivated. It came originally from the Old World, presumably from Africa, but is equally abundant in India, Australia, and the West Indies. When the fruits are ripe, the outer shell becomes brittle and is broken between the fingers and removed, the entire contents being then packed in kegs and covered with boiling syrup. In this way the West Indian tamarinds, which comprise most of those that reach our market, are prepared. In the East, sugar is often used instead of syrup, or they may be packed dry, without any sweetening, in a hard, semisolid mass.

Preserved tamarinds, as they reach us, are in a moist, reddish brown, pulpy, stringy mass, with numerous flattish-quadrangular, smooth seeds, and a little thick, dark syrup. They have a pleasantly sweet and acid taste. Mixed with water, they make a pleasant acid drink, which was formerly used in fevers and other forms of sickness. They are much less employed at present.

Composition.—Citric acid, eight or nine per cent., is the important constituent. About one and one-half per cent. of tartaric acid, a little malic acid, and, say, three per cent. of potassium bitartrate, are adjuvants to the former, and add to the acidity of the fruit. Gum, jelly, and ordinary vegetable matters, and, in our preserved tamarinds, the sugar that is added, complete the list of constituents.

Uses.—Tamarinds are rather an agreeable luxury than a medicine and in some countries are consumed extensively as a preserve. They possess some slight laxative properties, like prunes, barberries, figs, and other acid and sugary fruits. Here they are used to make a refreshing acid drink or as an adjuvant to some laxative compound. The Confection of Senna (*Confectio Sennæ*, U. S.) contains ten per cent. of them. The dose of tamarinds is indefinite.

W. P. Bolles.

TAMPA, FLORIDA.—This winter health resort, which acquired a somewhat unpleasant notoriety during the Spanish-American War on account of the hardships and illness suffered by the United States troops en route to Cuba, is situated about midway of the peninsula of Florida, on the Gulf side, at the head of Tampa Bay. It is about twenty-five miles distant from the coast, in Lat. 27° 57′ N., and has a permanent population of 15,839. It is one of the important commercial cities of Florida, and has extensive manufacturing interests, principally in cigars, employing large numbers of Cubans. There are various churches, an opera-house, street cars, electric lighting and water works, sewers, and clean-paved streets. Port Tampa, where the largest steamers land, is nine miles from the city, with which it is connected by rail, and from here steamers leave for Havana and various Gulf ports.

On the opposite bank of the Hillsborough River, at the mouth of which Tampa is located, is the Tampa Bay Hotel, situated in a beautiful park of one hundred and fifty acres, with a botanical garden containing a great variety of native and imported trees and plants. This hotel is one of the most imposing and extensive in Florida—the land of extravagant buildings of this sort. It is of Moorish architecture and contains nearly five hundred rooms, and is most luxuriously equipped. Connected with it is a casino, with a swimming pool, and an exposition building. There are several other hotels in the city proper, and one at Port Tampa. There are many opportunities for fishing, hunting, boating, and driving, and a variety of excursions about the beautiful bay. The surrounding country is sandy, but nevertheless supports a luxuriant tropical vegetation, groves of orange, lemon, and pine trees abounding.

The climate is a warm, equable, moist one, the mean annual temperature being nearly that of Cairo, Egypt. Both in climate and vegetation Tampa partakes of the characteristics of southern tropical Florida. It is well to remember that it was in May, June, and July that the United States troops congregated at Tampa, not the season when the visitor or invalid resorts to a warm country. Moreover, it was probably quite as much due to the sudden assemblage of a large body of men at this point as to the climate that the illness occurred. On account of the humidity and enervating quality of the climate, such a resort as Tampa is not favorable for tuberculosis; but it is useful for a variety of cases needing a mild, equable, sunny, winter climate, as has been indicated in the article upon *Florida* in Vol. IV. of the Handbook.

The accompanying chart gives the various climatic data for the four winter months and also for July. The characteristic features are seen to be mildness and equability of temperature, a high humidity, much sunshine, and a comparatively high annual rainfall, the larger part fall-

CLIMATE OF TAMPA, FLORIDA. LATITUDE, 27° 57′ N.; LONGITUDE, 82° 28′.

	Dec.	Jan.	Feb.	Mar.	July.	Year.
Temperature—Degrees Fahr.						
Average or normal.........	62.2°	58.6°	63.1°	66.4°	81.5°	71.6°
Mean of warmest	71.2	67.8	71.7	75.8	89.6	80.5
Mean of coldest	53.2	48.0	54.6	56.9	73.5	62.8
Average daily range	18.0	19.8	17.1	18.9	16.1	17.7
Highest or maximum	81.3	78.1	80.5	84.2	93.2	94.4
Lowest or minimum	34.7	32.7	35.7	39.7	70.0	28.1
Humidity—						
Average relative	83.4%	81.6%	83.8%	80.0%	82.4%	81.2%
Precipitation—						
Average in inches..........	1.57	2.45	2.81	2.68	7.99	53.09
Wind—						
Prevailing direction........	N.	N.	N. E.	S. E.	E.	N. E.
Average hourly velocity in miles	6.0	6.0	6.9	6.7	5.2	6.1
Weather—						
Average number clear days.	12.1	9.5	8.4	11.7	7.0	115.0
Average number fair days .	12.3	16.4	14.3	14.4	20.0	188.2
Average number clear and fair days	24.4	25.9	22.7	26.1	27.0	303.2

ing during the summer, features common to all the coast resorts of the Florida peninsula.

Tampa is readily reached by rail direct, or one can make a portion of the journey by water.

Edward O. Otis.

TANNAL, aluminum basic tannate, $Al_2(OH)_4.(C_{14}H_9O_9)_2 + 10H_2O$, is a brownish-yellow powder formed by precipitating an aluminum salt with tannic acid in the presence of an alkali. It is employed as an astringent dusting powder for wounds and ulcers, and as an insufflation in catarrhal conditions of the nose and throat. It is insoluble in water, but its combination with tartaric acid dissolves readily and is known as "soluble tannal." The solution, however, slowly decomposes.

W. A. Bastedo.

TANNALBIN is a tasteless, odorless, light-brown powder made by drying tannin albuminate at 110°–120° C. It is light and bulky and contains about fifty per cent. of tannic acid. It is insoluble in water or the gastric juice, but slowly dissolves in alkaline media, as in the intestine. Though tannalbin has very little astringency, the weight of evidence indicates that it is as efficient in diarrhœal conditions as any of the astringent drugs. It presumably sets free its tannic acid in the intestine, since Leonard Weber, Einhorn, Vierordt, and many others report an apparently prompt astringent action in tuberculous enteritis, enterocolitis, the summer diarrhœas of children, and acute or chronic dysentery. Most authors claim that it does not act at all in the stomach, but W. H. Porter recommends it in chronic catarrhal conditions of that organ, stating that its free administration arrests the excessive secretion of mucus. It is administered in capsule or in mixture, or in combination with small doses of calomel, or mixed with starch water as an enema. The dose for an adult is about 1 gm. (gr. xv.) several times a day. Ten grams (ʒ iiss.) a day have been given for several days without untoward effect.

W. A. Bastedo.

TANNIC ACID.—(*Acidum Tannicum*, U. S., Br., Ger. *Gallotannic Acid. Digallic Acid. Tannin.* $HC_{14}H_9C_9 = 321.22$.) An organic acid obtained from nutgall. A light-yellowish amorphous powder, usually cohering in the form of glistening scales or spongy masses, odorless, or having a faint, characteristic odor and a strongly astringent taste; gradually turning darker when exposed to air and light.

Tannic acid is freely soluble in both alcohol and water, as well as in glycerin. The characteristic blue-black color produced in a solution of tannic acid when a ferric salt is added forms the basis of tests for its presence. The form of tannic acid here considered is characterized by its convertibility into gallic acid, of which it is the anhydride. Although generally stated that it occurs in some other varieties of gall and in several other vegetable substances, certain differences are perceptible in these, and it has been questioned whether any of them can be considered as identical with the one under consideration. It may be extracted from the powdered galls by several processes. The most convenient method is to exhaust the latter with warm water and then thoroughly remove the impurities by churning with ether. The most common impurity present is resin, though after a time more or less gallic acid is likely to be formed, if carelessly preserved, the properties thus becoming weakened. Tannic acid is associated in the plant with more or less glucose, a part of it apparently combined as a glucoside, and this glucose often exists as an impurity of tannic acid.

Incompatibility.—The wide distribution of tannic acid, or its associates in the group, among vegetable drugs, lends great importance to its numerous incompatibilities, the more important ones being here stated. Tannin is slowly destroyed by remaining in aqueous solution, the process hastened by heat. Alkaloidal salts in aqueous or weak alcoholic solution are decomposed by tannin, their tannates, which are but slightly soluble in water, being precipitated. Other organic substances whose solutions are precipitated by tannic acid are albumen, gelatin, gluten, starch hydrate, and many glucosides and amaroids. A solution of antipyrin is also precipitated and iodoform is decomposed. Tannin in a solution of iodine prevents the latter from turning starch blue. Tannic acid is incompatible with ferrous salts, giving a gelatinous precipitate, and with ferric salts, giving a black color to a weak solution (its physiological action being not thus destroyed), and a black precipitate with a strong one, the strength correspondingly weakened. Solutions of salts of lead, copper, silver, chromium, mercury, bismuth, antimony, and most other metals yield tannates as precipitates, and nitric acid converts it into oxalic acid. With sulphuric, nitric, and hydrochloric acid, precipitates are yielded. Hydriodic acid is formed when tannin is added to iodine with water. Oxidizing agents are reduced by tannin. The stronger of them, like potassium chlorate, may produce explosions when triturated with tannic acid. With spirit of nitrous ether or amyl nitrite, a gas is yielded. Chlorine, iodine, and bromine are incompatible. Lime-water and tannin yield a precipitate, as do potassium and ammonia and their carbonates.

The physiological actions and uses of tannic acid depend almost wholly upon its chemical property of coagulating albumen in the form of a tannate, and this is especially true of its local action. In this way, the following effects are produced: A protective film is formed upon raw surfaces; bleeding orifices, if small, are closed by blood clots in their mouths and by a contracting clot about them; relaxed muscular tissue is contracted, thus increasing the hæmostatic effect; it coagulates the saliva and buccal mucus, and it is probably due to its mechanical action that the taste and general sensation of the mouth are diminished; in the same way it blunts the appetite and checks digestive activity, but arrests gastric and intestinal hemorrhage, as well as intestinal discharges, the latter effect not to be confounded with that of a stimulation of the vaso-motor nerves by volatile oils and other stimulants. Here again the mechanical blunting of the nerve endings results in a decrease of the peristaltic action, tannic acid being thus one of our most important constipating agencies. Here its local action may be said to end, while its systemic action becomes that of gallic acid, to which the reader is referred. It may be mentioned, however, that tannic acid has a distinct irritating tendency, which becomes apparent when overdoses are taken. In this way it may act as an emetic or even as a purgative.

The uses of tannic acid thus fall naturally into two classes, one of which is to be found discussed under gallic acid. Its chief local uses are to protect and stimulate the healing processes in all simple ulcers and in skin diseases which exhibit a superficial inflammatory tendency. Mild hemorrhages of the skin or of the nares, mouth, stomach, or intestines may be promptly arrested by it, the dry powder being best where direct application is possible. Excessive and malodorous local perspirations are checked, as well as foul exudations from the mucous membranes of nose, throat, and uterus. At the same time, an overrelaxed condition of these membranes, as well as of the rectum when hemorrhoids are present, is promptly corrected, although the effect is likely to be but temporary. Acute inflammatory conditions of the fauces, and to a less extent of the stomach, are often promptly relieved. Inhalation of a spray of tannic acid solution will check many cases of hæmoptysis, and this method, when possible, is much more efficient than its internal administration. The ordinary dose is gm. 0.06 to 0.3 (gr. i.–v.), but this is often largely increased in order to check hemorrhage. The official preparations are the styptic collodion, the glycerite, and the ointment, each of twenty-per-cent. strength, and the troches, each containing about one grain. A five-per-cent. or ten-per-cent. aqueous solution is often used for irrigating the nares or the vagina.

Henry H. Rusby.

TANNIGEN, di-acetyl tannin, $C_{14}H_8(CH_3CO)_2O_9$, is a yellowish-gray, odorless, and tasteless powder, prepared by the action of acetic anhydride or acetyl chloride on tannic acid dissolved in glacial acetic acid. It dissolves in dilute solution of sodium borate or phosphate and in alcohol, is slightly soluble in ether, and is insoluble in water, though it tends to absorb moisture from the air. It is decomposed by alkalies, and is colored blue-black by ferric salts. Passing unchanged through the stomach, it is broken up in the intestine, where the slow liberation of tannic acid gives a mild and continuous astringent effect. In diarrhœa, dysentery, and especially the summer diarrhœas of children, Clark, Biedert, Escherich, and Ewald have found it superior to the preparations of krameria, catechu, hæmatoxylon, and other vegetable astringents. Williams of Boston, Müller, and others recommend it in the diarrhœas of tuberculosis. The dose is 0.1 gm. (gr. iss.) several times a day for young children, and 0.35–0.7 gm. (gr. v.–x.) for adults.

Clark suggests the following for use in leucorrhœa: ℞ Tannigen 4 gm. (ʒ i.), boric acid 8 gm. (ʒ ij.), zinc sulphate 0.7 gm. (gr. x.) fluid extract hydrastis 8 c.c. (ʒ ij.). Dissolve in a cup of hot water and add to three quarts of hot water for injection. Tannigen has also been employed as an insufflation in nose and throat affections.

W. A. Bastedo.

TANNOFORM, methylene di-tannin, methylene di-gallic acid, $CH_2(C_{14}H_9O_9)_2$, is a condensation product obtained by adding a solution of formaldehyde to a solution of gallotannic acid in hot water and precipitating with hydrochloric acid. It is a loose pinkish-white powder, insoluble in water or acids and soluble in alcohol; it dissolves in alkalies with decomposition.

In the intestine tannoform sets free tannic acid and formaldehyde, and has been so used as an intestinal astringent and antiseptic. But it is not very widely employed thus, because of the possible irritation of the formaldehyde. It is a clean, dry antiseptic and deodorizing powder, and is used either pure or diluted with starch or talcum. In wounds, ulcers, and bedsores it seems to have marked healing properties, in hyperidrosis and bromidrosis it is siccative and deodorizing, and in moist eczema, pruritus, intertrigo, and burns it forms a serviceable dusting-powder. In chronic catarrh of the nasal passages, especially in ozæna, it is used as an insufflation.

Similar compounds prepared from formaldehyde and the tannins of aspidosperma, oak bark, and cinchona are called respectively *quebrachinoform, querciform,* and *quinoform.*

The bismuth salt of tannoform is "*bismal.*"

W. A. Bastedo.

TANNOPIN or Tannon, $(CH_2)_6N_4.3C_{14}H_{10}O_9$, is a condensation product of tannic acid and hexamethylenetetramine (urotropin). It contains eighty-seven per cent. of tannic acid and is a brown, odorless and tasteless, slightly hygroscopic powder, which is insoluble in water, alcohol, ether, or weak acids, but dissolves, probably undergoing change, in weak alkalies. It is said to liberate tannic acid and formaldehyde in the intestine, and for this reason is employed as an intestinal antiseptic and astringent. Schreiber, Meier, and Tittel have reported highly satisfactory results in tuberculous enteritis, and in acute, subacute, and chronic diarrhœas. The dose is 0.2–1 gm. (gr. iij.–xv.) several times a day.

W. A. Bastedo.

TANNOSAL, or Creosal, is the tannic acid ester of creosote, representing sixty per cent. of the latter. It is a dark-brown powder with biting taste and a slight odor of creosote, and is soluble in water, alcohol, and glycerin. As it sets free tannic acid and creosote in the intestine, it is employed as a means of administering creosote in pulmonary tuberculosis, or as an intestinal antiseptic and astringent. The dose is 0.2–1 gm. (gr. iij.–xv.) several times a day. As it is hygroscopic, a solution is marketed containing 1 gm. (gr. xv.) in each tablespoonful

W. A. Bastedo.

TANSY.—(*Tanacetum*, U. S.; *Tanasia*, Cod. Med.) The dried leaves and top of *Tanacetum vulgare* L. (fam. *Compositæ*). Tansy is a perennial herb, native of Europe and Southern Asia. It was introduced into the United States as a cultivated aromatic and has become abundantly naturalized as a weed along roadsides and in waste places. The stems are somewhat tufted, erect, nearly simple, a foot or two, rarely a yard, high; leaves shortly and stoutly petioled, rarely exceeding 20 cm. (8 in.) long and 10 cm. (4 in.) broad, obovate when flattened, pinnate, the pinnæ about ten or twelve pairs, linear-oblong, obtusish, pinnatifid, their segments oblong, acute, incisely serrate or lobed; thin, with a strong midrib, smooth, dark-green, finely depressed-glandular; flower heads in a small, loose, terminal corymb, long-peduncled, yellow, nearly 1 cm. (about ⅜ in.) broad, having an imbricated, saucer-shaped involucre, a convex, naked receptacle, and numerous yellow tubular florets, which are perfect, or the outer circle pistillate; highly and peculiarly aromatic, the taste pungent and very bitter.

It contains the peculiar bitter substance *tanacetin*, which is amorphous, very hygroscopic, and soluble in both alcohol and water. This imparts the most of the bitter taste, although the volatile oil is also bitter. The latter exists to the extent of about one-fourth of one per cent., has a specific gravity of about 0.955, and is of a yellowish-green color, becoming more or less brown upon exposure. It is soluble in about three parts of seventy-per-cent. alcohol. It is highly aromatic, bitter, and pungent, its important constituent being *thujone* (*tanacetone*). Tansy also contains some tannin, malic acid, and other unimportant constituents.

Besides the properties of tansy as one of the more powerful aromatic bitters, together with the diaphoretic and diuretic properties of its class, it and its oil have been used from time immemorial as anthelmintics. Oil of tansy, and tansy itself in large doses, are poisonous, the general symptoms being similar to those of the coniferous oils (juniper, turpentine, savin, etc.). These symptoms are: great irritation, vomiting, abdominal pain, painful diuresis, convulsions, coma, and death. They belong to the more painful class of poisons. They are also powerfully emmenagogue, though the symptoms are painful and the use of the drug for this purpose is not desirable. They are liable to cause abortion, though they usually fail of this purpose when taken with such intent, as is commonly done.

The dose of tansy is 1 to 4 gm., usually in the form of the fluid extract (1 to 4 c.c.), though this represents the extreme dose which should be used. The oil may be administered in doses of ♏ i.–v. So little as a fluid-drachm of the oil has proved fatal.

Henry H. Rusby.

TAPHOSOTE is a grayish syrupy liquid of faint odor and taste and containing tannic acid, creosote, and phosphoric acid. It is employed in pulmonary tuberculosis and as an intestinal antiseptic and astringent. The dose is 4 c.c. (ʒ i.).

W. A. Bastedo.

TAPIOCA.—*Manioca; Mandioca; Cassava Starch.* The starch of *Manihot utilissima* Pohl ("Sweet Cassava") and of *M. Aipa* ("Bitter Cassava"), (fam. *Euphorbiaceæ*).

The genus Manihot contains some eighty species of tropical America. Besides the above species, used as food, the genus is important as a rubber-yielder, by the species *M. Glaziovii* Muell. Arg., a small tree of Brazil. Our only interest in the Manihot is from a dietetic standpoint, if we except the poisonous properties of the bitter variety, due to the presence in it of hydrocyanic acid. The starch-yielding part is the cluster of large fleshy roots, which much resemble sweet potatoes, save in their paler color. These roots, under the above names, as well as that of *Yuca*, constitute the principal edible root crop of Brazil. Their use, boiled and baked, for the table, as well as for bread-making, far exceeds that for the manufacture of tapioca. Even among savage tribes, who had never before seen white men, the writer has seen it thus in use. Although slightly sweetish, it is far more like a white than a sweet potato in flavor. The finely ground pulp, pressed, dried, and then pulverized, is cassava meal, and is made into bread, in huge circular cakes, a yard in diameter and nearly a half-inch in thickness. These are transported in bales, bound with leaves. Their special advantage is to be found in their long-keeping qualities. The taste is negative rather than strongly pronounced, thus well qualifying the article for staple use. Bitter cassava is rarely used in its entirety, but is made into bread, or tapioca, after the poison has been dissipated by fermentation and other processes. The extraction of cassava starch as commercial tapioca differs only in details, as regards convenience, from that of other starches. It is, however, partly hydrated to cause it to form in the peculiarly irregular and hard masses known to us. In many parts of Brazil, dry tapioca is served at table, as a side-dish, as a substitute for bread. This is usually in smoothish, yellowish grains, resembling pebbles, very hard and trying to both teeth and gums. Tapioca is merely an amylaceous food, and has no medicinal properties.

Henry H. Rusby.

TAR.—*Pine Tar* (*Pix Liquida*, U. S. P., B. P., P. G.). An empyreumatic oleoresin obtained by the destructive distillation of the wood of *Pinus palustris* Miller, and of other species of *Pinus* (fam. *Pinaceæ* or *Coniferæ*).

The essential features of tar distillation are the partial burning of a wood rich in turpentine, the heat thus produced serving to expel from the wood near it the volatile and liquid products present, or which form during the process, the volatile ones ascending into the flame and being destroyed, the heavier ones settling downward and being collected as tar. It is almost altogether performed in rude stills constructed in the forest where the wood is gathered. The still is formed by stacking the wood upon a level and hardened spot of ground, surrounding it with a trench leading into a pit and surrounding the stack with a circle of earth and sods, thus preventing the free access of air. The stack is then ignited at the top and slowly burns downward, the expelled tar gradually trickling to the bottom and flowing into the pit, from which it is removed and stored in barrels, in which it hardens and is marketed. The wood used consists chiefly of dead branches and trunks and stumps of the trees which have been killed by tapping for turpentine. Tar is thus described by the Pharmacopœia:

"Thick, viscid, semi-fluid, blackish-brown, heavier than water, transparent in thin layers, becoming granular and opaque with age; odor empyreumatic, terebinthinate; taste sharp, empyreumatic.

"Tar is slightly soluble in water, soluble in alcohol, fixed or volatile oils, and solution of potassium or sodium hydrate.

"Water agitated with tar acquires a pale yellowish-brown color and an acid reaction, yields with ferric chloride T.S. a transient green color, and is colored brownish-red by an equal volume of calcium hydrate T.S."

The composition of tar is highly complex. Its constituents are, as might be expected, closely similar to those of coal tar, the sources of the two differing more in the length of time consumed in the production than in the essentials of the process. A large number of these constituents and their products are considered under separate titles in this work. The more important constituents are contained in the oil, considered below, and in the pyroligneous acid, which, when distilled off, leave *common pitch* or *naval pitch* (*Pix navalis*). In the distillate the acid and the oil separate, either on account of their different distilling points or on account of their different specific gravities. The acid is a source of acetic acid and numerous other substances. The relative percentages of the different portions, as also of the constituents of the latter, differ widely in different tars, depending upon the kind of wood employed, its condition and character, the details of the distillation, etc., so that both tar and tar oil are exceedingly irregular in character. The properties of tar are considered below, under Oil of Tar. Tar is itself employed externally, chiefly in the form of the *ointment* (*Unguentum picis liquidæ*, U. S. P., consisting of 50 parts of tar, 12½ parts of yellow wax, and 37½ parts of lard), and internally chiefly in the form of the *syrup* (*Syrupus picis liquidæ*, U. S. P., containing 7½ parts of tar, 10 of glycerin, and 80 of sugar, with water to make 100). The dose of tar is 1 to 4 gm. (grs. xv. to lx.); of the syrup, about four times as much. Tar is often given in the form of the water, made by thoroughly stirring four ounces of tar in a pint of water, allowing to settle, and decanting. Of this, half a tumblerful may be taken three or four times daily, and it is an excellent antiseptic diuretic.

Oil of tar (*Oleum picis liquidæ*, U. S. P.) is thus described in the Pharmacopœia: "An almost colorless liquid when freshly distilled, but soon acquiring a dark reddish-brown color, and having a strong, tarry odor and taste. Specific gravity about 0.970 at 15° C. (59° F.). It is readily soluble in alcohol, the solution being acid to litmus paper." It contains, as its principal part, creosote, which in turn consists of *guaiacol*, cresol, creosols, and phlorol, and which has been elsewhere considered; carbolic acid in small amount, toluene, xylene, paraffin, naphtalene, pyrocatechin, etc.

Oil of tar possesses, in lesser degree, the antiseptic and poisonous properties of the substances which it contains, as above stated. It has at the same time the diuretic and diaphoretic, as well as the irritant properties of the closely related substance oil of turpentine, though in milder degree, but is more distinctly expectorant than that substance. Its uses, both professional and domestic, depend directly upon these properties. As a counter-irritant, its action is very mild, and it is an excellent chest application for young children. Its antiseptic action is often secured as a constituent of mixtures destined for inhalation purposes. Internally, its chief use is in bronchitis, especially the chronic form, and its internal administration is commonly combined with its use as an application to the chest. Oil of tar is less frequently administered than the syrup, but may be given in doses of ♏ i. to v. or even ♏ x. There is no official preparation. *Henry H. Rusby.*

TARASP-SCHULS.—This health station and spa is situated in the Lower Engadine Valley, thirty four miles from Samaden, with which it connects by diligence twice daily. It consists of the three places, all near together, Tarasp-Schuls, Schuls, and Vulpura. Schuls, 3,970 feet above sea level, is the largest village in the Engadine, and contains about a thousand inhabitants. It is picturesquely situated on a slope of the valley, with the Inn below and, opposite, a stately range of well-wooded mountains, and is divided into an upper and a lower town, in the former of which most of the hotels and pensions are situated. On the high-road separating the two portions of the town is situated the bathing establishment, with eighteen bath- and two douche-rooms for iron and fresh-water baths.

Vulpura is a suburb consisting of large and well appointed hotels, lying on the opposite side of the river from Schuls, and about two hundred feet above it, on a thickly wooded height. It is at a distance of twenty minutes from the Kurhaus Tarasp, by a good road.

On the high road about a mile to the west of Schuls are the baths of Tarasp, consisting of an extensive Kurhaus with a "pump-room" and baths, and surrounded with pleasant gardens and parks. The whole country about is most attractive, and affords innumerable opportunities for walks and excursions in every direction, amidst grand scenery and in a pure mountain atmosphere. One who desires to take a course of these waters can conveniently reside at any of the three localities.

The climate of this region is somewhat milder than that of the Upper Engadine, although it partakes of the same general characteristics, viz., a rarefied atmosphere, moderate temperature, dry air and free from dust, protection from high winds, and increased intensity of the sunlight and heat. The mean temperature during the season (June 1st to September 15th) is 57.14° F.; the maximum, 87.08° F.; and the minimum, 33.8° F. The mean relative humidity is from 65 to 75 per cent., and there is an average rainfall of 9.40 inches. There are on an average during the season 39 perfectly clear days, 27 fair ones, 34 more or less overcast, only 6 or 8 of which are actually rainy.

The effect of the climate iss timulating and tonic, and may be rather severe for delicate persons, as sudden changes occur. For one, however, fairly robust and who desires to unite the high mountain air cure with a course of the waters and baths offered here, hardly a more admirable and charming resort could be found. "Scarcely another station in Europe," says Linn, "unites so many important qualities."

There are eight cold mineral springs that are used at this resort, although there are many more in the neighborhood. Four of the springs used yield sulphated alkaline waters of the class known as the "Cold Glauber's Salt Springs," similar to those at Carlsbad. The Lucius and Emerita Springs of this class are used for drinking and bathing; and the Ursus- and Neue Bade Quelle are only used for bathing. The rest of the springs are iron, yielding a gaseous chalybeate water known as "Sauerwasser." Of these the Bonifacius is used for drinking alone; the Wy for drinking and bathing; while the Carola is used for bathing alone. The four springs of Sotsass are used as a favorite table water. Compared with the waters of Carlsbad, Marienbad, Kissingen and Vichy, the Lucius Spring at Tarasp contains about the same amount of sulphate of soda as Carlsbad, but nearly or quite three times as much carbonate of soda and chloride of sodium, and at least three times as much carbonic acid. The carbonate of soda is slightly in excess of that found in the water of Vichy, and the chloride of sodium is about a fourth less than at Kissingen. Marienbad contains more sulphate of soda, but less of the other ingredients.

The analysis of the Luciusquelle by Husemann is as follows:

In Sixteen Ounces of the Water there were:

Sulphate of soda	16.131	grains.
Sulphate of potash	2.916	"
Borate of soda	1.312	"
Nitrate of soda	.006	"
Chloride of sodium	28.216	"
Chloride of lithium	.022	"
Bromide of sodium	.173	"
Iodide of sodium	.007	"
Bicarbonate of soda	35.425	"
Bicarbonate of ammonium	.507	"
Bicarbonate of lime	18.800	"
Bicarbonate of strontium	.005	"
Bicarbonate of magnesia	7.521	"
Bicarbonate of ferric oxide	.165	"
Total amount of fixed solids	113.216	"
True free carbonic acid	33.92	cu. in.

Of the Chalybeate Springs the Bonifacius is the strongest, containing 0.015 per thousand parts of the bicarbonate of iron. The iron baths are heated by a tube through which steam passes, so as to cause comparatively little of the carbonic acid to escape.

Three hours distant from Schuls are the acidulous mineral springs of Val Sinestra, containing a little arsenic. These waters are brought daily to Schuls.

As to the therapeutics of these waters, the four soda acidulous springs are more or less successfully employed in many different functional and organic diseases and conditions, such as obesity, chronic constipation, hemorrhoids, dyspeptic conditions, gall-stones, glycosuria of fat persons, affections of the kidneys and bladder, diabetes, gout. By warming the water before drinking, it can be made to resemble more closely Carlsbad water.

The Chalybeate Springs are used in anæmia and debilitated conditions. In combination with the hydrotherapeutic processes massage is given, and the diet is carefully regulated. Good physicians who speak English are found at this spa.

Most visitors taking the waters usually frequent the pump room at the Kurhaus Tarasp at an early hour in the morning, at which time there is music. There is a very delightful path along the river from Schuls to Tarasp, a walk over this occupying about half an hour; and the hotel-keepers at Schuls provide (gratis) conveyances which run at frequent intervals during the day between these two places. It is well to be provided with warm clothing, for the weather is frequently cool.

There are several ways of reaching Schuls: by rail to Davos Platz (soon to be extended to and beyond Schuls), and thence by diligence over the Fluela Pass; or, by rail to Landeck, and thence by diligence in eight hours. Coming from the south, one can go by rail to Chiavenna, and thence by diligence over the Maloja Pass and through the Upper Engadine, a long ride, but through grand and delightful scenery; by this route it is well to break the journey at Samaden. *Edward O. Otis.*

FIG. 4591.—View of Tarasp-Schuls in the Lower Engadine, Switzerland.

TARAXACUM. See *Dandelion.*

TARTARIC ACID ($H_2C_4H_4O_6$).—"An organic acid usually obtained from argols. Colorless, translucent, monoclinic prisms, or crystalline crusts, or a white powder, odorless, having a purely acid taste and permanent in the air." (U. S. P.).

Tartaric acid is soluble in both alcohol and water, very freely in the latter. It forms during the process of fermentation of wine, in the form of the bitartrate or acid tartrate, which is scraped from the insides of the casks in a mass called argols or tartar, or, after purification, cream of tartar. This is converted into calcium tartrate by the action of calcium carbonate in the form of powdered chalk. The calcium is then removed by sulphuric acid, setting free the tartaric acid, which must be carefully freed from traces of potassium, calcium, and sulphuric acid.

Tartaric acid has no special medicinal properties as distinguished from those of its class. It is one of the mild acids recommended for use in alkali poisoning, and it is useful (in the form of the effervescent powder or

Seidlitz powder) for freeing carbonic acid in the production of carbonated liquors. It is also much used as a fraudulent substitute for citric acid in the production of citrate-of-potassium solution. *Henry H. Rusby.*

TARTARIC ACID DIPHENYL ESTER ($C_6H_5COO.-CHOH_2$) is a condensation product of phenol and tartaric acid recommended in doses of 0.35 gm. (gr. v.) in gout and rheumatism. It occurs in fine silky needles of faint aromatic odor, which are insoluble in water or cold alcohol, but dissolve in hot alcohol, ether, or glycerin.
W. A. Bastedo.

TARTARLITHINE is a granular effervescent preparation of lithium bitartrate, a salt analogous to cream of tartar. As a uric acid solvent 0.35–0.7 gm. (gr. v. to x.) are given three or four times a day dissolved in a tumbler of water. *W. A. Bastedo.*

TARTROPHEN is a compound of phenetidin and tartaric acid analogous to *citrophen* (phenetidin and citric acid). Its uses and dosage are the same as those of citrophen, but clinical data are lacking.
W. A. Bastedo.

TASTE.—1. Definition and Introduction.—Taste is a special sense. A special sense is one provided with specialized end organs and located in structures that are especially adapted to serve the organism in receiving and conducting the stimuli to the sensory end organs.

The sense of taste possesses as specialized end organs the gustatory or taste buds, located on the surface of the tongue, the fauces, the soft palate, and the epiglottis. That the taste buds are the sole organs of taste is far less certain than it is that the eye is the sole end organ of vision. It is true that those portions of the oral mucous membrane which possess the sense of taste are the only places where the taste buds are found. On the other hand, there are many other nerve fibres which possess filaments and other endings in this same region. The other nerve endings in this region are similar to those found in other parts of the body, and serve in those parts the tactile and temperature senses. The tongue possesses the tactile and temperature senses to a high degree. Although our conclusion that the gustatory buds are the sole end organs of taste is reached by a course of inductive reasoning, we may feel secure that our conclusion is a tenable one.

2. Anatomical Considerations.—The taste bud is an epithelial structure composed of spindle-shaped cells grouped in a spheroidal mass with one pole at the surface of the epithelium. The cells may be classified in two orders, the sustentacular and neuro-epithelial. The sustentacular cells when located on the surface of this spheroid are called tegmental cells, and are somewhat larger than those which make up the internal part of the bud. Lying between the sustentacular cells in the midst of the bud are the delicate, spindle-shaped, neuro-epithelial cells, whose nuclei are in the basal portion farthest removed from the epithelial surface and whose external ends terminate in delicate hair-like filaments. Surrounding the nuclear end of the neuro-epithelial cells is a copious arborization of the delicate terminal fibrils of the telodendria of the gustatory neurones. These arborizations may also be found in some cases to surround the inner ends of the sustentacular cells. The taste bud possesses at the epithelial surface a minute pore, through which substances in solution may pass into the taste bud and will be drawn by capillary attraction into the innermost spaces between the sustentacular cells and neuro-epithelium, and thus be brought into immediate contact with the gustatory nerve endings.

Those gustatory nerve fibres which leave the posterior third of the tongue, the fossæ, palate, and epiglottis, pass to the gustatory centre by way of the glosso-pharyngeal nerve. Those which leave the anterior two-thirds of the tongue pass at first into the lingual branch of the inferior maxillary division of the fifth nerve. They all leave the lingual branch and pass by way of the chorda tympani back to the seventh nerve. From here to the gustatory centre their course has not been definitely traced. The clinical evidence seems to favor the view that they pass by way of the seventh nerve into the base of the brain, while experimental evidence as well as observations on the embryonic development of the cranial nerves indicates that the fibres leave the seventh nerve at the geniculate ganglion and pass by way of the Vidian nerve and Meckel's ganglion back to the fifth. Leaving the final course of the lingual gustatory nerves to be determined by further experiment, we may rest assured that eventually they make their way to the same gustatory centre to which the glosso-pharyngeal fibres make their way.

3. Physiology of the Sense of Taste.—Many of the perceptions attributed to taste really depend quite as much upon smell as upon taste. We usually apply the term *flavor* to those sensations which depend upon both smell and taste; *e.g.*, one speaks of the flavor of roast beef or of coffee. The fact that closure of the nose impairs the flavor of the beef or coffee indicates that a part of the flavor is to be attributed to the sense of smell. The sense of taste alone seems to be confined to sensations arising from four distinct stimuli: (1) *sweet*, (2) *bitter*, (3) *acid*, (4) *salt*. All purely taste sensations are either modifications of or combinations of these four fundamental sensations. The sense of taste is excited usually by those substances which pass into solution—*i.e.*, insoluble substances are tasteless. It may be noted in passing that mechanical stimuli applied to the gustatory surface are capable of arousing sensations of taste, and the same is true of electrical stimuli. In the case of the latter, the fact that the cathode usually tastes bitter-alkaline, while the anode usually tastes acid, would seem to show that the efficient stimuli are the basic ions which gather at the cathode and the acid ions which gather at the anode respectively. Though this is undoubtedly the way to account for the taste of the cathode and anode in the constant current, it does not throw light upon the fact that taste sensations are also aroused by induction shocks.

The sensation will vary in strength with: (1) the size of the area stimulated, the sensation being more intense the greater the area stimulated; (2) the concentration of the solution, being more intense the stronger the solution; (3) the temperature of the solution, being more intense the nearer the temperature is to that of the blood; (4) the mechanical friction of the tongue against the palate, being stronger with moderate friction than without it.

The sense of taste varies in acuteness (1) through certain hereditary influences, and (2) through cultivation. A good example of marked acuteness of taste acquired by cultivation may be found in professional tea-tasters and wine-tasters.

1. *To Determine the Acuteness of Taste.*—Make four standard solutions, as follows: (1) *Sugar*, 1 gm. of dry saccharose in 100 c.c. of distilled water. (2) *Quinine sulphate*, 1 cgm. in 1,000 c.c. of distilled water. (3) *Acetic acid*, 1 gm. of glacial acetic acid in 1,000 c.c. of distilled water. (4) *Salt*, 1 gm. of dry sodium chloride in 100 c.c. of distilled water.

In the use of these solutions prepare the gustatory surfaces by thoroughly rinsing the mouth with distilled water or with boiled water. Take a uniform quantity of the solution into the mouth at each observation. A convenient quantity is 4 c.c. or a common teaspoonful. Rinse the mouth before each new observation.

The following table gives results obtained by a number of observers. (The numbers indicate the number of parts of water to one of the substance to be tasted.)

Mr.	Sugar.	Quinine.	Acetic acid.	Salt.
A	700	1,000,000	7,000	425
B	600	500,000	8,000	500
C	....	250,000	1,400	....
D	300	400,000	3,000	700
E	700	......	4,000	400
F	400	400,000	6,000	600

Mr.	Sugar.	Quinine.	Acetic acid.	Salt.
G..............	333	400,000	6,000	....
H..............	500	400,000	4,500	480
I..............	500	450,000	6,000	325
J..............	650	200,000	7,500	325
Average.......	1 to 520	1 to 444,000	1 to 5640	1 to 469

Besides the results here recorded, numerous data were furnished by other observers.

This table and the supplementary data justify the following conclusions:

1. The acuteness of taste for sugar varies from 1 part of pure cane sugar in 300 parts of water to 1 in 708, with an average of 1 in 520.

2. The acuteness of taste for salt varies from 1 in 325 to 1 in 700, with an average of 1 in 469.

3. The acuteness of taste for acetic acid varies from 1 in 3,000 to 1 in 8,000, or an average of 1 in 5,640.

4. The acuteness of taste for sulphate of quinine varies from 1 in 200,000 to 1 in 1,000,000, with an average of 1 in 444,000.

From these results it is evident:

5. That there is considerable individual variation.

6. That the taste is most acute for the less common stimuli of bitter and acid than for the more common stimuli of salt and sweet.

7. Several subjects recorded a marked decrease in the acuteness after the use of tobacco.

8. One subject recorded a noticeable increase in the stimulation when the solutions were warmed from 20° to 40° C.

9. One observer found that the tip and edge of the tongue were more acute than other parts of the tongue in detecting slight differences in the strength of the solutions.

10. One observer, reporting a series of very careful experiments upon four individuals, three of whom are members of the same family and accustomed to the free use of salt and vinegar in their regular diet, concluded that the fourth individual, not accustomed to the free use of salt and vinegar, has a greater sensitiveness for saline and sour substances than have the three individuals who are so accustomed.

As to the interval of time between the application of the stimuli and the taste perception, the observations seem to justify the following conclusions:

11. The interval between stimulation and sensation (latent interval) varies inversely as the number of papillæ per unit area in the portion of the gustatory apparatus stimulated.

12. The interval between stimulation and sensation varies directly as the blood supply of the part at the time of stimulation.

II. *To Determine Localization of the Sense of Taste, i.e.,* to find whether there are areas of gustatory region which are especially sensitive to particular stimuli—quinine, for example.

Solution.—Through the aid of a probang or a camel's-hair brush apply to different limited areas of the tongue, palate, or fauces either the standard solutions given above or somewhat stronger solutions of the same substances.

Results.—The accompanying figure gives the results which coincide substantially with those of other observers: Outline of tongue showing location of tonsils (*T*), foramen cæcum (*F.C.*), circumvallate papillæ (*C.P.*), and fungiform papillæ (*F.P.*) upon the left side, while the right side shows the outline of the area particularly sensitive to quinine (——), acid (....), salt (—.—.—), and sugar (- - - -) respectively.

"O. Ehrwall has examined the different fungiform papillæ over the tongue with reference to their sensitiveness to taste stimuli. One hundred and twenty-five separate papillæ were tested with succinic acid, quinine, and sugar. Twenty-seven of the papillæ gave no response at all, indicating that they were devoid of taste fibres." [It may be suggested in passing that perhaps the twenty-seven papillæ were sensitive to salt alone.—W. S. H.]

"Of the remaining ninety-eight, twelve perceived acid alone, three perceived sugar alone, while none was found which reacted to quinine alone. The fact that

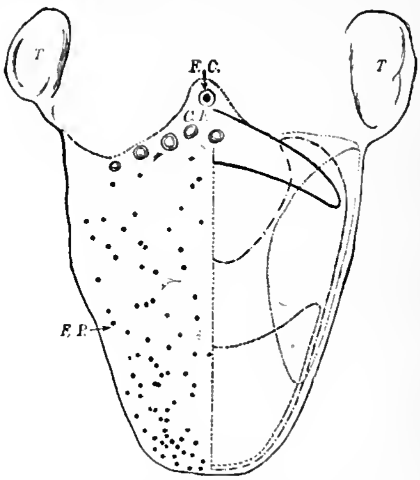


FIG. 4595.—Localization of Taste. Bitter, ——; acid, ...; salt, —.—.—; sweet, - - - -; *T*, Tonsils; *F.C.*, Foramen cæcum; *C.F.*, Circumvallate papillæ; *F.P.*, Fungiform papillæ. (Hall: "Text-book of Physiology." Lea Bros., Philadelphia.)

some papillæ respond to only one form of taste sensation is evidence in favor of the view that there are separate nerve fibres and endings for each fundamental sensation, but a majority of the papillæ (eighty-three) are provided with more than one variety of taste fibres." (Henry Sewall, in "American Text-book of Physiology.")

Winfield Scott Hall.

TATE SPRING.—Grainger County, Tennessee.

POST-OFFICE.—Tate Spring. Hotel and cottages.

ACCESS.—Viâ Morristown and Cumberland Gap Railroad to Morristown; thence ten miles by carriage to spring.

This resort is 1,400 feet above the sea-level, and is located in a charming valley environed by mountains 3,000 feet in height. It may be regarded as one of the strictly first-class summering places of the Tennessee Mountains. The beautiful and picturesque scenery and genial climate are supplemented by the addition of two excellent modern hotels and numerous cottages. There is but one spring, which yields one hundred and twenty gallons per hour. The following analysis was made in 1872 by T. S. Antisill, professor of chemistry in the National Medical College and chemist to the United States Department of Agriculture: One United States gallon contains (solids): Calcium sulphate, gr. 160.66; magnesium sulphate, gr. 32.91; sodium sulphate, gr. 8.50; potassium sulphate, gr. 1.54; sodium chloride, gr. 40.27; iron chloride, gr. 2.99; magnesium chloride, gr. 0.62; sodium iodide, a trace; calcium phosphate, gr. 1.14; calcium carbonate, gr. 21.56; silica, gr. 2.70; nitric acid, gr. 0.02. Total, 272.91 grains. The analysis shows a saline purgative water with tonic and alterative properties. It has been found beneficial in functional disorders of the nervous system induced by overwork and mental worry, in cases of hypochondria and insomnia, and in chronic metallic poisoning. Some forms of dyspepsia and liver disorders are also improved by its use. The water is now used commercially and shipped by the bottle, case, or barrel to any desired point.

James K. Crook.

TATTOO MARKS.—Tattooing consists in the introduction into the skin of insoluble colored substances which become encapsulated and thus form permanent stains. Microscopical examination of sections from tattoo marks shows that they consist of relatively large particles of pigment, situated part of them in the corium, but the larger part in the subcutaneous connective tissue. Particles of pigment are found also in the contiguous lymphatic ganglia. Powder stains, coal-dust stains, and similar stains produced by the accidental embedding in the skin of particles of colored substances, usually carbon, are in all essential characteristics identical with tattoo marks. One form of accidental marking of the skin to which attention should be called is the whitish marks which occasionally result from the precipitation of lead in the tissues during the use of subacetate-of-lead solution or lead and opium wash upon superficial wounds involving the connective tissue. The danger of these stains on the cornea from the use of subacetate of lead in the eye is well known. A staining of the skin which is in all essentials of the same character as these we are considering, but which is produced from within, is argyria, in which there is a precipitation of silver in the derma and subcutaneous tissue after the long-continued internal use of silver. The writer has seen a marked argyria in one case in which the silver was not being taken internally, but had been used daily during more than a year in the form of a solution of the nitrate for painting patches of leukoplakia buccalis.

Tattooing is one of the most primitive efforts of man at personal adornment. Like many other things that have their origin in vanity, various kinds of significance are attached to the practice, but the underlying reason for tattooing, not only among the primitive races, but among the civilized, rests probably upon an inherent barbaric taste for distinctive personal decoration. Among uncivilized peoples and among nations in a relatively low state of civilization, like the Orientals, the practice is general, and is often carried to the most extravagant extent. Among Caucasians, aside from its general use among sailors, it is largely confined to those individuals of both the lower and the higher classes who readily accept anything that is bizarre or that gives them a fancied distinction.

Brault divides tattooing among primitive peoples according to its significance, as follows: First, religious tattooing, as in the priests among the Polynesians; second, ornamental tattooing, seen in the Algerians, Tunisians, and in the inhabitants of Oceanica and Japan; third, therapeutic tattooing, practised in Tunis, in Egypt, and in the Congo region; fourth, distinctive tattooing, practised among the Arabs and negroes of Africa, for the purpose of defining not only different tribes, but also certain callings; fifth, obscene tattooing, which is found only rarely among savages, but which is very common among sailors and criminals.

Practical uses of tattooing are very limited. As a means of identification tattoo marks are of course valuable, and the tattooing of habitual criminals has been suggested as a means of their ready identification. Several years ago de Wecker suggested the tattooing in black of leucomatous areas on the cornea. The method has not had very wide application, and is of course not free from danger. Very recently the highly artificial suggestion has been made of tattooing the flush area of the cheeks to represent a healthy blush. It is interesting to try to imagine how this healthy blush would appear on the faded skin of later life.

Designs of the most elaborate character are often seen in tattoo marks, many of them showing some artistic taste and considerable technical skill. The extent to which tattooing has been carried in some individuals has been limited only by the cutaneous surface. In the well-known case of the tattooed man from Burmah, illustrated in Hebra's Atlas, the entire surface was occupied by tattoo marks. Numerous other cases of almost as great extent have been seen.

The usual method of tattooing is first to outline upon the surface the design, and then to prick out this design with a needle or a bundle of needles, and after that to rub in the pigments. For dark blues and blacks, carbon in some form is used, charcoal, lampblack, India ink; other pigments used for various colors are cinnabar, carmine, indigo, Prussian blue. The dangers of tattooing, at the hands of the unskilled persons by whom it is usually practised, are by no means small. All sorts of infections are possible: lymphangitis, erysipelas, chancroid, tetanus, tuberculosis, leprosy, and syphilis. Many cases of syphilis transmitted by this method are recorded in the literature. The means of transmission—by the saliva of the operator, the use of an infected needle, subsequent infection of the unhealed wound—are manifest.

Much ingenuity has been exercised in attempts successfully to remove these marks. The treatment of powder stains and similar stains is largely a matter of mechanical removal, and to be successful this must be done immediately after the production of the marks, before the particles of pigment have become so disintegrated that their mechanical removal is impossible. The individual masses of pigment have to be patiently picked out, for which purpose an iris needle or a small sharp-pointed knife is most convenient. The method requires great patience both on the part of the operator and on that of the patient, but if thoroughly done immediately after the injury it gives satisfactory results. A certain amount of anæsthesia may be obtained by the application of small quantities of weak cocaine solution or by the use of an ointment of ten- to twenty-per-cent. orthoform in lanolin. In connection with the mechanical removal of the particles of pigment, the use of a strong solution of H_2O_2 as a bleaching agent has been suggested, and it is perhaps the best antiseptic for use in these cases; but it is hardly possible that powder stains or coal-dust stains could be bleached by this means, since at the body temperature carbon (which causes most of the discoloration) cannot be bleached with oxygen.

The principle of almost all of the methods for the removal of tattoo marks is their destruction by mechanical means or by the production of a destructive inflammatory process which causes a superficial eschar. Very small stains can be destroyed by the use of the cutaneous punch or by electrolysis or by excision. In using electrolysis the needle attached to the negative pole of a battery with a current of from two to ten milliampères is inserted at various points around the periphery of the marks, and a sufficient reaction is produced to cause the destruction of the involved tissue. In a few days after the application a dry superficial eschar forms, which is thrown off, leaving a white scar. Of course these mechanical methods can only be applied to very small lesions on account of the scars which they produce. The various methods for the treatment of larger lesions depend upon the application of some chemical irritant which sets up an acute inflammatory process sufficiently intense to cause destruction of the superficial layers of the skin. Many irritants have been suggested for this purpose: chromic acid, carbolic acid, acetic acid, tincture of cantharides, potassium nitrate, etc. The two methods of treatment after this principle which have been most definitely worked out are those of Variot and Brault.

Variot's plan of treatment, according to Brocq, is as follows: First, he places on the tattoo marks a concentrated solution of tannin, and tattoos this in. Then a silver-nitrate pencil is rubbed vigorously over the surface. The action of the silver nitrate is allowed to go on for some moments until the surface becomes black from the formation of silver tannate in the superficial layers of the skin. In the next few days a slight inflammatory reaction occurs, and over the surface treated a closely adherent dark crust forms. After the third or fourth day there is no pain except when there is movement of the muscles under a large crust. Occasionally there is a little suppuration under the crusts, but if secondary infection is avoided no severe inflammation occurs. After fourteen or sixteen days the crust comes off spontaneously, the corium and the epidermis underneath have been repaired, and the locality of the mark is recognizable only by a superficial pink cicatrix which gradually becomes of normal color. A couple of months after the operation the scar is hardly noticeable.

In Brault's plan the irritant used is a solution of chloride of zinc, 30 gm., to 40 gm. of water. The mark is tattooed with needles dipped in this solution, and in addition the surface is lightly moistened with the same solution after the tattooing. A mild inflammatory reaction is produced, followed by the formation of a crust which subsequently exfoliates, leaving a pinkish, slightly scarred surface similar to that after Variot's operation.

In the use of either of these methods several attempts may be necessary. The surface treated at one time should not exceed one or two square inches, and of course ordinary surgical precautions as regards the cleanliness of the surface, both before the operation and during the subsidence of the inflammatory process, should be observed. Both of these methods are founded upon correct pathology and are worthy of trial. Variot's method would seem the one of preference, as the action of silver nitrate can be more accurately controlled than that of zinc chloride.

Ohmann-Dumesnil has proposed a method of removing these marks by digesting with digestive ferment the connective tissue which encapsulates the pigment particles and thus liberating them, so that they can be carried away by the lymphatics. For this purpose he uses glycerole of papoid or of caroid. His method is as follows: The skin is made surgically clean and then anæsthetized with a spray of ethyl chloride. The surface is then covered with glycerole of papoid or of caroid and tattooed with a bunch of six to ten very fine needles which have been dipped in the solution. The tattooing should be firmly done, but the needles should be driven in just far enough to draw the least possible blood. Glycerole of papoid or of caroid is then poured over the area and it is covered with gauze. On the removal of this after two or three days the tattoo marks present a hazy appearance. Shortly after, a crust forms which later falls off, and with it the marks disappear. If any trace remains the process is to be repeated. This idea is ingenious, but the results have not been satisfactory in the hands of some workers. It is questionable whether the results obtained are not those due simply to a destructive inflammatory process, as in the other methods.

William Allen Pusey.

TEA.—(*Thé*, Codex Med.) The prepared and dried leaves of *Thea sinensis* L. (*Camellia Thea* Link, etc. Fam. *Theaceæ*). This definition includes, as varieties, *Thea* (*Camellia*) *viridis*, *T. Bohea*, and others, as well as the wild Assam tea tree, supposed to be the origin of them all. The tea plant as seen under cultivation is a shrub, a metre or so in height (from two to five feet), but in the wild state it becomes a small tree of from five to ten metres. The leaves are alternate, evergreen, rather thick and leathery, smooth when mature, short-petioled, lanceolate, of varying bluntness, serrate, feather-veined, the veins not reaching the margins, and from 5 to 10 cm., or in the much larger wild plant, from 15 to 20 cm. long (Fig. 4596).

Tea is a native of Asia, and grows in a semi-wild state in many of the districts where it is cultivated, but has only been found in an unquestionably indigenous condition in Assam, where it was discovered, some fifty years ago, by Mr. Robert Bruce, as a good sized tree with very large leaves. It is now cultivated in many parts of the world; first in importance in China, where it is said to have been domesticated more than a thousand years ago, also in great quantity in Japan, Java, and India, to a slight extent in South America and elsewhere, and finally in the United States, experimentally. Although it grows pretty well in many places and is comparatively hardy, the higher price of labor is a bar to its profitable production in most civilized countries.

The earliest knowledge of the use of tea is from the Chinese, to whom it was familiar one thousand and perhaps two thousand years ago. It was introduced into Japan in the thirteenth century A.D., and into Java and India in recent times. It was first used in Europe near the middle of the seventeenth century.

Tea is planted in gardens and tended without gathering until two or three years old; then the leaves and buds are plucked for two or three successive crops each season. If green tea is to be made, they are immediately dried over a heated stove, and afterward colored more or less. For black tea the leaves are pressed in little heaps, and allowed to wilt and ferment a little before drying, which

FIG. 4596.—Tea Plant, Flowering Branch. (Baillon.)

is effected in the same way as above; by this process some of the tannin is decomposed, and the essential oil altered so as to modify the taste and smell a little; its color is also very much darkened, as well as that of the infusion made from it. The principal varieties of tea are: Black—flowery pekoe, orange pekoe, souchong, congou, bohea, etc. Green—gunpowder, imperial, hyson, young hyson, etc. The teas of our market are nearly always "blends," made by mixing several grades together.

The usual shape of tea is attained by compressing and rolling the leaves in the hand or upon a table until they are crumpled into the little rolls or wads of which commercial tea consists; in the nicer sorts each leaf is rolled by itself.

COMPOSITION.—In the proportions of the ingredients there is considerable variation, but the following are the principal ones: *Essential oil* from one-half to one per cent., which is the source of its flavor; *caffeine* (theine) from one-half to two or three per cent., which gives it bitterness. This alkaloid is found in half a dozen other plants, most of which are used somewhere as stimulating food adjuncts (see *Caffeine, Guarana, Cola Nuts*, etc.). It is also related to cocaine and theobroma. The amount of *tannin* in tea is large (from twelve to seventeen per cent.).

ACTION AND USE.—The large amount of tannin found in tea makes it an active astringent, especially to those unaccustomed to its use. It constipates the bowels, impairs the digestion, and reduces intestinal secretion when taken in large quantity; locally it makes tea a mild hæmostatic, and a useful wash for indolent ulcers, exuberant granulations, etc. The essential oil gives to tea its agreeable flavor and a good part of its exhilarating character; it relieves fatigue, stimulates thought, postpones sleepiness, and cheers the mind. The *caffeine* is the chief mental and nervous stimulant and cardiac tonic element. By long-continued, habitual use neither of the above effects is much felt, unless carried to the extent of diminishing the appetite and developing dyspeptic troubles.

The least desirable of the constituents of tea is the *tannin;* it is also one of the slowest to dissolve out, and can, therefore, with a little care, be largely left with the dregs. The quicker an infusion of tea is made, the more fragrance and less bitterness and astringency it has; and the more slowly, the more tannin. Tea for drinking should be made by pouring *boiling* water into a suitable vessel containing the tea and allowing it to stand for from five to ten minutes, no longer. A better way is to rinse the cup in boiling or very hot water until it is heated through, then put in a teaspoonful of dry tea, fill the cup with boiling water, and allow to stand a few minutes. Tea should never be boiled or stand long unless the *tannin* is wanted. If made in an iron vessel or in a tin one which has begun to wear, it will become dark from the formation of a bitter tannate of iron. On account of its almost universal use over the entire world, tea is not often available as a medicine; its effects are identical with those of coffee, but perhaps more astringent and less stimulating than that article. As is the case with coffee, the commercial value of tea depends more upon its aroma than on the amount of caffeine it contains.

ALLIED PLANTS.—There are a dozen or more species of *Thea,* one of which is *Thea Japonica,* the beautiful camellia of the gardens. Besides this there is nothing of economic importance in the order. *W. P. Bolles.*

TEETH.—ANATOMY.—The teeth are commonly divided into two sets, according to the period of their eruption. The teeth which erupt first are variously designated as the deciduous, the temporary, the milk, or the primary teeth. The teeth erupting subsequently to the first set are called the permanent or secondary teeth. In addition to these there are supernumerary teeth, which usually occur in connection with the permanent, but may, in rare instances, be found with the temporary teeth; and there are so-called third dentitions, the genuineness of which, though fairly well established, is not without question.

The permanent teeth are thirty-two in number, sixteen being placed in the upper, and sixteen in the lower, jaw.

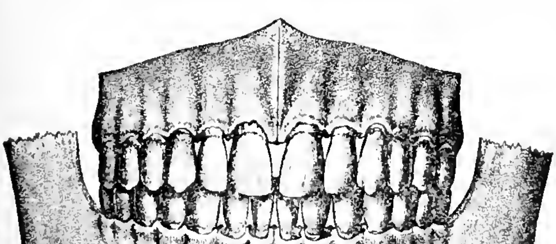


FIG. 4597.—The Permanent Teeth, natural size, showing their Method of Arrangement and Articulation. (Carabelli.)

In each jaw there are four incisors (two central and two lateral), two canines, four bicuspids, and six molars.

A formula to express the number of the various teeth in each jaw is written as follows: I $\frac{4}{4}$, C $\frac{2}{2}$, Bic. $\frac{4}{4}$, molars $\frac{6}{6}$ = 32.

The teeth of the upper jaw are symmetrically arranged along the alveolar margin of the superior maxillary bones. When viewed from below, their crowns are found to describe a parabolic curve. This curve, however, varies according to nationality, heredity, and accidental circumstances. The teeth of the lower jaw are ar-

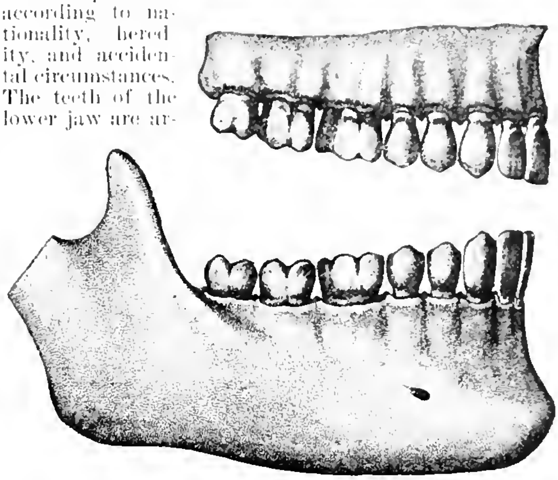


FIG. 4598.—The Permanent Teeth, natural size, showing the Curves in the Alignment of the Crowns. (Carabelli.)

ranged along the alveolar margin of the inferior maxillary bone, and their crowns describe a curve similar to that found in the upper jaw. This curve, however, is more pointed in front and more divergent behind. Speaking roughly, the masticating surfaces of the teeth of each jaw lie in a single plane, no crown projecting in a marked way beyond its neighbor. The teeth, also, when normally arranged, show no gap in the row, each tooth thus by its position giving and receiving support. In both these respects human teeth contrast strongly with those of the lower animals. In these it is common to find that certain teeth, as the canines in the carnivora, present a marked elongation, and also that between the teeth there occur intervals which allow of their interlocking.

The curve on which the upper teeth of the permanent set are arranged is normally somewhat larger than that of the lower teeth. In consequence, the anterior superior teeth overlap the anterior inferior teeth, as do also to a slight extent the superior bicuspids and first and second molars the corresponding lower teeth. The wisdom teeth, however, meet practically edge to edge. It is to be further noted that the superior teeth are not situated directly opposite corresponding inferior teeth. The superior centrals are opposite the inferior centrals and a portion of the inferior laterals; the superior laterals are opposite a part of the inferior laterals and a part of the inferior canines; the superior canine occludes between the inferior canine and the first inferior bicuspid; the first superior bicuspid occludes between the first and the second inferior bicuspids; the second superior bicuspid occludes between the second inferior bicuspid and the first molar; the first superior molar occludes with the first and the anterior portion of the second inferior molar; the second superior molar occludes with the second and the anterior part of the third inferior molar; the third superior molar occludes with the third inferior molar, and is the only tooth in the upper jaw having a single antagonist. While it has been stated that the masticating surfaces of the teeth of the upper and lower jaws are on a single plane, yet slight deviations from this rule are to be noticed. If we follow the lower edge of the upper teeth from a superior central around to the wisdom, we shall find that the line ascends gently from the central to the interval between the first and second bicuspids, then descends till past the first molar, when it ascends slightly to the end of the row. On the lower jaw the anterior teeth are slightly elevated above the posterior, and between the canine and the wisdom tooth a slight concavity is to be observed.

In its description a tooth is to be divided into a crown, a root or fang, and a neck. The crown of a tooth is that part which normally appears beyond the margin of the gum. The root or fang is that part which is normally embedded in the alveolus of the maxillary bone. The neck is a more or less constricted belt lying at the margin of the gum where the crown joins the root. The surfaces of the crowns are thus designated. Those surfaces lying adjacent to the lips are called labial surfaces, those lying adjacent to the buccinator muscle are called buccal surfaces. Those surfaces on the inner side of the teeth lying adjacent to the tongue are called lingual surfaces. In the case of the upper bicuspids and molars, however, such surfaces are more commonly called palatal surfaces, from their relation to the hard palate. The grinding surface of the bicuspids and molars is called the coronal surface. The surfaces between adjoining teeth are called approximal surfaces, and are divided into two classes—mesial and distal. The mesial approximal surface of a given tooth is that surface which, were the row of teeth in a straight line, would face toward a line drawn between the central incisors. The distal approximal surface is the corresponding surface at the opposite side of the tooth. These names are, as a rule, applied to the crowns of the teeth, though they are, with the exception of the term coronal, used also in connection with the roots.

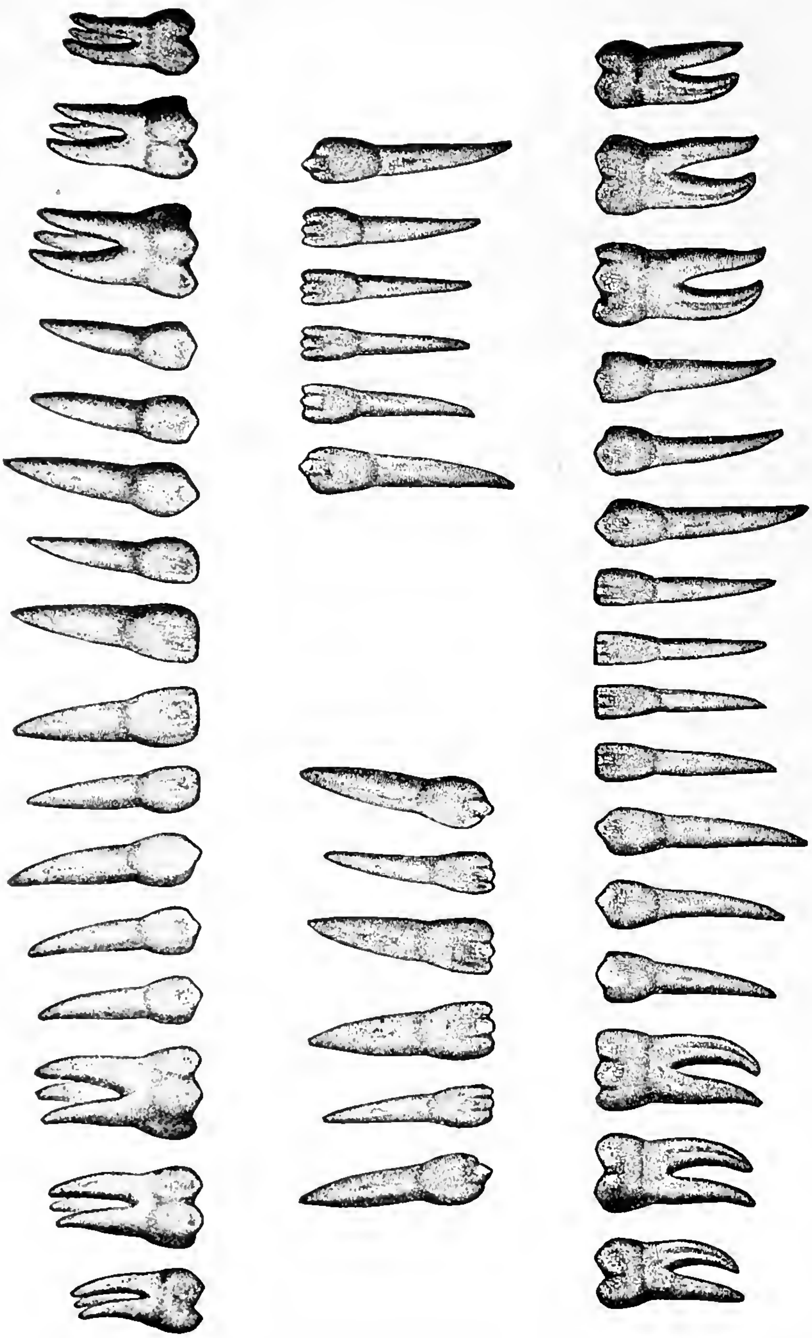


Fig. 4590.—The Permanent Teeth (slightly reduced in size), showing the Labial and Buccal Surfaces. The middle row of teeth represents freshly erupted incisors and canines, with the tubercles on their cutting edges intact. (Carabelli.)

The *temporary teeth* are twenty in number. In each jaw there are four incisors, two canines, and four molars. The dental formula is I $\frac{4}{4}$, C $\frac{2}{2}$, molars $\frac{4}{4}$ = 20.

This formula differs from that of the permanent teeth by the entire absence of bicuspids, and by the loss of four molars. The temporary teeth can best be described by comparing them with the permanent teeth, which they closely resemble.

The incisors and canines of the upper and under jaws are very much smaller than the corresponding teeth in the permanent set, and the root of the upper central incisors is somewhat curved on the mesial side where the corresponding root in the permanent teeth is practically straight.

The first upper molar is situated behind the canine, and in appearance is a compromise between a bicuspid and a molar. Its crown resembles in general shape that of an upper molar, but is quite small, and bears only three cusps—two external and one internal. The roots are three in number, resembling in shape and position those of the permanent molars. They are, however, more divergent, thus providing room for the first bicuspid, whose crown is situated directly beneath the temporary tooth, and within the grasp of its roots.

The second upper molar is a much larger tooth than the first, and resembles so closely the first permanent molar that it might be mistaken for it. Its roots are more divergent, however, in order to embrace the crown of the second bicuspid, to which it gives way in the permanent dentition.

The first molar in the lower jaw is situated behind the canine, and resembles in shape a permanent molar of the lower jaw. Its crown is surmounted by four cusps—two external and two internal. It has two roots, one anterior and one posterior, between which is developed the crown of the first inferior bicuspid.

The second lower molar is larger than the first, and a little smaller than a permanent lower molar, which it

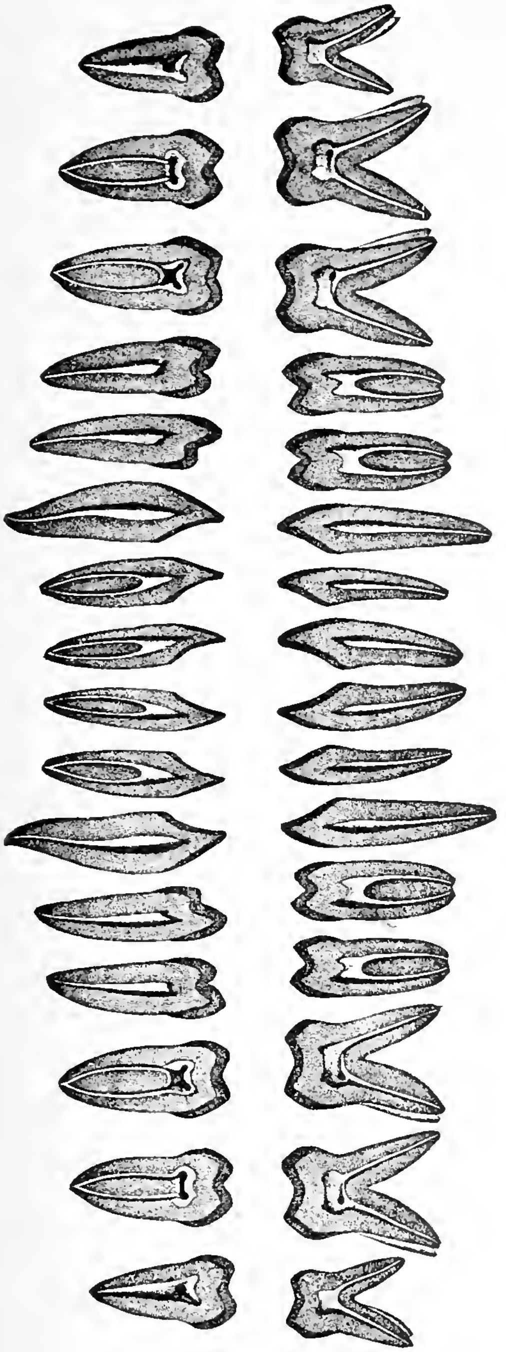


FIG. 4600.—The Permanent Teeth, natural size; a Section through the Pulp Cavity, showing its Size and Shape. (Carabelli.)

closely resembles. Its crown has five cusps—three external and two internal. There are two roots, one anterior and one posterior, which embrace the developing crown of the second lower bicuspid. It is characteristic of the temporary teeth that the foramen at the apex of the roots is larger, that the necks of the teeth are more constricted, and the color whiter and more delicate than in the permanent teeth; also, that the six anterior upper teeth do not overlap the corresponding lower teeth to such an extent as in the permanent set.

MICROSCOPIC ANATOMY OF THE TEETH.—A longitudinal section through a tooth will reveal four distinct structures—the enamel, the cement, the dentine, and the pulp. The pulp is a soft mass of connective tissue richly supplied with blood-vessels and nerves, and located in the centre of the tooth. It fills the pulp cavity. The pulp cavity starts at the apex of the root or roots, as the case may be, as a thread-like canal, and gradually enlarges till it reaches the crown, where it attains its greatest size; throughout its whole course it imitates in shape the external contour of the tooth. An artery and nerve, and sometimes more than one of each, enter the apical foramen of each root of a tooth, and, branching freely, distribute themselves to all parts of the pulp, being especially abundant about its periphery. A venous system returns the blood through the apical foramen into the general circulation. It is a matter of dispute whether a lymphatic system is present or not; most observers consider that it is not. Around the periphery of the pulp, and distinct from the connective-tissue cells forming its body, there exists a layer of cells called the odontoblastic layer, or the membrana eboris. In shape these cells are large in comparison with the connective-tissue cells; they are of columnar form and have several processes. By these processes they are in close relation with the terminal filaments of the nerve of the pulp, joined to one another, and connected with the dentinal fibrils.

Immediately surrounding the pulp comes the dentine, which is the most abundant tissue of the tooth. It is

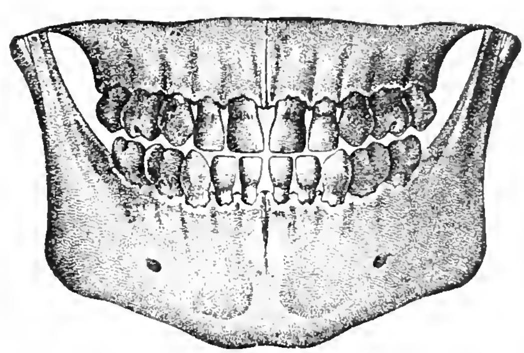


FIG. 4601.—The Temporary Teeth, natural size, showing their Arrangement in the Maxillary Bones, and Relations to one Another. (Carabelli.)

hard and dense in structure, of a yellowish-white color and silky lustre. On analysis it is found to contain animal matter, twenty-eight per cent.; earthy matter, seventy-two per cent. Its various components are thus given by von Bibra:

	Per Cent.
Organic matter	28.01
Phosphate and fluoride of calcium	66.72
Carbonate of calcium	3.36
Phosphate of magnesium	1.18
Other salts	.73
Total	100.00

Morphologically considered, it is composed of a structureless matrix permeated by countless tubules, each tubule possessing a lining membrane and a central fibril. The tubules start from the pulp cavity, where they have a diameter of about $\frac{1}{5000}$ of an inch, and radiate toward the periphery of the dentine, becoming smaller and more numerous as they advance. While the direction taken by the tubules in different parts of the tooth varies greatly, yet contiguous tubules are essentially parallel. Two or three undulatory curves are to be noticed in the length of a tubule, and the name primary curvature has been attached to them. Numerous spiral turns occurring in the course of the undulatory curves have been named the secondary curvatures. The tubules give off

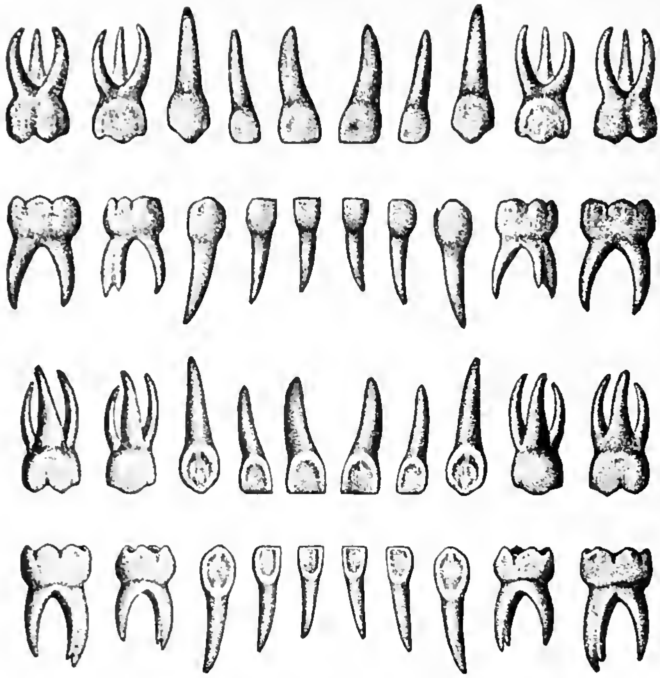


FIG. 4602.—The Temporary Teeth, natural size, showing the External and Internal Surfaces. (Carabelli.)

frequent branches throughout their entire length. Some of these branches are important, extending to the outer layers of the dentine parallel to the main channel. Other branches serve merely to connect one tubule with another, and still others are blind processes. At the outer layer of the dentine the tubules become diminished in size and very numerous. Some of the tubules can be seen entering the granular layer of the dentine, while others either terminate blindly or anastomose with neighboring tubules. The "granular layer of Purkinje" consists of numerous irregular cavities filled with cells having nuclei, and forming a layer about the peripheral portion of the dentine, being especially well developed where the dentine is covered by the cement of the root. The cavities of this layer communicate with each other, and in some cases with the canaliculi of the cement, besides being connected with the tubules of the dentine.

FIG. 4603.—An Upper Temporary Molar, with a Bicuspid within the Grasp of its Roots. (Weil.)

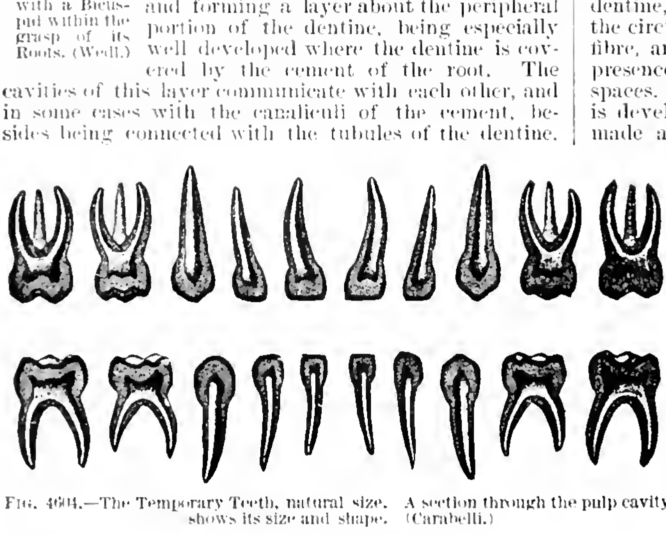


FIG. 4604.—The Temporary Teeth, natural size. A section through the pulp cavity shows its size and shape. (Carabelli.)

The tubules of the dentine have been shown to possess a lining membrane, and to this the name dentinal sheath has been applied. This structure resists the action of reagents which destroy the matrix in which the tubules are embedded, and is supposed to consist of elastic tissue, though its composition is not surely determined. The dentinal fibril which occupies the centre of the tubule is a soft homogeneous substance, having a nerve-like function, but lacking true nerve structure.

The fibril is connected at one end with an odontoblastic cell in the periphery of the pulp, and the other end enters, in many cases at least, the granular layer of the dentine, coming into contact with the soft tissue therein contained. Through the dentinal fibril communication is maintained with the nerves of the pulp, and sensation is supplied to all parts of the dentine. In longitudinal section of that part of the dentine which lies in the crown of the tooth are to be seen lines which are called the "incremental lines of Salter." They run, in general, parallel to the external contour of the crown, and mark stages in the development of the dentine, being not unlike the circular rings of wood fibre, and are due to the presence of interglobular spaces. That the dentine is developed by stages is made apparent by treating it with hot caustic potash. By this reagent the dentine becomes separated into layers, which cross the tubuli at right angles, and are concentric about the pulp. In the crown of the tooth, between one layer of dentine and another, there occur imperfectly calcified spots where

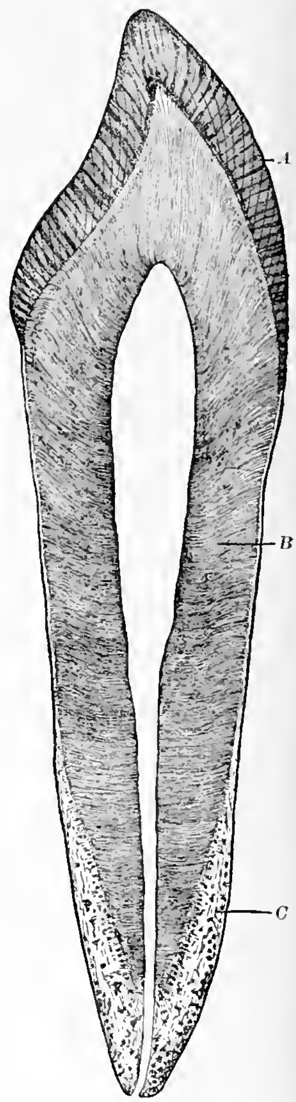


FIG. 4605.—A Microscopic Section of a Canine Tooth, showing, *A*, the enamel, with its enamel rods running from the dentine to the outer surface. The dark strips indicate places where the enamel rods cross each other. The fine parallel lines are the "brown lines of Retzius." *B* is the dentine, with its tubules radiating from the pulp cavity. The undulatory curves of the tubules are called the primary curvatures. The secondary curvatures are not visible at this enlargement. The granular layer is indicated by the dotted line about the periphery. It is especially marked between the cement and dentine, and practically absent between the enamel and dentine. The interglobular spaces are represented in the coronal portion of the dentine just removed from the junction of the dentine and enamel. *C* indicates the cement, with its lacunæ and canaliculi.

the dentine assumes a globular form, and where irregular interglobular spaces are found. Series of minute interglobular spaces give rise to the "incremental lines of Salter."

The dentine is surrounded in the crown by the enamel, and in the root by the cementum.

The cementum, or crusta petrosa, is the outer covering of the root. It is thinnest at the neck of the tooth, where it meets and slightly overlaps the enamel, and grows gradually thicker toward the apex, about which point it is most abundant and its structure is most perfectly developed. Cement has essentially bone structure; it possesses lacunæ and canaliculi, but has normally no Haversian canals. The lacunæ and canaliculi are wanting or rare in that part of the cement near the neck of the tooth, but about the apex of the root they are numerous and well developed. The lacunæ lie in parallel planes encircling the pulp cavity, their canaliculi anastomose freely with each other, and in some cases they connect with the granular layer of the dentine, thus establishing a communication between the lacunæ of the cement and the pulp of the tooth through the granular layer and tubuli of the dentine.

Immediately surrounding the cementum of the root exists the peridental membrane, which is identical with the periosteum which lines the bone forming the socket of the tooth. The peridental membrane serves a triple function. It nourishes the bone of the socket and the cement of the root, besides forming a bond of union between the root and its socket. The peridental membrane, like all periosteum, is composed of connective tissue richly supplied with blood-vessels. The arterial supply comes from capillaries of the gum about the neck of the tooth, from the deep substance of the bony socket, and from a branch of the artery entering the apical foramen of the tooth.

The enamel forms the outer covering of the crown; it is the hardest structure in the body. It resembles den-

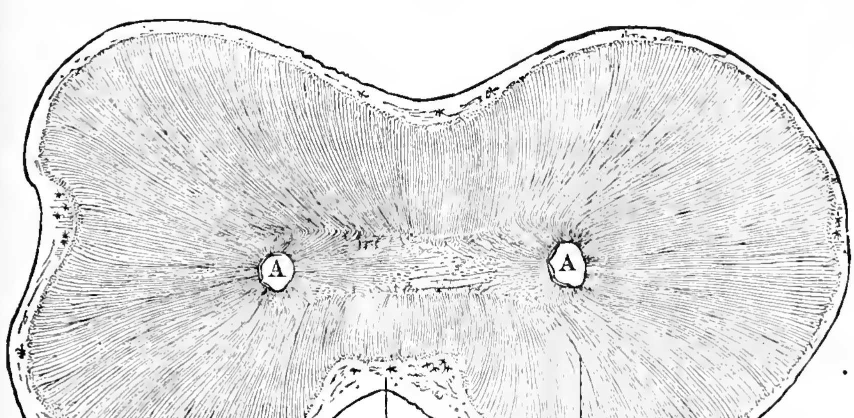


FIG. 4606.—Cross-section of an Upper Bicuspid Tooth. A, A, The root canals; B, the granular layer of the dentine; C, the cementum, showing occasional lacunæ; D, the dentine.

tine in its chemical constituents, but has a much greater proportion of inorganic material. The following analysis is given by von Bibra:

	Per Cent.
Phosphate and fluoride of calcium	89.82
Carbonate of calcium	4.37
Phosphate of magnesium	1.34
Other salts	.88
Cartilage	3.39
Fat	.20
Total	100.00

The proportion of organic and inorganic matter is as follows.

	Per Cent.
Organic	3.5
Inorganic	96.5
Total	100.00

Morphologically considered, enamel is composed of rod like, hexagonal prisms, arranged side by side, one end of the prism resting on the outer layer of the dentine and the other forming the free surface of the crown of the tooth. Each prism extends, as a rule, through the entire thickness of the enamel. There are some, however, which extend only from the centre of the enamel to its free surface, thus preventing gaps which would otherwise occur, the outer surface of the enamel being of greater extent than the inner. In diameter the enamel prisms measure $\frac{1}{7000}$ to $\frac{1}{5000}$ of an inch. Each prism, when isolated, has slight varicosities and presents a striped appearance similar to muscular fibre. The prisms run, in general, parallel to each other, and in a wavy course; their inner ends are implanted in slight hexagonal depressions in the surface of the dentine, and their outer ends are received into similar depressions in the under side of the cuticle of the enamel when the cuticle is present. A vertical section of the enamel shows that it is thickest in the crown, especially in the region of the cusps, and becomes thinnest at the neck of the tooth, where it is overlapped by the cement of the root. The enamel prisms are seen to leave the outer surface of the dentine at right angles, and radiate toward the external surface of the tooth. The general yellowish-white color of the enamel is varied by dark bands extending vertically from the dentine to the free surface of the enamel, caused by the crossing of bundles of enamel prisms. Certain delicate lines running longitudinally through the substance of the enamel are also to be noticed. These are called the "brown lines of Retzins," but it is not known to what they are due. Also between enamel rods, usually near the surface of the dentine, are

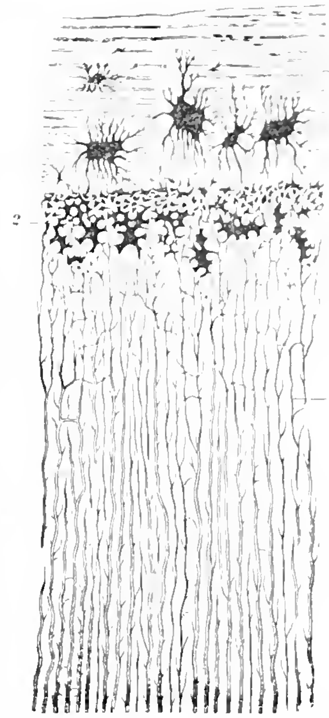


FIG. 4607.—A Section of Dentine and Cement. The figure 1 represents the cement with its lacunæ and canaliculi; the figure 2 represents the granular layer of the dentine. It is to be noticed that the lacunæ communicate with the cells of the granular layer. The figure 3 represents the tubuli of the dentine, showing their diminution in size as they go toward the cement, also their frequent anastomoses and their connection, in some cases, with the cells of the granular layer. (Quain.)

found irregular cavities due to an imperfect calcification of the enamel. On cross-section the enamel has the appearance of a mosaic pavement, each prism showing its hexagonal shape.

The cuticle of the enamel, or Nasmyth's membrane, is to be found in a freshly erupted tooth. It consists of

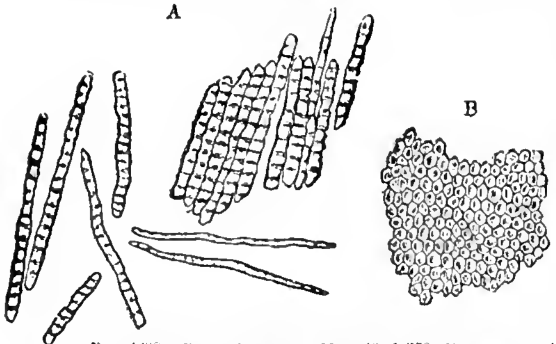


FIG. 4608.—Enamel Prisms. Magnified 350 diameters. *A* shows the varicosities and striations of the prisms; *B* is a cross-section of enamel, showing the hexagonal shape of the prisms, and their tessellated appearance. (Quain.)

a delicate epithelial covering which encloses the enamel; it is, however, so delicate that in the slightest use it is worn away. It receives in hexagonal depressions on its under side the outer ends of the enamel prisms.

TIME OF ERUPTION OF THE TEETH.—The first dentition begins about the seventh month, and is completed about the twenty-fourth month. The second dentition begins about the sixth year, and is completed about the twenty-first. Considerable variation exists in the time at which individual teeth erupt, and no date can be absolutely fixed for the appearance of a given tooth. It is possible, however, to state the time when the eruption of a tooth is normally to be expected, and the following tables are appended:

Temporary Teeth.

The central incisor erupts at the	7th month.
The lateral incisor erupts at the	9th month.
The first molar erupts at the	12th month.
The canine erupts at the	18th month.
The second molar erupts at the	24th month.

Permanent Teeth.

The first molar erupts at the	6th year.
The central incisor erupts at the	7th year.
The lateral incisor erupts at the	8th year.
The first bicuspid erupts at the	9th year.
The second bicuspid erupts at the	10th year.
The canine erupts at the	11th year.
The second molar erupts at the	12th year.
The third molar erupts at the	17th to 21st year.

As a rule, in both the first and second dentitions the lower teeth erupt before corresponding teeth in the upper jaw.

PHYSIOLOGY OF THE TEETH.—Under this head we naturally consider the purposes for which teeth exist, and how they perform their several functions. The subject may be divided into three heads:

(1) The function of the teeth in facial expression. (2) The function of the teeth in mastication. (3) The function of the teeth in articulation

The importance of the teeth in facial expression becomes apparent when we consider the effect of their absence, as shown in aged people. In such the lower part of the face has lost the round and graceful lines of early years; the chin is pointed, and approximates the end of the nose; the lips are retracted and flabby, and a characteristic hollow extends along the cheek. When present, each tooth aids in sustaining the proper proportions of the face. The upper front teeth, by being slightly in advance of the lower, produce that slight projection of the upper lip beyond the lower, found in normally shaped features. The bicuspids and molars, by their apposition, fix the relation of the lower to the upper jaw, and by their bulk give fulness to the cheeks. The bony alveolus, also, in which the teeth are embedded, has an important relation to facial expression, for when a tooth has been lost its bony support, being no longer needed, is absorbed, and thus the features are still further deprived of support.

The function of the teeth in mastication is the most obvious and important. Standing as they do at the entrance to the digestive tract, it is their duty to seize upon food, sever its connection with its surroundings, and comminute it so that it can be acted upon readily by the various digestive fluids. The act of seizing and cutting is performed by the six anterior teeth, whose edges, by the protrusion of the lower jaw, are brought opposite to each other. When once a morsel of food has been detached by the anterior teeth, it is passed backward by the tongue and cheeks, to be operated upon by the bicuspids and molars. The bicuspids are fitted both to cut and to grind. They cut by the outer cusps of opposing teeth meeting and passing each other like the blades of a pair of scissors. They crush by a lateral motion, the crowns of the lower bicuspids moving across those of the upper. The function of the molar teeth is to crush and grind, for which purpose they are fitted by their broad crowns. They crush by means of an up-and-down movement, and grind by a lateral movement.

FIG. 4609.—The first profile represents the features undisturbed by loss of teeth. The second represents the edentulous condition, in which the lips fall in and the chin becomes pointed and inclined toward the nose.

The function of the teeth in articulation is best understood by a brief survey of the mechanism of speech. This mechanism includes the vocal cords, and a resonant cavity above the cords, formed by the pharynx and the oral and nasal cavities. This resonant cavity reinforces and modifies sounds made by the vocal cords. Articulation is concerned with sounds of two kinds—vowels and consonants. The vowels are musical notes formed by the vocal cords, and given quality or timbre by the size and shape of the air column in the resonant cavities above. The consonants are sounds produced by the same mechanism, but due to irregular vibrations, and hence are noises. The oral cavity, being able to change its size and shape in numberless ways, is the most important agent in sound modification.

To produce articulate sounds the column of air must be obstructed and forced into channels of definite size and shape. The column of air is obstructed in three ways: first, by applying the back of the tongue to the palate; second, by applying the tip of the tongue to the posterior surfaces of the anterior teeth; and third, by a closure of the lips. It is forced into definite channels by pressing the tongue against different parts of the roof of the mouth, and against the inner surface of the upper teeth.

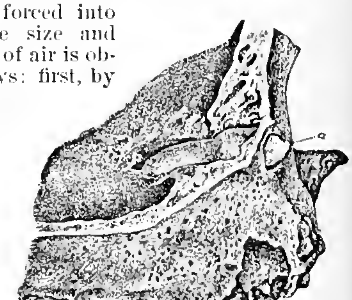


FIG. 4610.—Illustrates the Impaction of a Right Superior Lateral (*a*), which lies in the superior maxillary bone at right angles to its normal position. (Wedl.)

PATHOLOGY OF THE TEETH.—*Pathology in the Number of Dentitions and their Time.*—While two is the normal number of dentitions, much can be heard and read of a third dentition, the authority for which, however, rests, as a rule, with unscientific observers, and is of very little value.

The entire absence of one or both of the normal dentitions is an established fact; such cases, however, are decidedly rare, especially those in which neither dentition has occurred. There is usually associated with this condition a failure in the growth of hair throughout the body. The condition of the alveolar ridge in such cases is similar to that which ensues on the extraction of the permanent teeth. Artificial substitutes, however, are not always necessary, inasmuch as the gum, in such cases, is very tough, and capable of performing with remarkable facility the duties of mastication.

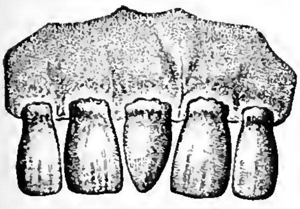


FIG. 4611.—A Conical Supernumerary Tooth Located between the Superior Central Incisors. (Carabelli.)

Pathology in the Time of Dentition.—The deciduous teeth are in rare instances erupted at birth. When deciduous teeth are delayed in their eruption it is commonly due to rickets. A delay in the eruption of the permanent teeth is also frequently noticed. An important cause for this delay is the prolonged retention of the deciduous teeth, an obstacle being thus present which prevents the permanent teeth from taking their place. Cases are on record of deciduous teeth persisting till middle or old age. It often happens, however, that a permanent tooth is kept from eruption because its place has been taken by another permanent tooth which had an earlier start, and which has occupied all the available room. This is especially liable to happen with the superior canines, on account of their coming to the surface after the lateral and the first bicuspid have taken their place in the arch. If, as often happens, the temporary canine has been prematurely extracted, allowing the adjoining teeth to close in the gap, or if the arch is unusually narrow, or the teeth unusually large—and sometimes the two latter conditions exist together—then the canine is likely to be crowded out beyond the arch or to be imprisoned in the alveolus. The canine may be permanently imprisoned, or until the extraction of a bicuspid or lateral incisor offers it a chance to erupt.

The wisdom teeth are always very liable to detention within the jaw, and their eruption may be either prevented or long delayed. This happens from causes similar to those just described with regard to the canine. The modern civilized jaw seems to be made too short to contain a full complement of developed teeth, and, as the wisdom teeth come last, they, though of stunted size, are frequently unable to enter the arch. Imprisoned or partly erupted wisdom teeth, especially of the lower jaw, may cause very serious symptoms, both local and reflex. The local symptoms consist of pain and swelling in the vicinity of the tooth; the reflex symptoms of neuralgias about the head, and a tonic contraction of the muscles which close the jaw. In some cases an abscess may be formed which, if lacking prompt exit, may open by fistula on the outside of the face, at the angle of the jaw, or in the neck, or even as low down as the subclavicular region. Imprisoned canine and incisor teeth are sometimes found far from their normal position. Cases are cited in which the crown of the superior canine has penetrated the nasal cavity and the antrum; they have also been located in the palatine portion of the superior maxillary bone. Lower canines have been found with their long axes parallel to the body of the jaw, at or near the tips of the roots of the inferior lateral and bicuspids. The superior lateral may be delayed in its eruption, or imprisoned for want of room in the arch, and may in consequence take abnormal positions similar to those taken by the superior canine.

Pathology in the Number of Teeth in a given Dentition.—In connection with both the first and second dentitions we find at times both an excess and also a deficiency of teeth. Teeth in excess of the normal are called supernumerary teeth. Such may be coincident in time of eruption with the teeth in whose neighborhood they appear, or they may precede or follow. Supernumerary teeth are divided into two main classes—teeth whose form differs from that of normal teeth (conical teeth), and teeth whose form resembles that of normal teeth. Supernumerary teeth are not common in connection with the first dentition; when they occur they are found more frequently in the lower jaw, and belong in shape to the second class, inasmuch as they resemble the teeth with which they are associated. The duplicate tooth is usually a lower incisor, and it takes its place regularly in the arch, being erupted at about the same time as its companion incisor. Supernumerary teeth are more frequently found in connection with the second dentition, and are usually located in the upper jaw.

They as a rule make their appearance just after the adjoining tooth is erupted. Conical supernumerary teeth are the most common kind. They have the same structure as normal teeth, but in shape resemble a diminutive cuspid. Their crown, however, has not the angular outline belonging to that tooth, but is cone-shaped, as their name implies. The root is round and tapering. These teeth occur most frequently in connection with the superior incisors. One may be located between the two centrals in the arch, or between the central and the lateral. They may be placed without the arch, on either its labial or palatal side. Conical teeth are not commonly found adjoining the molars, bicuspids, or cuspids, though they may exceptionally be found in all these localities. If found outside the arch, conical teeth are of no value and should be extracted; if found in the arch, it often becomes a question whether their presence or absence produces the greater deformity. Supernumerary teeth which resemble normal teeth are generally found among the upper incisors and regularly placed in the arch; they do not necessarily produce deformity, and by the unprofessional eye would not be noticed. A supernumerary superior lateral is most commonly found; next in frequency comes the superior central, while duplicates of the superior molars, bicuspids, and canines are rare. Carl Wedl, in his "Pathology of the Teeth," gives a drawing of the superior and inferior maxillæ of a negro, in which appear four molars on each side of both the upper and under jaw, besides an extra bicuspid in the lower jaw, making five supernumerary teeth in all; the molars are all in the dental arch, but the bicuspid is situated at the inner side of its neighboring bicuspid. A third kind of supernumerary tooth, sometimes described, is called the cubic-crowned tooth; it resembles in shape the lower bicuspid, and occurs in the anterior part of the mouth behind the superior incisors.

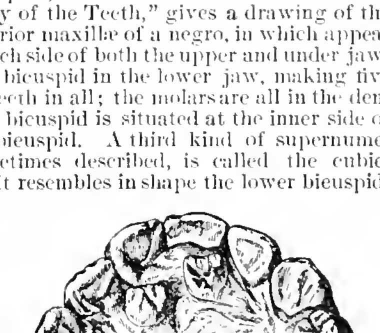


FIG. 4612.—Shows Two Cubic-crowned Supernumerary Teeth, Occurring Behind the Upper Central Incisors. (Salter.)

Pathology in the Arrangement of the Teeth.—A pathological arrangement or irregularity may affect groups of teeth or individual teeth. Among the irregularities which affect groups of teeth are cases in which the anterior teeth of the upper jaw project so far in advance of the corresponding teeth of the under jaw that a considerable space exists between the anterior surface of the lower teeth and the posterior surface of the upper teeth. This arrangement is in many cases hereditary, but may be induced by thumb-sucking in infancy. Infants addicted to this habit place the thumb between the front teeth and pry the upper teeth forward, using the under as a fulcrum. The force exerted is very slight, but, being continued for perhaps several hours during the day, is sufficient to move the imperfectly calcified bony alveolus.

An irregularity the reverse of the above, and of frequent occurrence, is produced when the anterior teeth of

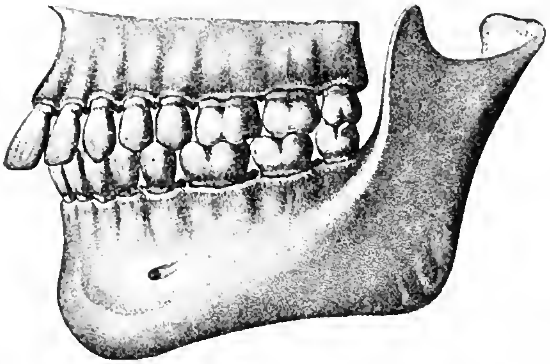


FIG. 4613.—A Case of Projecting Upper Front Teeth. (Carabelli.)

the under jaw are placed in advance of those of the upper jaw, leaving an interval between their posterior surfaces and the anterior surfaces of the superior teeth. To this condition the name underhung jaw has been given.

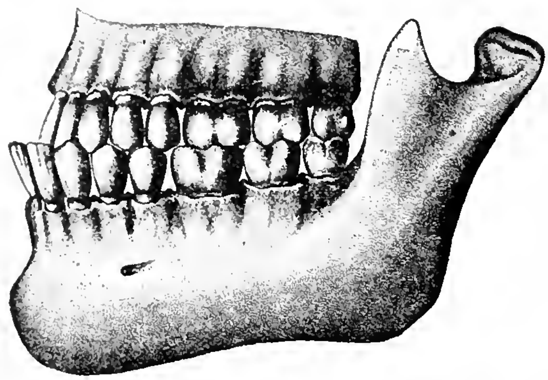


FIG. 4614.—An Underhung Jaw, the Lower Front Teeth in Advance of the Corresponding Upper Ones. (Carabelli.)

It is usually hereditary, and results either from an overdeveloped under jaw or from an underdeveloped upper jaw, the under jaw being normal. This irregularity, as well as the one first described, is very unfavorable to facial expression. The former causes an excessive protrusion of the upper lip beyond the under, and the latter a protrusion of the under lip beyond the upper. A third irregularity is produced when the superior anterior teeth, instead of slightly overlapping the inferior anterior teeth, meet them edge to edge. This arrangement causes no marked facial blemish, but is detrimental to the teeth, which become worn away by edge to edge contact, and thereby shortened.

The six anterior teeth of both jaws are sometimes tilted forward to a marked degree. This irregularity is commonly caused by the loss of molar and bicuspid teeth, which allows the whole force of occlusion to come upon the anterior teeth. This irregularity causes the upper and under lips to protrude.

On the other hand, the six anterior teeth of both jaws may be inverted, and a corresponding falling in of the lips occurs.

A V-shaped jaw is often seen; this irregularity is confined to the upper jaw, whose alveolar arch, instead of being in the form of a parabola, becomes so contracted in front that it resembles in shape the letter V. In such a jaw the room for the tongue is much diminished, and a thick and somewhat indistinct articulation may result.

There are cases in which the back teeth are of undue length and prop the mouth open so wide that the anterior teeth do not meet. Such an arrangement is likely to keep the lips from closing, except as the result of conscious effort.

The dental arch may be asymmetrical. Such a condition may be congenital, or produced by tongue-sucking in infancy. In this habit the tongue is crowded against the alveolus bordering the upper molars and bicuspids, a constant repetition of force in this direction unevenly spreading and thus distorting the dental arch.

The "flat mouth," so called, is produced when the six anterior teeth of both jaws are arranged in nearly a straight line instead of in a curve. When so placed they join the bicuspids at a right angle, or nearly so, and give a characteristic flatness to the expression about the mouth.

These various irregularities are, as a rule, confined to the permanent set. An underhung jaw has, however, been noticed in the temporary set, followed by the same in the permanent.

Irregularities of individual teeth are to be explained by several causes, of which the most important is the occurrence of a small-sized jaw associated with large-sized teeth, a small-sized jaw being inherited from one parent and large teeth from the other.

The premature extraction of the temporary teeth is responsible for many cases of irregularity. The place of each temporary tooth is taken normally by a tooth of the permanent set, and, unless the temporary tooth remains *in situ* till the permanent is ready to be erupted, there is danger that the place which the permanent tooth should occupy will be encroached upon by an adjoining tooth.

The too long retention of the temporary teeth may produce irregularity. In this case the temporary teeth become an obstacle to the descending permanent teeth, and may deflect them from their course, forcing them to appear inside or outside the dental arch; or, as not infrequently happens, keeping them imprisoned within the maxillary bones.

Irregularities of individual teeth of the temporary set are rare. There may be a slight twisting or lapping of the incisors, but no great deformity has been observed. Most important irregularities occur in the permanent set; the superior central incisors may stand inside the dental arch, so that the inferior centrals close in front of them. Their crowns may be rotated either toward the median line or away from it, or may overlap each other. In the lower jaw the central incisors, owing to the frequent crowding of the lower anterior teeth, are often twisted or overlapped. The superior laterals are more frequently

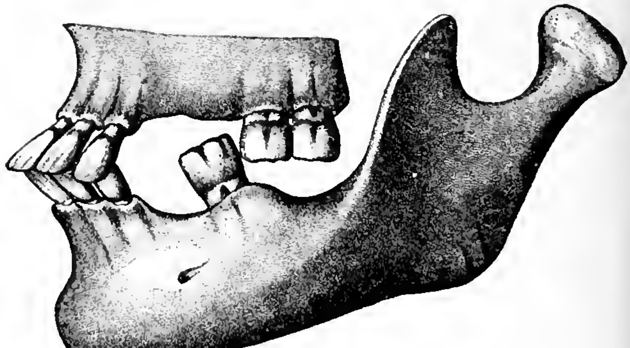


FIG. 4615.—Protrusion of the Anterior Teeth, caused by Loss of Bicuspids and Molars. (Carabelli.)

irregular than are the centrals. The most common irregularity consists in the crown of the lateral overlapping that of the central. The laterals may be placed within the dental arch and held in that position by the interlocking of the lower teeth. Sometimes it happens that they are prevented from eruption by the canines, which have, by premature eruption, occupied their

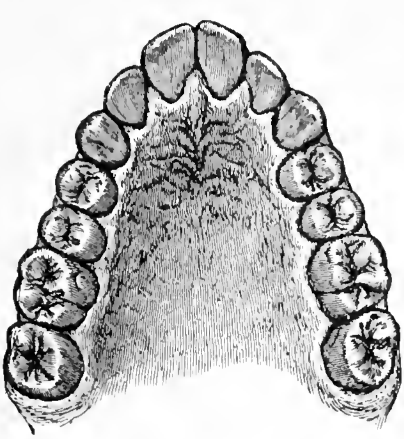


FIG. 4616.—A V-shaped Upper Jaw, from Kingsley's "Oral Deformities." (By permission.)

space. The inferior laterals are liable to irregularities similar to those described in connection with the inferior centrals; such irregularities produce, as a rule, no marked deformity, and are not usually of sufficient importance to be regulated. The superior canines are more often irregular than any other tooth in the mouth. The reason for this is not difficult to find, and has already been partly explained. Erupting, as they do, subsequent to the lateral and first bicuspid, it often happens that the space necessary for their regular appearance in the dental arch has been encroached upon by the adjoining teeth. In consequence the canines must take a position either on the outside of the arch or within. Sometimes the canine takes a position alongside the central incisor; when this is the case, the displaced lateral is usually within the arch. A rotated canine is not uncommon, the rotation being toward the median line or away from it. The lower canines are seldom irregular. The upper first bicuspid also usually finds its normal place, on account of the period of its eruption and the fact that its crown is smaller than that of the first temporary molar which it supplants.

The second upper bicuspid is much more frequently out of place than is the first. Though its crown takes up much less room than that of the second deciduous molar, which it replaces, still the teeth adjoining it (namely, the first bicuspid and first molar), being in position some time before the second bicuspid is ready to erupt, may encroach upon the space which should have been reserved for that tooth. Such a condition usually results from the too early extraction of the second deciduous molar. As a result of such extraction the neighboring teeth move together, and sufficient room is not left for the free eruption of the second bicuspid, and that tooth in consequence, finding its way in the direction of least resistance, is compelled to appear within or without the dental arch, as the case may be. The lower bicuspids are subject to irregularities similar to those of the upper bicuspids, although they occur less frequently. The first and second molars are rarely irregular in either jaw; each in turn being developed behind teeth already in place, there is nothing to crowd them from their normal position. The third molar, on the contrary, has scanty room for eruption, and in consequence presents frequent irregularity. The lower third molar is often found with its crown presenting toward the posterior surface of the crown of the second molar. Sometimes it is tipped forward so far that the force of occlusion and mastication is borne upon its distal surface. This is the most usual form of irregularity, but the tooth may assume almost any position, even with the crown pointing backward toward the ramus of the jaw. The most frequent irregularity of the upper wisdom tooth is the turning of its crown outward or backward.

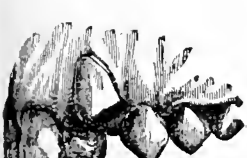


FIG. 4617.—A case in which the superior canine has not room to erupt regularly in the arch, and is forced to appear outside of the arch. (Salter.)

Pathology in Size and Shape of the Teeth.—As a rule, the size of the teeth is in harmony with the proportions of the body. Giants have teeth which would be abnormally large if found in a person of ordinary size. The teeth of males are larger than those of females. When teeth are of unusual size, but proportioned to the size of the individual, they are normal for that individual. There occur cases, however, in which certain teeth are entirely out of proportion to the alveolar arch. Such

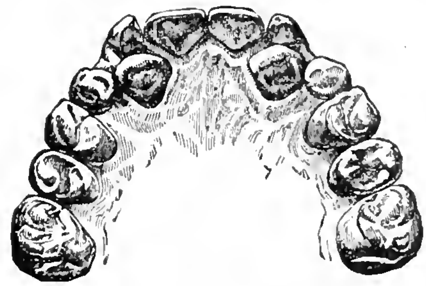


FIG. 4618.—A case in which the superior canines have not room to erupt regularly in the arch, and are forced to appear within the arch. (Salter.)

teeth may be too large or too small. Upper central incisors, in rare instances, become a monstrosity in the excessive size of their crowns; the roots in such cases are not developed in similar proportion.

The superior canines sometimes possess abnormally long roots, whose length may not be suspected till an attempt is made to extract them. Their extraction, on this account, is very difficult, or perhaps impossible. The molar teeth are sometimes abnormally developed, the crowns and roots alike being of unusual size. An abnormal diminution in the size of the teeth is not commonly found, except in the case of the upper wisdom teeth, which are often quite small, no larger than a conical supernumerary tooth. Teeth which are pathological in shape are frequently observed. Their unusual shape may be due to a constitutional disturbance, occurring during their formative period, or it may be due to a freak of nature—a cause unknown. Of the irregular

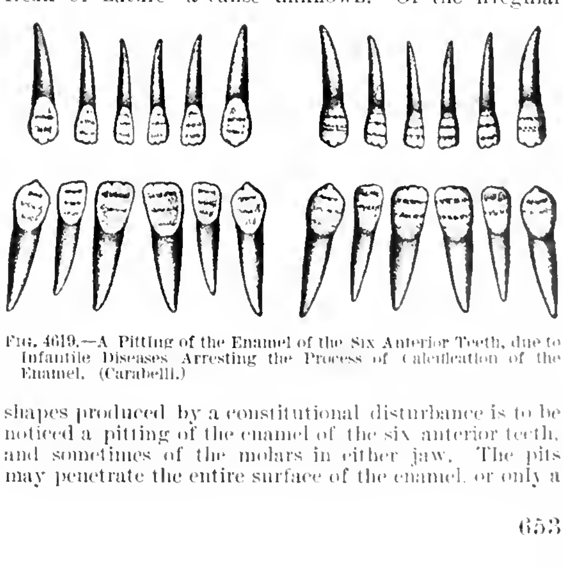


FIG. 4619.—A Pitting of the Enamel of the Six Anterior Teeth, due to Infantile Diseases Arresting the Process of Calcification of the Enamel. (Carabelli.)

shapes produced by a constitutional disturbance is to be noticed a pitting of the enamel of the six anterior teeth, and sometimes of the molars in either jaw. The pits may penetrate the entire surface of the enamel, or only a part of it. They may be irregularly disposed, or, as usually occurs, may be arranged in horizontal rows, of which there may be two or three in a single crown. Sometimes the pits are stained a yellowish or yellowish-

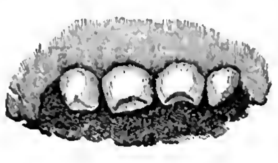


FIG. 4620.

FIG. 4621.

FIGS. 4620 AND 4621 Illustrate the Effects of Hereditary Syphilis on the Superior Incisors of a Boy and a Girl, aged Twelve and Fourteen Years, Respectively. These cases came under the observation of Henry W. Williams, M.D., and are copied by permission, from his "Diagnosis and Treatment of the Diseases of the Eye."

brown color. This irregular development is caused by some severe infantile disease occurring during the period in which the enamel of these teeth is being calcified, the process of calcification being thus interrupted. The administration of mercury in the early years of childhood has also been considered by some to account for this irregularly formed enamel, but such a view is not now generally accepted.

Another malformation due to a constitutional disturbance is that produced by inherited syphilis. The effects of this disease upon the teeth are most notably seen in the upper central incisors of the permanent set. The crowns of these teeth are stunted in size, are somewhat irregularly placed, and their cutting edges are narrower in width than are the necks of the teeth. The enamel on their cutting edges is imperfectly developed and soon crumbles away, leaving crescentic notches. The upper laterals and canines, as well as the lower centrals, laterals, and canines, may be affected in a similar but less marked way. The first molars are usually imperfectly developed, and from a loss of enamel the corners of the teeth are rounded off, giving to the crowns a domelike appearance. As the characteristics of teeth affected by inherited syphilis were first described by Jonathan Hutchinson, it is common to call such teeth Hutchinsonian teeth. They are also called notched teeth, from the notch which may be found in the cutting edge of the six anterior teeth. This notch, however, is obliterated by wear, and thus in time becomes lost as a diagnostic sign. The term peg teeth in this connection is commonly used, and refers to the peglike appearance of the crowns of the anterior teeth. The peg shape does not become obliterated by wear, and always remains a diagnostic sign. While inherited syphilis does not always leave its mark upon the teeth, yet when the appearances described are present they are considered to be positive evidence of this disease. The temporary teeth are said by good authority to be sometimes affected by hereditary syphilis, and to become notched and peg-shaped after the manner of the permanent teeth.

FIG. 4622.—A Case of Fusion of the Superior Central and Lateral Incisors.

Pathological shapes to be ascribed to a freak of nature are not commonly met with; still, a large number of such cases have been reported and drawings made to illustrate them. As one of the more frequent irregularities may be mentioned the fusion of adjacent teeth. There are two kinds of fusion: in one the union is accomplished by the cement of one root becoming increased and uniting itself to the cement of another root. In such cases each tooth has a separate pulp cavity and independent nourishment, the union being merely upon the outside and not affecting the individuality of either tooth. The other kind of fusion consists in the union of the dentine as well as the cement, and a fusion of the pulp cavities into a single irregularly shaped space. Such teeth have a common and interdependent life.

Fusion of this kind may be confined to the roots or include the crown as well, in which case a union occurs between the enamel of the two teeth. Fused teeth may be found in the temporary or in the permanent set, and any teeth may be so affected. Generally the fusion is confined to two teeth. It is sometimes unsuspected when involving only the roots, and the attempt to extract either of the fused teeth may result in its companion also being dislodged, or in a failure to extract either. The first form of fusion probably takes place after the formation of the teeth, the latter while the teeth are in a developmental stage.

There are irregular shapes not due to fusion, and which come under the head of miscellaneous forms. The incisors sometimes have their crown developed at right or obtuse angles with their roots, or have more than one root. The canines may have a twisted root, or one with a sharp bend occurring at the middle or upper end of its length. The bicuspids may have two or even three roots. In consequence of the tendency of the roots of the bicuspids to bifurcate, this occasional development of two distinct roots is to be expected. The upper and lower molars may have as many as five roots, or all their roots may be fused into one.

Pathology of the Component Tissues of the Teeth.—Of these tissues the pulp is most subject to pathological changes. Normally this delicate and sensitive organ is well guarded by rigid walls, which not only protect it against external force, but also against the extreme thermal changes to which the oral cavity is exposed. So long, then, as the pulp remains thus protected, it is not subject to pathological changes; morbid processes do not originate in its tissue. It is true that there are writers who describe affections of the pulp independent of outside influences, but the genuineness of such cases has not been well established. In general the pulp is subject to pathological changes similar to those found in the soft tissue in other parts of the body; such peculiarities as are found are due to the existence of the pulp within a bony incasement. It must be borne in mind that the pulp is very vascular and very sentient; that the vessels and nerves are supported by a parenchyma of connective tissue, and that the whole organ is contained in an unyielding cavity whose only entrance and exit is a small foramen, whose calibre may not be larger than a bristle. Through this foramen the blood enters, and is in due time returned—a delicate piece of machinery capable of easily performing its duties when in natural adjustment, but impaired or destroyed when affected by force from without. Any agency which interferes with the protection which nature has thrown around the pulp is calculated to set up morbid changes in its structure and interfere with its function. The most potent and frequent agency to be named is caries. When once this disease has located itself upon a tooth it usually progresses, unless checked by appropriate mechanical means, till a considerable portion of the enamel and dentine is destroyed and the pulp laid bare. Long, however, before the pulp is reached it has been subjected to conditions unfavorable to its healthy activity, and the chances are that when exposed by caries it is already in a pathological condition.

FIG. 4623.—A Right Superior Canine with an Abrupt Curve at the End of the Root.

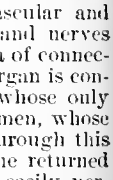


FIG. 4624.—A Superior Bicuspid with Three Roots.

An agency in producing disturbances of the pulp less important than caries is the natural wearing away of the substance of the teeth in the process of mastication. Such wear is usually without serious effect upon the pulp up to the period of middle life. Subsequent to that time, however, it may so deprive the pulp of its natural covering as to induce pathological changes.

A third outside agency, and one less frequently met with than the other two, is mechanical violence, in the form of a blow or fall, of such a nature as to sever the union between the pulp and its blood and nerve supply. Under such circumstances the pulp, as a rule, dies. There are, however, cases reported in which a sound tooth having been pushed out of its socket has been replaced, and the pulp has apparently remained in a healthy condition. Such cases lend support to a supposition that a reunion is possible between the pulp and its blood and nerve supply; but this point has not yet been satisfactorily settled.

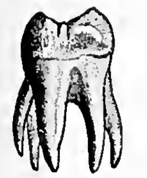


FIG. 4625.—A Molar Tooth with Five Roots.

One of the simplest and commonest pathological affections of the pulp is congestion. A pulp examined in this condition shows increased redness, due to an increased flow of blood to the part and dilatation of the vessels. This condition is brought about through the vaso-motor system, which responds to an irritation of the dentinal fibrils, which are in connection with the nerves of the pulp, and so with the general nervous system. Inasmuch as the normal pulp fills its cavity, an increased supply of blood must compress the tissue in the neighborhood of the vessels. The nerves share this compression, and hence the severe pain which is the usual accompaniment of a congested pulp. Caries of the tooth is the most common cause of congestion of the pulp. Through it a cavity in the direction of the pulp is produced which allows hot and cold drinks, food, and cold air to approach so near the pulp that they irritate it. Salt and sweet substances, also, if allowed to enter the cavity produced by the caries, will act upon the dentinal fibrils and irritate the pulp. A congested pulp is hypersensitive, giving pain upon the slightest occasion. A draught of cold water, the effect of which upon a normal pulp might be but a momentary twinge, would cause a congested pulp to ache violently. This ache is one of the more common kinds of toothache; it is violent, intermittent, throbbing. It is very likely to be worse at night when the body is in a recumbent position. Congestion of the pulp does not necessarily result in a permanent pathological condition, provided the environment of the pulp can be so improved as to become normal, or nearly so. The normal environment may be restored by filling the cavity produced by caries, the pulp being thus removed from the near approach of heat or cold and irritating substances. The filling material should be a poor conductor of heat and cold, resembling in this respect, as far as possible, enamel and dentine. Gutta-percha or oxyphosphate cement have proved the best substances with which to protect a congested pulp. It frequently happens that the pulp becomes congested in a tooth which contains a large metallic filling. The metal filling, being a good conductor of heat and cold, conveys injurious shocks deep into the dentine and unfavorably affects the pulp. Such a condition may be remedied by substituting a non-metallic filling for a metallic one.

FIG. 4626.—A Molar Tooth whose Roots are Fused into One.

While a congested pulp may recover its normal condition, it frequently passes into a state of inflammation which may be either acute or chronic. In acute inflammation there succeeds to the active hyperæmia of congestion a stasis of blood in the inflamed portion; the vessels become dilated more than before, and often assume a tortuous course. The leucocytes can be seen leaving the capillaries and invading the surrounding tissue. If the inflammation is purulent, pus cells and broken-down tissues become abundant. The affection may be local, confined to a small point which has been exposed by caries, or it may be general, involving the entire pulp. The organ is swollen, as in congestion, and pain results from pressure upon the nerve fibres. If the inflammation is very violent, it is likely to destroy the life of the pulp in a short time, through pressure upon the blood-vessels at the foramen. The symptoms attending an inflammation of the pulp are similar to those of a congested pulp, but more severe. The pain is violent, throbbing, paroxysmal, and is commonly known as a "jumping toothache." The tooth is extremely sensitive to heat and cold, to sweet and salt substances, and to pressure within the cavity of decay.

Such an acute inflammation may subside or pass into a chronic inflammation, the symptoms of which resemble those of the acute, but are of a less severe grade. The cause of inflammation of the pulp is caries, which, as a rule, has penetrated to the pulp cavity and laid bare a minute portion of that organ, exposing it to the irritation of foreign bodies, thermal changes, and the secretions of the oral cavity. When suppurative inflammation occurs, the probable agency of bacteria is of interest, as it is well known that many varieties of these organisms exist in the mouth. Their approach to the pulp is made easy through the carious cavity, which lays bare the pulp, and the conditions seem favorable for their peculiar activity. Dr. H. C. Ernst says, in his "Consideration of the Bacteria of Surgical Diseases" (page 4): "The point being determined that there is at least a very strong probability that no suppuration occurs without the presence of bacteria, the study of the organism concerned in these processes becomes at once of great interest." Dr. Black, in the "American System of Dentistry," vol. i., p. 854, says: "I have found suppuration, or more properly ulceration, following a very superficial inflammation, in which the tissue was apparently melting down into a sanious pus thickly inhabited by micro-organisms." The course pursued by an inflammatory affection of the pulp depends largely on the extent to which its surface has been exposed through caries. That there is always such an exposure in case of inflammation of the pulp cannot be affirmed, but that it does exist in the large majority of cases is attested by experience. If this exposure is small and allows no relief to the swollen condition of the organ, and no sufficient outlet to products of inflammation, then an acute inflammation is likely rapidly to destroy the pulp, and transmit an inflammatory process along the root canals to the peridental membrane. If, however, the pulp has been freely exposed before an inflammation has been started up, then the inflamed pulp has a way of relief to its enlarged substance, and an exit for the products of inflammation. Such cases are more likely to assume a chronic form, inasmuch as the life of the pulp is not immediately threatened. It is a matter of some chance, in the case of a pulp exposed by caries, just how soon an inflammatory affection will be started up, though no pulp when once exposed can long escape. If the cavity which exposes the pulp is hidden away in the back of the mouth, or protected by adjoining teeth, so that the pulp of the tooth is, in a measure, protected from alternations of temperature and severe contact with food, then the inflammatory affection may be delayed, and, when it does come, decay may have so opened the pulp cavity as greatly to modify the severity of the inflammation. On the other hand, when caries attacks the crown of the first molar and lays bare the pulp, it is immediately subject to severe irritation in the process of mastication, and trouble begins at once. Inflammatory affections of the pulp do not tend to recovery, but generally end in death of the pulp. This result may be, however, somewhat delayed by appropriate treatment. The exposed pulp may be capped over with non-irritating, non-conducting material and thus shielded. It is sometimes possible to prolong the life of the pulp several years, provided the treatment is not long delayed after the beginning of the inflammatory affection. After having been thus treated the pulp may give no further sensation of pain; it does not, however, often regain its normal condition when it has once passed through the inflammatory process.

To alleviate the pain of a congested or inflamed pulp it is important, first, to determine which tooth is giving trouble. The testimony of patients cannot be relied upon to settle this point. They can usually indicate correctly the side upon which the affected tooth is located, but will often point to a perfectly sound tooth as the cause of their pain. A thorough examination should be made, by the aid of the mouth mirror and a fine exploring point, of all suspected teeth. If a tooth is found with a carious cavity of any considerable size, especially if the cavity is sensitive to the touch of an instrument, it is fair to infer that such a tooth is the one giving pain. The diagnosis can be confirmed by the application of a little cold water to the cavity of decay. Where a congested or inflamed pulp exists, this application will cause an exacerbation of the pain.

Having located the tooth which is the seat of the difficulty, its carious cavity should be washed out with a syringeful of warm water, in order to remove irritating particles of food. The next step is to make an application to the exposed pulp, or, if the pulp is not exposed, to the dentine in the neighborhood of the pulp, which will allay the pain.

A simple and efficacious remedy is the oil of cloves. More powerful remedies are: carbolic acid, ninety five per cent.; creosote; a mixture of equal parts of oil of cloves and chloroform; a mixture of equal parts of oil of cloves and creosote.

One drop of any of these remedies is usually sufficient for a single application. The medicine should be applied to the cavity on a pledget of cotton. Care should be taken not to press the cotton too tightly into the cavity, as it might thus become a mechanical irritant to an exposed pulp. In the use of concentrated carbolic acid, care should be taken to prevent its spreading to the adjoining gum and mucous membrane of the lips and cheek.

It is very important, in treating toothache, to know whether the pulp in the affected tooth is alive or dead. If alive, it will respond to thermal changes and be sensitive to exploration in the carious cavity, and should be treated as just described. If the pulp is dead the tooth is usually sore to percussion, and unaffected by applications of cold, though heat will sometimes be painful.

It is not sensitive to the exploration of an instrument in the cavity of decay. The carious cavity of such a tooth should not be plugged with a dressing, but should be opened freely to give vent to the decomposing pulp in the manner described in the section on affections of the peridental membrane.

Closely allied to inflammation of the pulp is abscess of the pulp. This affection, clinically, cannot always be distinguished from the preceding. Upon microscopic examination, however, it is possible to make out true abscess cavities. These may be deeply situated in the body of the pulp, or near its surface.

Among the more advanced pathological changes in the pulp may be mentioned gangrene. This, as in other parts of the body, may be moist or dry. Gangrene follows upon the sudden cutting off of the circulation from the pulp, as a result of acute inflammations, or violence to the tooth of such a kind as to sever the artery at the apical foramen. A gangrenous pulp is of a grayish-green color, of slight consistence, and fetid odor. In such a pulp the normal structural elements become undistinguishable. In dry gangrene the pulp contracts to a very small compass, and the part of the pulp cavity thus left vacant is occupied by a gas of decomposition. Gangrenous pulps, unless the pulp cavity is freely opened, produce severe inflammation of the peridental membrane.

Another group of pathological changes embraces the various forms of calcification to which the pulp is subject. Among such may be mentioned the nodular form. In this variety small nodules of calcareous matter are sprinkled through the substance of the pulp, giving to it a gritty feel. The calcareous matter is similar in chemical composition to dentine, but does not have its characteristic structure. The calcareous nodules are located between the component parts of the pulp, and are not formed at their expense. This condition seems to be compatible with a healthy activity of the pulp, and apparently does not lead to serious consequences. Its etiology has not been explained. Another form of calcification exists, in which the new formation takes the place of the normal tissue of the pulp and is formed at its expense. The calcareous points are found scattered here and there through the pulp, usually in the coronal portion. These points become confluent till an aggregation is formed ranging in size from a grain of sand up to a mass sufficient to fill the entire pulp cavity, coronal and radical portion as well. This form of calcification apparently does not take place when the tooth is in a normal condition, but seems to be induced either by the wearing down of the crowns of the teeth or by caries. In both cases the dentinal fibrils are subject to irritation, and this irritation determines the deposition of lime salts in the substance of the pulp. When once such a deposition begins, it tends to increase till the pulp is changed from a highly sensitive living organism to one practically lifeless, without nerves or vessels, and without the system of tubules which exists in the dentine. During the course of calcification quite severe pain may arise, evidently due to the pressure of the calcareous masses upon the nerve filaments.

A pathological change similar to that occurring in calcification of the pulp is that which takes place in the formation of secondary dentine. This formation is found on the periphery of the pulp at a place adjacent to a carious cavity, and is deposited by the odontoblastic layer of the pulp, which is the formative agent in normal dentine. Secondary dentine is evidently a means taken by nature for the protection of the pulp against the injurious influences incident to advancing caries. Secondary dentine is similar in structure to normal dentine, containing, like it, tubules and fibrils. Its formation is, however, somewhat less regular, and in case the secondary dentine extends far toward the interior of the pulp, it loses its supply of dentinal tubes and becomes less like dentine and more like a calcified pulp. While the formation of secondary dentine in the neighborhood of decay undoubtedly tends for a time to prolong the life of the pulp, experience seems to show that secondary dentine, when once deposited, tends to increase to such proportions as in the end to destroy the life of the pulp.

The process just described is to be distinguished from that deposition of dentine which takes place by degrees during the whole life of the tooth. This deposit is very slow in formation, and takes place uniformly around the inner side of the whole pulp cavity. By this physiological deposition of dentine the pulp cavities in the teeth of old people are reduced to very small proportions. This seems to indicate that the pulp is useful and necessary inversely to the age of the tooth.

There remains to be mentioned a pathological change which increases the size of the pulp. Such an increase can occur only in case the pulp has been exposed. Let such a pulp be subjected to the irritation of foreign substances, and likewise to that of the sharp edges of a carious cavity, and it will sometimes proliferate and fill the cavity.

Why the pulp does not become inflamed and destroyed under such circumstances cannot be explained. This process has usually been noticed in the case of young teeth. The growth may assume the size of a pea, or be larger. It is of fleshy consistence, and is organically united to the pulp by a narrow pedicle, hence it is called polypus of the pulp. In microscopic examination it is found to consist of numerous round and spindle-shaped cells, interspersed with fibrous tissue, and an epithelial covering has been described by some writers. Its blood-vessels pursue a tortuous and irregular course, unlike those in the pulp. No nerves have been found in this tumor, yet it is slightly sensitive to touch, resembling the gum in this respect. Sometimes a muco-purulent discharge issues from its periphery. A polypus protects the pulp against external violence. It is extremely tenacious of life, and will grow again if cut off.

A growth similar to a polypus takes place in some cases of fractured teeth. The pulp, having been exposed, proliferates through the openings caused by the fracture and forms a tumor outside the pulp cavity. This tumor, morphologically, resembles a true polypus of the pulp; it has, however, a nerve supply, and is quite sensitive to the touch, thus differing from a polypus. Salter has named this growth a "sensitive sprouting of the pulp."

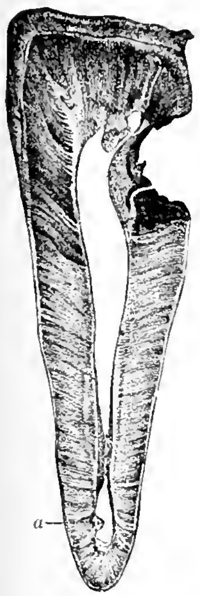


FIG. 4627. — An Incisor Tooth Affected with Caries. a, A deposition of secondary dentine about the cavity of decay.

Under pathology of the dentine the most important process to consider is caries. This process affects the enamel and cementum as well as the dentine, but has more to do with the dentine than with the other tissues. In the first place, it may be said that caries of the teeth does not resemble caries of bone. The term caries as applied to the teeth is a misnomer, given at a time when the true nature of the process was not understood. However, the term has become so generally used that it cannot now be easily dropped. The pathological change which occurs in caries is a decalcification and disintegration of the several tissues of the teeth. The latter condition follows very quickly upon the former, on account of the large proportion of earthy constituents existing in the parts attacked. Caries may affect any of the teeth of either dentition, but it affects certain teeth more frequently than others. Magitot has tabulated ten thousand cases of caries occurring in the permanent teeth, and his tables show that the tooth most liable to caries is the first lower molar, after which follow in succession the first upper molar, the second lower molar, first upper bicuspid, second upper bicuspid, upper lateral, second upper molar, upper central, second lower bicuspid, upper canine, first lower bicuspid, upper wisdom, lower wisdom, lower canine, lower central, and lateral. Caries not only shows a preference for certain teeth rather than for others, but it also shows a preference for certain parts of individual teeth rather than for other parts. Those surfaces of the teeth which are smooth and kept clean by the motions of the tongue, lips, and cheeks, are not attacked by caries; while surfaces presenting an uneven contour, abounding in pits and fissures, are its favorite seat. Hence, we find it located in the crowns of the molars and bicuspids, in the pits on the lingual surfaces of the six superior front teeth, and on all approximal surfaces which, though not uneven, are not cleansed by the motions of the mouth. The buccal and labial surfaces of the teeth, just at the margin of the gum, are likewise often the seat of caries. Caries manifests its presence by a change of color in the tissues attacked. This change may be merely from translucency to opacity, or to a variety of colors ranging from yellow to brown, and even black; sometimes a gray or bluish gray is seen. As a rule, the slower the progress of the disease the deeper the color of the affected parts, and conversely, the more rapid its progress the lighter the color of the affected parts. Caries usually attacks the enamel first, though it may begin with the cementum. It starts in a small pit or fissure, where soon the enamel is found to have lost its peculiarly hard and dense surface. Instead of resisting the most highly tempered steel instruments, as does normal enamel, it crumbles away under slight force. Thus a small opening is made through the enamel to the dentine. This opening may be as large as the head of a pin, or it may be very minute. During this process the enamel has become decalcified and disintegrated. Some authorities say that the centre of the enamel prisms are first affected, and others that the interprismatic substance is first destroyed, in consequence of which the prisms separate and fall to pieces. When once caries has perforated the enamel it no longer confines itself to a narrow area, but spreads out laterally between the enamel and dentine. The degree of lateral extension varies greatly, but seems to be somewhat dependent on the structure of the dentine. If the dentine is well calcified, and with few interglobular spaces, the lateral extension is not so great as when the dentine is imperfectly calcified and abounding in interglobular spaces. The carious process in its lateral extension seems to follow the anastomoses of the dentinal tubules, which are very abundant at the junction of the dentine and enamel. After having affected a certain area on the periphery of the dentine, caries penetrates its substance, following the tubules toward the pulp. Inasmuch as the tubules converge from the periphery of the dentine toward the pulp cavity, the progress of caries is marked by a cone-shaped area, the large end of the cone being in the periphery of the dentine, and the small end pointing toward the pulp. Caries tends to penetrate the pulp cavity, and rarely fails, unless checked by mechanical means. When once the pulp cavity has been penetrated, the pulp is exposed to the degenerative changes already described, and, as a rule, dies and disintegrates. The carious process then invades the pulp cavity, meanwhile spreading laterally through the dentine from the area originally attacked, and disintegrating the enamel from the under side. By degrees the crown of the tooth becomes so hollowed out by the continuous softening and disintegration of the dentine that the shell of enamel left becomes unable to withstand the force of mastication, and consequently is broken away. Nor does caries stop with the destruction of the crown; it continues its work in the root, enlarging the root canal at the expense of the surrounding root substance until the root becomes a mere shell and is finally entirely disintegrated. The carious process in the root is not so rapid as in the crown, and roots may withstand its action for years.

The microscopic examination of the carious process shows the change in color of the affected parts which has been described, and the disintegration of the enamel rods.

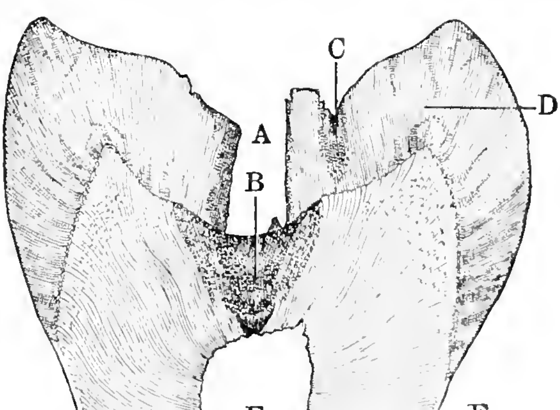


FIG. 4628. —Microscopic Section through a Carious Cavity Occurring in a Molar Tooth. *A*, The initial opening through the enamel; *B*, the cone-shaped area of decay—the affected tissue being discolored and somewhat softened, but not disintegrated; *C*, a minute pit in the enamel where caries has just started; *D*, the enamel; *E*, the dentine; *F*, the pulp cavity.

The tubules of the dentine appear enlarged in calibre; and their size increases as the process advances. The intertubular substance diminishes with the enlargement of the tubules, and finally disappears with the confluence of adjacent tubules. Micro-organisms are found in great numbers within the tubules.

In the cement, the carious process is similar to that found in the dentine. The lacunæ and canaliculi are enlarged at the expense of the surrounding tissue, which softens and breaks down as the process advances.

Micro organisms are present as in carious dentine.

A chemical change to be especially noted in connection with all the tissues affected by caries is the acid reaction which is invariably present.

Etiology of Caries.—There are certain predisposing causes upon which all are agreed; of such may be mentioned a faulty calcification of the enamel, which leaves the dentine exposed; a faulty calcification of the dentine, which leaves it less able to resist degenerative changes; a crowded condition of the teeth, on account of which it is difficult to keep the spaces between the teeth clean.

With regard to the exciting or immediate causes of caries, there has been great diversity of opinion. Of the ancient pathologists, some ascribed caries to a disturbance in the "humors of the body." Others regarded it as due to the ravages of worms which infested the oral cavity.

When we come to observers of scientific repute, we find that the older ones held to a vital or inflammatory theory. According to them, the disease began from within, by an inflammatory process of the dentine or pulp, the process in dentine resembling caries of bone; hence the term caries was applied to it also.

The vital theory of caries has been effectually disproved by the fact that when natural teeth have been mounted upon artificial plates, and thus worn in the mouth, they have been subject to caries, precisely resembling the caries of the teeth normally situated in the jaw.

By others, caries was considered to be a sort of gangrene, due to a disturbance in the nutrition of the dentine.

When, however, the secretions of the mouth came to be studied with reference to their possible agency in producing caries, and when they were found to be at times acid, and when, also, the acid fermentations occurring in the mouth came to be studied in this connection, there was developed what is called the acid theory of caries. According to this theory, caries originates from without and not from within, as those holding the vital theory claimed. The active agency in producing it is acids, which are always present in the mouth, due either to acid secretions or acid fermentations. These acids are to a large extent, it is true, neutralized by the alkalinity of the normal mixed saliva; but in some places, as in the crowns of molars and in the spaces between the teeth, the acid secretions are so protected from the neutralizing influence of the saliva that they are able to retain their reaction and attack the enamel, decomposing the phosphate of lime and other mineral constituents, of which it is largely composed. Having penetrated the enamel, the acids act in a similar manner upon the dentine. According to this theory the tissues of the tooth are affected by chemical decomposition, as if there were no vital element whatever concerned. To substantiate this view many experiments were made, by subjecting extracted teeth to the influence of a weak acid solution imitating conditions found in the mouth. Teeth thus treated underwent a softening and decalcification similar to that found in the mouth in the case of caries. The point was thus well established that caries consisted in the decalcification and disintegration of the mineral constituents of the teeth by an acid.

While some have held a vital theory to account for caries, and others an acid theory, still others again have taken middle ground and held a chemico-vital theory.

The discovery of the presence of micro-organisms in the tubules of dentine affected by caries was an important step in advancing our knowledge of the process. The name of leptothrix buccalis was given to these organisms when first discovered. Though their true agency in caries was not at once understood, they were considered to play an important rôle. Extensive investigations have been made to determine more accurately the nature of the micro-organisms found in the mouth, and their relation to the process of caries. The most valuable of these investigations have been conducted by Dr. W. D. Miller, of Berlin. His method has been to infect sterilized culture media of various kinds with neutral saliva or with neutral carious dentine, and he has found, invariably, that, when the culture medium contains sugar, an acid is produced. By successive cultures he has isolated the organisms which produce the acid. Of the organisms he writes as follows: "We have, then, in carious dentine, two distinct fungi—one always, the other often, present; the former surely, the latter probably, producing lactic acid from sugar" ("American System of Dentistry," vol. i., p. 803). Perfectly sound dentine, subjected to a pure culture of the fungi just mentioned in a medium containing sugar, underwent, in course of time, typical caries. According to Dr. Miller—and his theory is now quite generally accepted—the history of caries is as follows: It starts wherever, from the contour of individual teeth or from the relation of one tooth to another, a collection of food is possible. In every such collection are multitudes of micro-organisms which are capable of thriving in the presence of sugar, and of decomposing this substance and forming lactic acid. This acid decalcifies the enamel and forms a small pit which, being constantly filled with food, offers a favorable nidus for the continued growth of the same organisms. When the enamel has been penetrated, the organisms begin to multiply in the tubules of the dentine, and there continue the decomposition of sugar absorbed from the mouth. The resulting lactic acid enlarges the tubules by the decomposition of the mineral constituents of the dentine. It is possible that at one time the secretions of the mouth may be more unfavorable to the life of micro-organisms than at another, since it is well known that, at certain times and in certain individuals, caries progresses very rapidly.

A condition resembling caries, and yet essentially differing from it, is erosion. Erosion is commonly found on the labial surface of the six anterior teeth, either at the margin of the gum, or between it and the cutting edge. It also sometimes affects the bicuspids and molars. Erosion produces shallow cavities, which involve the enamel and penetrate to the dentine. These cavities are larger at their external opening than in their deeper parts, and are smooth, hard, and polished throughout. They present neither the characteristic softening nor undermining growth which are found in caries. The cavities do not rapidly enlarge, but may become of such size as to threaten the life of the pulp. Caries is sometimes superadded to erosion, thus modifying the course of the destructive process. The etiology of erosion is not definitely determined.

Pathological Changes in the Cement.—The most common pathological change of the cement is an hypertrophy, which is due to an irritation of the peridental membrane. This membrane, lying between the cement of the root and the bony alveolus, is at once the formative membrane of the cement of the tooth and of the adjacent bone of the alveolus. When, however, the cement of the root has been completed, the activity of the peridental membrane, so far as its cement-forming function is concerned, normally ceases. It does not resume this function unless subjected to irritation, in which case it may deposit additional cement upon the root in various ways. The deposit may be diffuse, covering the entire root, though most abundant at the apex. It may be nodular, the nodules being found at any point on the root, and being of various sizes; or it may consist of a club-shaped enlargement at the end of the root.

The added cement is similar in structure to the primary cement, the union between the two deposits being, as a rule, not noticeable. In certain cases, however, blood-vessels penetrate this secondary deposit of cement, a condition not found in the primary deposit. Hypertrophy of the cement has never been observed in the case of the temporary teeth, and affects the permanent teeth during adult life. The teeth most commonly involved are the upper bicuspids and molars, though the others are not exempt. Hypertrophies of the cement are called hypercementoses, osteomata, and exostoses. Of the causes which produce an irritation of the peridental membrane, and consequent hypertrophy of the cement, perhaps the most frequent is caries with its sequelæ, viz., inflammation and death of the pulp, with extension of the inflammation to the peridental membrane. Another cause is the undue pressure which teeth are sometimes subjected to in the process of occlusion and mastication. This arises when many of the teeth have been lost and the few remaining ones are compelled to bear all the strain of service. In such cases the peridental membrane is overworked, literally crowded to the wall, and in consequence may become irritated. The same effect may be produced by the insertion of fillings which project from the crown of a tooth so far as to concentrate the force of occlusion on the filled tooth. While hypertrophy of the cement is commonly due to irritation from undue force, there are cases in which teeth having no antagonists are found to have hypertrophied cement. The symptoms which may arise from an hypertrophy of the cement are caused by the pressure of the new growth upon the nerves of the peridental membrane and upon the nerves of the pulp at the apical foramen. Many cases of hypertrophy exist which occasion no symptoms, the condition becoming known only after extraction. In old people it is usual to find the cement somewhat thickened, and this change can almost be called physiological, so constantly does it occur. Doubtless the process is so gradual that the surrounding tissues accommodate themselves to the enlarged root, and their nerves are subjected to no irritation. In other cases pain is an important and persistent symptom. The pain may be localized and accompanied by a soreness in the socket, or it may be diffused throughout the jaw or reflected to adjoining parts of the head. Severe neuralgias of the head, face, and neck have been found to owe their origin to the hypertrophy of the cement of a tooth. The tooth may appear to be perfectly sound, in which case it is exceedingly difficult to locate the source of the pain. When, however, neuralgias exist in connection with teeth which, though not carious, are the seat of pain or are sore in the socket, it is fair to suspect either an hypertrophy of the cement or a calcification in the pulp. Not only does an enlarged cement cause severe neuralgic pains about the head and face, but cases of epilepsy and insanity have been reported as due to the same cause. A case from Tomes' "Dental Surgery" is in point. "A lad, a farm laborer from Windsor, was admitted into the Middlesex Hospital for epilepsy. The usual remedies were tried for six weeks without effect. His mouth was then examined and the molar teeth of the lower jaw found to be much decayed, the fangs of some alone remaining. Although he did not complain of pain in the teeth or in the jaw, the decayed teeth were removed, and the fangs of each were found to be enlarged and bulbous from exostosis. During the eighteen months that succeeded the removal of the diseased teeth he had not suffered from a single fit, though for many weeks previous to the operation he had had two or three per day."

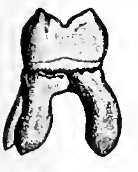


FIG. 4629.—General Hypertrophy of the Cement about the Roots of a Superior Molar Tooth.

A second pathological change of the cement is absorption. This is often found in connection with hypertrophy, and occurs at scattered points and produces depressions in the surface of the cement. In cases of long-continued inflammation about the apex of the root, the cement is likely to be in part absorbed, giving a rough outline to the apex.

Pathology of the Peridental Membrane.—Disease of the peridental membrane may be due to a constitutional disturbance, or to pathological affections of the pulp, or may be dependent upon, or associated with, calcareous deposits upon the root of the tooth. Of the constitutional affections which react upon the peridental membrane, Tomes enumerates rheumatism, syphilis, and the exhibition of mercury.

Inflammation of the peridental membrane from rheumatism is independent of caries, and may involve one or more teeth. The inflammation is distributed over the entire membrane, causing a loosening of the tooth and a soreness in the socket. Its course is subacute or chronic, does not tend to abscess, and is amenable to constitutional treatment.

Inflammation of the peridental membrane from syphilis is chronic. Pus may be discharged around the neck of the tooth, which becomes sore in the socket and loose. If the disease is unchecked the teeth may fall out of their own accord, owing to a complete destruction of the peridental membrane. Associated with this process there often occurs a necrosis of the surrounding bone.

Inflammation from the administration of mercury, whether in the treatment of syphilis or not, is associated with ptyalism, and is of a subacute or chronic character. The teeth become loosened and sore in their sockets, and, if the drug is long continued, a discharge of pus around the neck of the teeth and final loss of the teeth may result.

The effect of phosphorus upon the peridental membrane, though not belonging strictly under constitutional affections, is of great interest. Persons subjected to the fumes of phosphorus, as are those who work in match factories, often have necrosis of the maxillary bones. This necrosis starts with an inflammation of the peridental membrane, which is very sensitive to the irritating fumes of phosphorus. As a result of inflammation the membrane is destroyed, and the bony alveolus being thus cut off in large degree from its source of nourishment, necrosis is invited. It has been found that this disease mainly affects operatives in whose mouth are carious teeth, or who have had teeth extracted while pursuing their occupation. The phosphorus fumes enter a carious cavity and reach the peridental membrane by way of the apical foramen. If, however, the teeth are sound and the gums healthy, phosphorus has little if any destructive effect in the mouth.

Pathological affections of the peridental membrane consequent upon disease of the pulp are of frequent occurrence. When the pulp has become severely inflamed it is common to find, in addition to the symptoms attendant upon simple inflammation of the pulp, a soreness of the tooth in the socket. If the tooth is then percussed with a steel instrument the patient will flinch. This is an indication that the inflammation has proceeded up the root canal and extended to the peridental membrane situated around the apex of the root. Symptoms pointing to inflammation around the root do not always appear during the inflammatory stage of the pulp; they more commonly follow its death and putrefaction. When this has occurred, irritating products of decomposition, both gaseous and liquid, pass up through the canal and set up acute inflammation in the membrane at the apex of the root. In the light of our knowledge of the agency of micro-organisms in inflammatory processes, we must consider that the germs, which were active in producing inflammation of the pulp, are also active in the consequent inflammation of the peridental membrane. This membrane being of connective tissue, and richly supplied with blood vessels, is an excellent field for inflammatory action, and being closely confined between unyielding walls, and having an abundant nerve supply, is capable of producing symptoms of the severest character. When an inflammatory process has started at the apex of the root, the tissues become swelled and engorged with blood, the condition extending from the apex toward the neck of the tooth. In consequence of the swelling of the membrane, the tooth is pushed slightly from its socket and becomes loose. The clinical symptoms are ushered in by a dull, continuous pain, which is not occasioned by changes of temperature, as is often the case with inflammation of the pulp. The tooth upon pressure feels sore in the socket, yet during the first stages of the inflammation a grinding of the affected tooth against its antagonists gives some relief. The inflammatory process sometimes stops at this point, but very often goes on to the formation of an alveolar abscess.

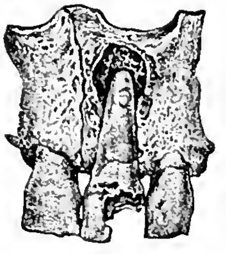


FIG. 4630. — Absorption of Bone, produced by an Alveolar Abscess at the Tip of the Root of a Left Superior Incisor.

Alveolar abscess forms about the tip of the root. As pus collects, the neighboring bony tissue is absorbed, and a cavity is formed varying in size according to the severity of the inflammation. Like abscesses in other parts of the body, it seeks an outlet at the point of least resistance. There are several ways in which the pus may make its escape. It may penetrate the bony alveolus in a line which is, roughly speaking, at a right angle to the root of the affected tooth, and thus make its escape into the mouth, or, in some cases, upon the face. Or it may pass down the length of the root, either between the peridental membrane and the cement, or between the peridental membrane and the bony socket, in both cases discharging about the neck of the tooth. When an alveolar abscess occurs in connection with the six anterior teeth and bicuspids of the upper jaw, it usually discharges on the labial surface of the alveolus, at a point about opposite the tip of the root of the affected tooth. In rare instances an abscess connected with these teeth may discharge on the outside of the front part of the face or into the nasal cavity, and in the case of the bicuspids, into the antrum Highmorii. An abscess occurring in connection with the upper molars most commonly discharges on the buccal surface of the alveolus, about opposite the tips of the roots affected. It may, however, discharge in the neighborhood of the hard palate, when proceeding from the palatal root. Besides these usual points of discharge, the abscess may open into the antrum or upon the outside of the face, near the union of the malar and superior maxillary bone. Abscesses formed about the lower anterior teeth usually open on the labial side of the alveolus, within the mouth. They may, however, open on the outside of the face, below the horizontal portion of the jaw. Abscesses in connection with the lower bicuspids usually open on the buccal side of the alveolus, though they may discharge on the face, along the body of the jaw. Abscesses connected with the lower molar teeth usually find exit upon the buccal side of the alveolus, but sometimes on the outside of the face, adjoining the inferior maxillary bone. Cases are reported in which the abscess has opened in the neck, and even as low down as the infraclavicular region. Alveolar abscesses usually assume a chronic condition, and keep up a discharge of pus from their fistulous opening as long as the root in connection with which they have been formed remains in the mouth, or until the pulp canal of the root has been properly cleaned and filled. The opening of an alveolar abscess upon the face or neck has oftentimes been mistaken for the discharge from necrosed bone. A case coming under the observation of the writer, while in charge of the Dental Infirmary of the Harvard Dental School, will illustrate the point. A farmer, from the western part of Massachusetts, came to the Massachusetts General Hospital to be treated for a fistula opening at the symphysis of the lower jaw. The fistula discharged more or less, and was thought to be due to necrosis of the lower jaw. The condition had existed for about two years, and had been treated by injecting the fistula with various medicaments. At the hospital they declined to operate till his teeth had been examined. Such an examination showed a lower incisor which, though not carious, was believed to contain a dead pulp and to be the origin of the fistula. The tooth was extracted at the Dental Infirmary, and the patient advised to return home and report in a month's time. In due time the patient reported that the fistula had completely healed. While not all cases of fistula about the face are due to dental abscess, yet the teeth should always be examined when such a case presents itself.

The clinical symptoms attendant upon alveolar abscess are well marked and of peculiar severity. Since alveolar abscess starts with simple inflammation of the peridental membrane, the first symptoms are the same as those described under that affection. As the condition advances, however, the pain becomes more intense, the tooth is farther protruded from its socket, and is exquisitely sensitive, the touch of a finger often being sufficient to produce great agony. Sometimes the formation of pus is marked by a chill and rise of temperature. This formative stage may last from twenty-four to forty-eight hours; meanwhile the pus has been working its way through the surrounding bone into the soft parts. When this has occurred the face in the neighborhood of the affected tooth becomes swollen, and there is a marked remission of pain. The mucous membrane of the gum about an alveolar abscess is much congested and swollen, besides being sore to the touch.

As peridental inflammation and alveolar abscess are very common causes of toothache, it is necessary to distinguish between the toothache so caused and that due to irritation of the pulp. Toothache from irritation of the pulp is started by the pressure of food against the pulp, by a sudden variation of temperature, or by sweet or salty substances. The pain is violent, but intermittent, and no soreness of the tooth in the socket, as a rule, exists. Toothache from inflammation of the peridental membrane or alveolar abscess is started by the death and decomposition of the pulp. The pain is continuous; it is increased by the application of heat, diminished by the application of cold. The tooth is sore in the socket, and if the crown is tapped with an instrument the patient will flinch. The tooth is protruded from the socket, the gums are inflamed, and the face is swollen.

The treatment of peridental inflammation or alveolar abscess is, first, to remove the cause of the irritation. If the tooth is without value to the individual it should be extracted. This is the quickest way out of the difficulty. If, however, it is desirable to preserve the tooth, its pulp cavity should be at once opened and cleansed from all decomposing material. If this is done in the first stage of the difficulty it is usually sufficient, and, the source of irritation being removed, the inflammation subsides. If the case be one of alveolar abscess the cleansing of the pulp cavity is of advantage, not only in removing the source of irritation, but also in giving a vent to the forming abscess through the root canal. In many cases, however, the abscess will open through the alveolus in spite of treatment. Such an opening can sometimes be hastened by incising with the lance over the affected root. Whether pus can be reached with the lance or not, the incising of the gum gives relief by diminishing the congestion of the part. The use of leeches upon the gum is an old and often effective remedy. The tincture of iodine painted upon the gum is of

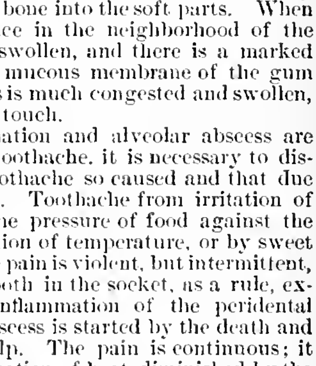


FIG. 4631. A Vertical Section through a Lower Incisor and Surrounding Parts, Illustrating two Ways in which an Alveolar Abscess may find Vent. The first, and more common way, is by the fistula opening at *c*; the second, and less common way, is by the fistula opening at *c'*. *a*, the tongue; *b*, the lower lip; *d*, the abscess cavity; *e*, the inferior maxillary bone.

common use; also the application of capsicum plasters, slippery-elm poultices, and roasted raisins. A poultice should never be applied to the outside of the face, on account of the danger of causing the abscess to discharge externally and leave a scar upon the face which is a permanent disfiguration.

Pathological Affections of the Peridental Membrane dependent upon, or associated with, Calcareous Deposits on the Teeth.—Calcareous deposits are of two classes: those originating from the saliva, and called salivary tartar or salivary calculus, and those originating apparently from a serous exudation from the peridental membrane, and called serumal calculus. The salivary tartar or calculus is composed mainly of phosphate of calcium, which is contained in the saliva and is precipitated upon the teeth. It is found in greatest abundance on the buccal sides of the upper first molars, near the opening of the parotid gland, and on the lingual side of the lower anterior teeth, near the opening of the submaxillary and sublingual glands. Salivary calculus is first deposited at the neck of a tooth, and, if not removed, spreads both toward the cutting edge and in the opposite direction up the root. In its progress along the root it presses away the gum from the neck of the tooth and separates the peridental membrane from its attachment to the cement. If allowed to rest in contact with the peridental membrane, it destroys its life, and also that of the adjacent bony alveolus, thus largely diminishing the natural support of the tooth. In this way the teeth affected become loosened, and may be entirely dislodged. Salivary calculus, though, as a rule, limited to the regions described, may in much neglected mouths cover the entire lingual side of the lower teeth and the buccal sides of the upper teeth. The treatment of this deposit consists in its removal, after which the peridental membrane quickly resumes its normal character, except such portions as have been destroyed, and the gum closes around the neck of the tooth.

The second form of calcareous deposit, called the serumal, has nothing to do with the saliva, nor is it limited to certain localities in the mouth. It is supposed to be due to a deposition from serum exuded from the gingival margin of the gum and peridental membrane; this deposition taking place in consequence of irritation. It may affect any of the teeth, and is located at the margin of the gum, often hidden from sight. In color it varies from yellow to brown, and even black. It often encircles the root of the tooth, but may be deposited in patches. It increases slowly, but is destructive to the peridental membrane, which becomes separated from the root. The alveolar bony processes about the neck of the tooth are in time absorbed, and the natural support of the tooth is diminished.

In connection with this deposit there may be a flow of pus, due to irritation of the peridental membrane. To this condition the name pyorrhœa alveolaris has been given. While salivary calculus causes the loosening and falling out of the lower front teeth, the serumal deposit may effect the loosening and falling out of any of the teeth, and is the most common cause of that result.

There remains to be described an affection of the peridental membrane which is very destructive to that tissue. It is usually associated with a deposit of serumal calculus, and may be very similar to the affection just described. The calcareous deposits are, however, more likely to be in patches, and to advance more rapidly to the apex of the root. By this means pockets are formed along the side of the root, due to a separation of the peridental membrane from the cement of the root. In the first form of serumal deposit the peridental membrane is separated from the tooth around the entire circumference of the root, and from its neck as far up as the deposit reaches; the tips of the root meanwhile being firmly attached to the peridental membrane until the tooth falls out. In the second form, however, the root may be separated from its peridental membrane on one side up to its apex, and in other parts firmly attached. At the apex the root is often entirely separated from its surrounding membrane, though at its neck there may be a fairly good union. Whether the deposit of calculus is due to the inflammation of the peridental membrane, or the inflammation is due to the deposit of calculus, is not decided. This form of calculus is associated with a flow of pus and rapid destruction of the peridental membrane. This membrane having been destroyed, the tooth loses its hold in the socket, and in time drops out. There is some reason to suppose that this disease is due to a special micro-organism, and that it is infectious. On this account it has been called infectious pericementitis. The term pyorrhœa alveolaris is commonly applied to this as to the preceding condition. The treatment of both kinds of serumal calculus with associated inflammation of the peridental membrane is to remove the deposits of calculus and to keep them removed. To this must be added thorough cleanliness of the teeth, and a washing out of all pockets produced by the separation of the root from its membrane. The use of antiseptic and astringent fluids in such pockets is a desirable and effective treatment, especially in that form of deposit last described. In people of middle or advanced life calcareous deposits are more destructive to the teeth than is caries.

Extraction of the Teeth.—The extraction of the teeth may be called for by various conditions, of which the more common are:

1. A crowded condition of the teeth which threatens or has caused irregularity. Teeth may be placed entirely outside or inside of the dental arch. The extraction of such teeth is often advisable. It may, however, be laid down, as a rule, that the superior canines and central incisors should not be extracted to correct irregularity; nor should the inferior canines, except in rare instances. For example, it often happens that when the superior canines make their appearances through the gum there is no room for them between the superior lateral incisors and first bicuspids. As the canines descend they in consequence take a position outside of the arch and are a deformity. They are not on this account, however, to be removed, because by their position and size they give character to the expression of the face. A bicuspid, or sometimes a first molar, should be extracted instead, and thus room gained for the canine. In many such cases, however, there is no need for extraction, inasmuch as the enlargement of the dental arch, either by nature or by mechanical appliances, will furnish the required room.

2. The existence of a few teeth in the mouth which interfere with the adjustment of an artificial plate. This is a very common cause for extraction, inasmuch as a more satisfactory plate can, as a rule, be made for a mouth having no teeth than for one having a few scattered teeth.

3. The existence of pain due to:

(*a*) Congestion or inflammation of the tooth pulp.

(*b*) Inflammation of the peridental membrane.

(*c*) Alevolar abscess.

More teeth are extracted to relieve pain than for any other cause. Where teeth, however, by treatment can be relieved of pain and made useful organs, they should not be extracted.

4. The existence of diseased conditions of the tissues in the neighborhood of the teeth.

An inflammation of the antrum is sometimes best treated by extracting an upper first molar or second bicuspid and making an opening through the end of the root socket into the antrum. By this process the antrum can be thoroughly cleansed and good drainage established. There are tumors of the jaw, and cases of caries or necrosis of the maxillary bones, which necessitate a removal of teeth.

5. The persistence of the temporary teeth when the permanent teeth are about to erupt.

It may be laid down, as a rule, that the temporary teeth should not be removed until the permanent teeth are ready to take their place. When this condition exists, the roots of the temporary teeth have been for the most part absorbed, and the crowns have become loose. While the above rule should be adhered to as far as possible, yet there are cases in which severe inflammation connected with the temporary teeth requires their premature extraction.

The Process of Extraction.—The process may be divided into three stages.

1. Seizing the tooth with the forceps.
2. Loosening its connection with its surroundings.
3. Removing the tooth from its socket.

The process of extraction and the instruments employed vary greatly with the different teeth in the mouth. A knowledge of the number, shape, and size of the roots of the teeth is necessary to insure success in their removal. To extract the teeth of the upper jaw, the patient should be placed with the head thrown well back, and the operator should stand at the patient's right side. With the left hand the lips and cheeks should be retracted and the upper jaw firmly grasped.

The upper central incisors are extracted with a forceps whose beaks are made to adapt themselves to the nearly conical neck of this tooth. The forceps should be applied with one beak at the labial surface of the neck of the tooth, and the other at the lingual surface. The beak of the forceps should be carried well up between the margin of the gum and the root of the tooth. When the tooth has been thus grasped, it should be gently but firmly rotated, in order to loosen it from its socket. A forward-and-back motion may with advantage be combined with the rotatory motion. When the tooth is felt to have been loosened, it should be removed by a steady pull in the direction of its long axis.

The superior lateral incisors are extracted in a manner similar to that of the central incisors, and with the same forceps. Inasmuch as their roots are somewhat compressed laterally, the rotary motion is not so important as with the central incisors.

The superior canines are quite difficult to extract, owing to their very long roots. The upper incisor forceps are usually employed for the canines. The tooth should be grasped as high up on the root as possible. To loosen the tooth from its socket the rotary motion must be combined with the forward-and-back motion. When loose, a straight pull in the line of its long axis is necessary for its removal. It must be borne in mind that the root of the canine is decidedly flattened on its sides, and therefore offers considerable resistance to rotation.

The upper bicuspids may be extracted with the upper incisor forceps; or they may be conveniently extracted with the alveolar bayonet-shaped forceps. The upper bicuspids should be grasped well up on the root and loosened by a side-to-side motion. Their roots being long and slender, great care is required to prevent their fracture. If the first upper bicuspid has a bifurcated root, it is often impossible to remove the tooth without breaking off the tip of one of the roots.

The first and second upper molars are extracted by a forceps whose inner beak is fashioned with a single concavity, it is thus fitted to embrace the inner buccal root of the first or second upper molar. The outer beak is divided by a longitudinal ridge into two concavities, while the tip of the beak is pointed in the middle. It is so made in order to embrace the two buccal roots of the first and second upper molars, and to conform to the depression between these roots. These forceps should be grasped in the palm of the hand, the thumb being brought into position between the angle formed by the two handles and the joint. The third and fourth fingers should be closed over the curve of the left handle. Owing to the divergence of the three roots of the upper first and second molars, considerable loosening is necessary before they can be extracted. This is effected by a side-to-side motion; as the outer alveolar plate is thinner than the inner, the main force should be applied in an outward direction. When the tooth is thoroughly loose in its socket, it can be removed by a downward and outward motion

Upper wisdom teeth are not usually difficult to extract, as their roots are commonly fused together. In order to loosen them they should be turned firmly outward. By this movement their attachment to the socket can be readily broken up and the tooth removed.

In case the crowns of the upper teeth are badly decayed or entirely lost, the alveolar or root forceps should be used. With this instrument any root of the upper jaw can be extracted; the rules for the extraction of roots being substantially the same as those for teeth with crowns. It is necessary, however, to carry the blades farther up into the alveolus than when the crown is present. Great care should be taken not to crush the root by too firm a grasp. With the first and second upper molars it often happens that the three roots must be extracted separately.

In extracting the inferior teeth the patient should be situated much lower down than for extracting the superior teeth. The operator should stand at the patient's right side, oftentimes well to the back. The lower jaw should be grasped by the left hand, and supported from beneath by the palm and last three fingers, while the thumb and forefinger are placed within the mouth to retract the lips and tongue from the tooth to be operated on. The lower incisors, owing to the lateral compression of their roots, cannot be rotated in the process of loosening them. This must be accomplished by a forward-and-back movement.

The lower canines, owing to their very long roots, are often quite difficult to extract. They are to be loosened by a forward-and-back movement, to which a slight rotary motion may be added. When loose, they are removed by being pulled straight up from the socket.

The lower bicuspids should be grasped well down upon the root and loosened by an in-and-out motion. The alveolar plate being much thinner on the outer than on the inner side, it will yield more readily outward. When loosened, the lower bicuspids are removed by being pulled straight up from the socket.

The lower molars are extracted by a forceps whose beaks are divided by a median ridge, and are terminated by a pointed tip; it is thus able to embrace the two roots of the lower molars, and to engage the depression between them. To extract the lower first and second molar teeth, they should be rocked from within outward till loose, using more force when turning them outward than in the opposite direction. When loose, they may be removed by an upward-and-outward pull. The lower third molar often gives great difficulty in extraction, owing to the curve of its roots, which hook backward toward the ramus of the jaw. It must be loosened by a side-to-side rocking. Owing to the backward curve of its roots it cannot be lifted from its socket by a force exerted directly upward.

Elevators are often useful; they are straight and curved levers, with which a tooth is pried out of its socket, a neighboring tooth being used as a fulcrum.

The extraction of the temporary teeth is performed after the same manner as that of the permanent teeth. The operation is, however, much simpler, especially if performed at a time when the teeth are about to be shed by nature. In the premature extraction of the temporary molars there is always the possibility of bringing away the crown of the developing bicuspid, which is located between the roots of the molar tooth. Diminutive forceps are made for the temporary teeth, but temporary teeth can be readily extracted by the root forceps made for the permanent teeth.

Accidents of Extraction.—In the extraction of the teeth certain accidents may occur; they may be unavoidable or due to unskilfulness or carelessness. The following are the more common:

Fracture of the Tooth.—This often happens, and is due usually to an excess of force, or to misdirected force, or to an insufficient grip upon the tooth. Cases occur, however, in which fracture of the tooth is unavoidable; this is especially the case when the roots are misshapen and locked into the jawbone. When the tips of roots are, as the result of fracture, left in the maxillary bones, it is not always wise to remove them. Nature will usually expel them in due time.

Fracture of the Alveolus.—This occurs, to a limited extent, in every tooth extraction, and produces, as a rule, no troublesome symptoms. By unskilfulness, however, a large portion of the alveolus surrounding a tooth may be crushed or fractured, and necrosis sometimes ensues.

Fracture of the jaw may result from tooth extraction. The fracture may be in the upper jaw, or in the body of the lower jaw. It may or may not imply fault on the part of the operator.

Dislocation of the Lower Jaw.—This usually happens with people whose jaws are loosely hung, and are in the habit of slipping out of the socket. If this tendency is known to exist, it is well to apply a roller bandage over the head and under the jaw before operating.

Removal of the Wrong Tooth.—This accident happens, as a rule, only to inexperienced or careless operators.

Removal of Two or More Teeth Instead of One.—This may happen from an hypertrophy of the cement uniting adjoining roots below the gum. It may happen when the tooth to be extracted is overlapped by an adjoining tooth. It may happen also by the slipping of an extracting instrument, whereby a loose tooth is knocked out.

Laceration of the Mucous Membrane of the Gum.—This occurs to a limited extent in every extraction, but, through carelessness or unskilfulness, may be very extensive.

Falling of the Tooth into the Œsophagus or Air Passages.—A tooth will sometimes escape from the grasp of the forceps and be swallowed. From this accident no serious results are to be expected. Cases are now and then reported in which a tooth falls into the larynx. This constitutes the most serious accident that can attend extraction. Such a tooth may be coughed up from the larynx, or it may enter the bronchial tubes, causing symptoms which are always serious and often fatal.

The inferior dental nerve has been crushed in the extraction of the lower wisdom teeth. In such cases a loss of sensation has occurred in the lower part of the face. Usually this passes away, though it may be permanent. In attempting to extract the roots of the upper bicuspids and molars they have been pushed into the antrum. When this happens, the opening into the antrum should be enlarged and the roots removed.

Hemorrhage after Extraction.—This is usually moderate in amount and of short duration. Such cases require no treatment. There are cases, however, in which the hemorrhage is so prolonged as to produce alarming symptoms, and in rare instances death has resulted. Great care should be taken in dealing with people having the hemorrhagic diathesis. To control hemorrhage after extraction the most successful method is to apply pressure to the bleeding parts. The bleeding usually takes place from the socket of the extracted tooth. The socket should be packed with cotton, lint, sponge, or any soft unirritating material. After packing the socket a compress of soft material, covering the socket and surrounding parts, should be superadded. Upon this compress a gentle pressure should be maintained, either by the fingers or by the opposing jaw. An effective method of applying pressure after the socket has once been plugged is to soften a piece of gutta-percha in hot water and mould it to the affected region. Enough gutta-percha should be used so that the opposing teeth or alveolus can be embedded in it by the closing of the jaws. Let the jaws be closed and a roller bandage passed over the head and under the chin, and firm and constant pressure is secured upon the bleeding area.

In severe cases care should be taken to keep the head upright and the extremities artificially warmed.

As styptics can be mentioned perchloride of iron, tannic acid, and preparations of the suprarenal capsule. Of these, perchloride of iron is the least valuable. Tannic acid is a reliable agent; the powder may be applied to the socket on a pledget of cotton. Preparations of the suprarenal capsule are especially valuable in arresting dental hemorrhage. Styptics can be used with advantage in connection with the use of pressure, as described above. Very severe cases of hemorrhage have been controlled by the use of the actual cautery. If this be used, it should not touch the parts, but be held just near enough to bake them. If the cautery touches the tissues, a fresh laceration is made by its removal.

In desperate cases of hemorrhage internal remedies are usually resorted to. They consist of tannic acid, gallic acid, and ergot.

General Considerations.—Haste in extracting should be avoided; the hand should never move faster than the eye can follow. The tooth should be under complete observation from the time it is grasped by the forceps till it is out of the mouth. The head of the patient should be firmly fixed, and under the control of the left hand or arm.

While considerable force is necessary to extract a tooth, the force should be so guarded and moderated as not to endanger surrounding parts. No jerks or sudden pulls are allowable.

The forceps should never grasp the crowns of teeth alone, as the crown will usually break off, leaving the root undisturbed, but should engage the tooth at its neck, or a little higher up if possible.

In extracting roots the beaks of the forceps should follow down between the root and its alveolus till a firm hold is obtained.

The cutting through of gum and alveolus with a root forceps is not a desirable procedure, but is allowable in certain cases.

An excellent substitute for a dental chair is a rocking-chair with medium high back, a pillow thrown over the back forming a good head-rest.

William Henry Potter.

TELANGIECTASIS; TELANGIOMA. See *Angioma.*

TELLURATES.—The tellurate of potassium and the tellurate of sodium are recommended as remedies for the profuse sweatings due to phthisis and other causes. They are given in doses of one-third to one-half grain daily. In some cases this quantity requires to be increased, but generally the second or third dose is followed by a cessation of the sweating. It is supposed to produce its effect by an inhibitory action on the nerves of the sweat glands. In some cases it causes a loss of appetite and nausea, and in some advanced cases the sodium salt has produced a profuse liquid diarrhœa which is very difficult to check. The most serious obstacle to its general use is the persistent garlicky smell which it communicates to the breath and to the perspiration.

Beaumont Small.

TENDON REFLEX. See *Knee-jerk*, and *Reflexes, Clinical.*

TENDONS AND THEIR SHEATHS, INJURIES AND DISEASES OF.—It is most unusual to find tendons diseased independently. Morbid conditions of the tendons are so commonly the result of disease in their sheaths that in most systematic treatises they are not separately described. Owing to their dense fibrous structure and an intrinsic blood supply that is far from abundant, they lend themselves more easily to disturbances of nutrition than to invasion by infectious processes. Arcoleo has shown experimentally (*Gaz. degli ospedali*, 1898, No. 151) that the intactness of the sheath is necessary for the perfect nutrition of the contained tendon; but, on the other hand, that the complete removal of the sheath is not followed by necrosis of the tendon.

The most frequently observed morbid conditions of tendons themselves have been in cases of the so-called "snapping finger" (*schnellender Finger, doigt à ressort*). This consists of a sudden interference with the movements of extension and flexion, or of either alone. It occurs always at the same period of the movement, and is overcome with a peculiar snap, either as a result of great muscular exertion or with the assistance of the other hand. In some instances its nature has remained obscure, but operations for its relief have disclosed a nodular thickening of the tendon in quite a number of instances. It is, under these circumstances, probably most often of traumatic origin, but has on rare occasions been ascribed to tuberculosis, syphilis, and neoplasms. Operative removal has been almost invariably successful in its treatment; this may at times be accomplished without completely severing the tendon.

With this exception, disease of tendons will almost invariably be found coincident with or consecutive to primary disease of the sheaths. Malignant growths, tuberculosis of articular origin, and acute suppurative processes frequently involve the tendon sheaths in their extension. These do not require separate description in this place.

In consequence of overexertion or traumatism, there is sometimes observed in the extensor tendons of the hand (less often in the leg) an acute, dry inflammation of the sheaths, *tenosynovitis acuta sicca*. It is apt to occur in persons whose occupations necessitate excessive use of a particular muscle or group of muscles, and especially if there is superadded to the accustomed amount a period of forced labor carried beyond the point of fatigue. The disease has been observed with a certain frequency in washerwomen, pianists, fencers, carpenters, and gymnasts, being in them localized at the wrist. At the ankle it occurs frequently in porters, and infantrymen, and still more often in women operating sewing machines. The prolonged use of the hand trephine has occasionally accounted for its appearance in the surgeon's wrist. A fibrinous exudate upon the surface of the tendon and its sheath gives rise to a rubbing or creaking sensation to the examining hand, whence the name "tenalgia crepitans." It has in some instances also been considered as the result of gonorrhœa or syphilis. Under these conditions, but also in their absence, a serous effusion may appear. When it does so, the crepitation is masked by it to an extent proportionate to the amount of fluid which has been poured into the sheath. Considerable pain and disability may be associated with it. It may be made to subside promptly by fixation of the part by splints, or, still better, by a plaster-of-Paris dressing, this to be followed in from ten to fourteen days by a course of massage and superheated air.

Acute suppuration of the tendon sheaths occurs most frequently in consequence of infected wounds, but may result by extension from phlegmonous processes without demonstrable traumatic origin. It is of especial frequency in connection with wounds of the fingers, when it is spoken of as thecal whitlow. We have here to deal with a most painful septic condition; redness, swelling, intense pain, and throbbing are present. The constitutional symptoms are, or may rapidly become, alarming, and unless incision of ample length is promptly made the tendon will be completely lost by slough; this being escaped, adhesion between the tendon and its sheath occurs, so that its function may be completely abrogated. Prompt and free incision with thorough drainage and preferably moist antiseptic dressing (1 to 5,000 sublimate), to be followed by elevation of the affected part, may be depended upon to avert these unfortunate terminations in the greater number of cases. For this reason such temporizing measures as poulticing, the application of cold, and incisions of very limited extent are to be avoided.

Chronic simple inflammation of the tendon sheaths may be considered as occurring very infrequently. To such an extent is this true that all chronic disease of tendon sheaths is ascribed by some writers to tuberculosis. It has been shown, however, that this is not justifiable, but that *chronic simple tenosynovitis* may occur as a dry, serous, or hemorrhagic inflammation. The dry form is characterized, like its congener of the acute variety, by crepitation upon movement of the tendon in its sheath. Gout and continuous overexertion have been held responsible for it. The serous variety has doubtless been looked upon as tuberculous by many, but is sometimes the result of trauma, rheumatism, or gonorrhœa. Blake has reported a case (*Annals of Surg.*, xxxiv., p. 577) in which operation and subsequent careful microscopic examination showed its non-tuberculous character beyond question. According to Lejars, it is most frequently due to repeated traumatisms, and must sometimes be regarded as a disease of occupation. It presents itself as a fluctuating swelling in the course of the affected tendon, the movement of which is usually interfered with or is productive of discomfort. It is frequently difficult to distinguish it from tuberculous hygroma (see below) without exploratory incision. Aseptic incision is, however, the treatment most likely to be successful. The hemorrhagic variety has, in the few reported cases, been the sequel of trauma. Juvara has reported three cases of such effusion into the sheaths of the radial extensors (*Rev. de Chir.*, June 10th, 1902). There was present an almond-shaped, fluctuating tumor which could be made to slip about by pressure. There was no crepitus to be obtained.

Tuberculosis of the tendon sheaths is by all means the most frequent of the chronic conditions affecting these structures. It is, however, less often primary than secondary. In this latter case it usually occurs by extension from a bone- or joint-focus. This is frequently observed at the wrist and ankle. As a primary condition it is, however, far from rare, and is frequently found in individuals showing no other predisposition to tuberculous infection. For this reason, and because its course may be extremely chronic and unaccompanied by great disability, its real nature is often not appreciated, and is considered rheumatic.

Three forms are usually described, but should not be considered as pathologically distinct, as they are frequently found in combination. The first form may be described as the *tuberculous hygroma*. This presents itself clinically as an effusion of serous character, found most often at the wrist and hand, where, being constricted by the annular ligament, it is also known as compound ganglion. In its symptoms it does not differ materially from simple serous chronic tenosynovitis. Its progress usually is quite slow, and it may be objectionable to the patient solely on account of the deformity which it causes. Upon incision there is found in addition to the serous exudate a formation of miliary tubercles upon the lining of the sheath. If in addition we find the so-called "rice bodies," we are dealing with the second form. These may vary greatly in size and number. Usually this is in inverse proportion. These bodies derive their name from their resemblance in size and color to grains of boiled rice. They are frequently smaller, however, and, on the other hand, the writer has removed from the palmar sheaths a number of the size of large cherries. For this reason they were easily palpated before incision was made. This is, however, not usually possible, for the reason that abundant serous distention is often present, and because such large size is exceptional. There is commonly imparted to the examining hand a characteristic sensation akin to crepitation, but to be distinguished from it. The fluid may be sufficient to make these bodies impossible of recognition without incision.

The formation of *fungous granulation tissue* upon the serous lining of the sheath and even upon the tendon itself is the distinguishing mark of the third variety. This tuberculous tissue is identical with that found in "joint fungus," and gives rise to doughy, elastic swellings of the sheaths. It is distinctly less benign than the preceding forms, inasmuch as the tubercles are actively disintegrating. The peritendinous structures are, therefore, soon involved; caseation, liquefaction, and the formation of fistulæ are apt to be observed in rather rapid development. Secondary involvement of neighboring joints may occur. This variety, in contrast with the other two forms, causes marked disability from the first, and is frequently very painful. If the disease is allowed to progress, the contiguous structures may suffer to a great extent; the swelling becomes very great, and amputation may become necessary as a last resort. On the other hand, if employed before such extensive spread has occurred, radical operative measures are almost invariably successful if sufficiently thorough. Treatment by

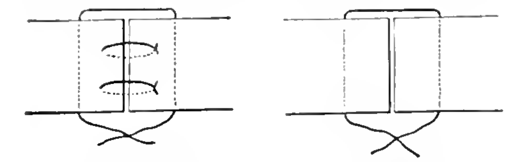


FIG. 4632. FIG. 4633.

FIGS. 4632 AND 4633.—Suture of Divided Tendons.

iodoform injections has not proved satisfactory in this country, although much lauded by some European authors. In the hygromatous form, evacuation of the rice bodies and fluid with scraping of the sheath is, as a rule, all that is required. In the fungous form it is best to remove all infected tissue, and, therefore, to practise the complete extirpation of the tendon sheath. This is usually followed by complete restoration of function if aseptic healing is obtained.

Beck (*N. Y. Med. Journ.*, p. 705, 1901) has described a chronic inflammation of the tendons and tendon sheaths of the hand characterized by the formation of granulation tissue and chalky deposits; he has named this tendovaginitis prolifera calcarea.

INJURIES OF TENDONS.—*Dislocation of tendons* occurs as a rather uncommon accident, and in most of the reported cases the peronei tendons were concerned. After a traumatism to the foot, usually of the kind spoken of as sprain, great disability of the foot is observed, and the tendon of the peroneus longus, with or without that of the brevis also, is found to have slipped from the groove behind the external malleolus, and may be felt as a prominence in front of it. The replacement by manual pressure and retention by means of a crescentic pad and adhesive strips are easily accomplished. In most of the reported cases, however, recurrence of the luxation has occurred, and on this account operations of narrowing the sheaths or deepening the bony groove have been successfully done. Shaffer (Fitzhugh, Trans. Am. Orthop. Assn., 1902) holds the accident to be due to a shortened condition of the gastrocnemius and peroneal tendons. In three cases cure was obtained by stretching these by means of his traction shoe.

Dislocation of the long head of the biceps has been described in a few cases, but on anatomical and experimental grounds there is cause for doubting the possibility of this.

Subcutaneous rupture of tendons occurs rather frequently and may be due to unusually violent muscular action. In some cases it would appear that a pathological condition of the tendon or the neighboring structures was to blame. The rupture usually occurs near the union with the muscle belly or at the bony attachment of the tendon. It is ordinarily felt as a sudden snap with disability, due to loss of function of the affected muscle. Often the gap in the course of the tendon can be felt, and the muscle itself is more prominent than usual on account of its contraction. Although fixation of the limb in such a position as will tend to approximate the torn ends often secures satisfactory healing, it is not wise to depend upon this in the case of important muscles, but rather to approximate and suture the ends through an incision. The tendons most frequently torn are those of the biceps brachii, the plantaris (tennis leg), quadriceps extensor, ligamentum patellæ, and tendo Achillis.

Open wounds of tendons occur very frequently, and especially about the wrist and hand. They may be incised or lacerated. When incompletely divided, union will occur without injury to function. When completely divided, retraction of the muscular end takes place; the ends become adherent to the sheath, and union between them does not occur. Exception to this must be taken in the case of certain operative wounds, such as tenotomy of the tendo Achillis and other tendons of the foot.

Division of the tendons calls for the approximation and union of the ends, and is especially important in the hand, where the usefulness of the member may depend upon it. The muscular end is often difficult to find, and may necessitate considerable enlargement of the wound to make such union possible. Centrifugal wrapping of the extremity with an elastic rubber bandage will occasionally bring the proximal end to view, thus avoiding the necessity of extensive incision. Suture should be done with silk or catgut (chromicized). The sheath may often be sewed over the tendon. As the sutures tend to tear out, one of the methods illustrated here may be employed to prevent this (Figs. 4632 and 4633).

When secondary suture must be done, *i.e.*, after the external wound has healed, it may be extremely difficult or even not feasible to find the proximal end. In this case tendon transplantation has been done (*vide infra*). The proximal end having been found, it may be impossible to approximate it to the distal sufficiently to make ordinary suture practicable. In this event tendon lengthening may be done by splitting the distal end, as shown in Fig. 4634, or a bridge of silk or silkworm gut may be made, uniting the ends and serving as a framework upon which new tissue is afterward formed. Silk will usually be found preferable for this purpose.

Operations on Tendons.—In addition to those above described, operations on tendons are done for a variety

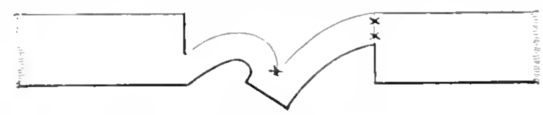
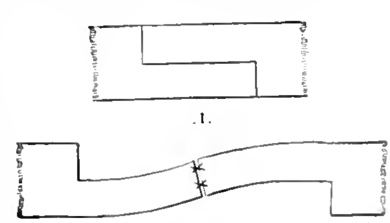


FIG. 4634.—Lengthening of Divided Tendon.

of conditions. The most frequent of these by far is tenotomy, simple division of a tendon. This may be open or subcutaneous. The open operation consists in making an incision parallel with the tendon; the tendon is then divided upon a grooved director in the open wound. The method is one of choice when it is necessary to avoid important structures (*e.g.*, the peroneal nerve in division of the biceps femoris), or where the anatomical situation makes complete division of tendons or muscles not feasible by the subcutaneous method. The muscular variety of wryneck may serve as an example of this; likewise the adductors of the thigh in cases of spastic infantile paralysis. Otherwise, on account of its simplicity and the ease and certainty of the healing process, the subcutaneous method will be chosen. It may be done from within outward or from without inward. The former is the method of choice. The tenotome is a knife with a short blade (1.5 to 2.5 cm.) at the extremity of a long shank (2 to 2.5 cm.), and may be pointed or blunt. The length of the blade should equal the width of the tendon to be cut. An assistant holding the part so as to put the tendon on the stretch, the operator feels for the edge of the tendon and inserts the tenotome behind this with the flat of the blade parallel to the tendon. The tenotome is then pushed through until its point is felt on the opposite side. The edge is then turned toward the tendon, and the



A.

B.

FIG. 4635. Lengthening of Tendon. (Plastic tenotomy.) A, Incision to be employed in dividing the tendon; B, mode of suturing the divided ends.

division is made by a sawing motion. The tendon is felt to yield suddenly and often with an audible snap. The knife is then withdrawn and the minute opening is closed by pressure with a compress of gauze.

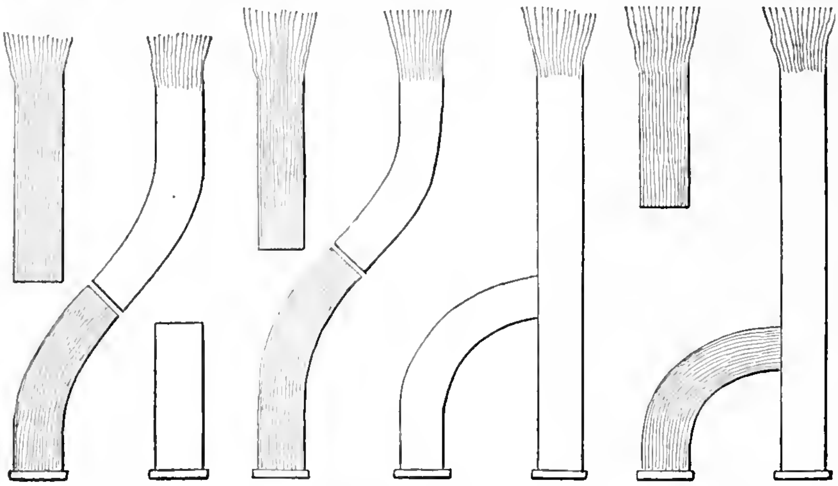


FIG. 4636. FIG. 4637. FIG. 4638.

FIGS. 4636, 4637, AND 4638.—Methods of Functional Transfer. (After Vulpius.) Shading represents paralyzed tendon.

The operation should be done with all aseptic precautions. The wound in the tendon heals by the organization of the blood clot between the divided ends; these soften and become fused with the new fibrous tissue. For some time this has the appearance, both gross and microscopic, of scar tissue. After about three months the new tissue can scarcely be distinguished from the old. Immediately after the division of the tendon the necessary correction in the position of the part is made, and fixation is usually accomplished by plaster of Paris applied over the aseptic dressing. The operation is most frequently done upon the tendo Achillis for clubfoot, either congenital or paralytic; the tibialis posticus and anticus, and the plantar fascia are often divided for the same purpose. Tenotomy may be indicated for the lengthening of any contracted muscle, or when it is desirable for any reason to exclude the action of a muscle, *e.g.*, the tendo Achillis, in the correction of anterior bow-leg.

In some instances, and especially in spastic paralysis, the overcorrection of deformity causes such extensive separation of the divided ends of a tendon that their subsequent union may be in doubt. For the avoidance of this, plastic tenotomy or tendon lengthening is often done. An incision is made over the tendon, which is then split longitudinally for a distance equal to the amount of lengthening desired. Incisions are then made at right angles to this at either extremity of the longitudinal cut and in opposite directions (Fig. 4635, *B*). The figure shows the method of uniting these flaps. For the tendo Achillis, Bayer has proposed a subcutaneous method in place of his original plastic tenotomy. This consists in cutting through half the width of the tendon above and below subcutaneously. Upon making forcible dorsal flexion of the foot the tendon will now split lengthwise and the effect be the same as in Fig. 4635. It has the additional advantage of avoiding adhesion between tendon and sheath. The writer has done the operation repeatedly with satisfaction.

The greatest advance in tendon surgery during the last twenty years has undoubtedly been in the field of tendon transplantation. In this operation the whole or a part of one tendon is engrafted upon or united with the whole or a part of a second tendon. In this way we may either transfer the function of the one to the other, or divide it between the two. The essential indication for performing the operation is a disturbance of the equilibrium between the muscles controlling a joint. This may be due to paralysis or weakening of certain of them, or, in some instances, to the excessive activity of others. It is, of course, assumed that this disturbed equilibrium is incapable of spontaneous recovery or not to be corrected by simpler means. The feasibility of the procedure depends, moreover, upon the persistence of a certain total of muscular power, and its success will to a considerable degree be measured by the amount of this. Before proceeding to describe the technique of the operation and the various combinations from which we may choose, it will be well to discuss in some detail the indications for its performance. In doing so, indebtedness is acknowledged to the admirable monograph of Vulpius ("Die Sehnenueberpflanzung," etc., Leipsic, 1902).

The first group of cases to be considered as calling for tendon transplantation comprises those in which the muscular disability is of traumatic origin. The traumatism may involve the muscles directly, as by incision or subcutaneous rupture of the tendon, or, indeed, the loss of the tendon by suppuration or injury. Tendon transplantation should be considered for these cases, however, only when a very long time has elapsed since the injury, making the finding of the central end of the tendon exceedingly difficult or impossible, or rendering it likely that the muscle belly has degenerated to such a degree as to unfit it for use. Otherwise tendon lengthening by the plastic method, as before described, or by means of silk strands, should be considered the ideal. Traumatisms of peripheral nerves, such as the musculo-spiral, in which for similar reasons direct repair is not feasible, may also call for tendon grafting. In all of the beforementioned conditions it is to be borne in mind that tendon grafting is a procedure of second choice, to be done only in the event that direct repair by suture is excluded.

By far the most frequent indication for the employment of transplantation of tendons is paralysis of central origin, either spinal or cerebral. The largest class of these cases results from acute anterior poliomyelitis. It is well known that in such cases the paralysis, quite extensive to begin with, is recovered from during the first few months, so that after a year has passed there remains an involvement, of more or less circumscribed extent, of permanent character. We have then to deal with paralysis of certain muscles or groups of them, the remaining ones of the limb possessing normal power. In this event deformities are likely to develop, unless prevented by treatment, because of the lack of antagonism to the normally innervated muscles. These latter being made to share their power with the paralyzed muscles, equilibrium may be restored to the affected part, deformity prevented, and a considerable gain in the total power achieved by adaptation to the increased function. In those unfortunate cases in which flaccid paralysis of all the muscles of a part persists, or in which the paralyzed greatly overbalance in number and strength the unaffected ones, the operative stiffening of the joint, *i.e.*, arthrodesis, offers far more than operation upon the tendons. On the other hand, it has been observed after tendon transplantations that muscles which were paretic or atrophic from lack of use have under the new functional conditions regained their usefulness, so that the sum total of muscular power, after operation, was considerably above what was anticipated. Whether in a given case arthrodesis will be preferred to transplantation or treatment by braces to either of these, will depend largely upon individual experience and judgment. Occasions, furthermore, arise in which these methods may with advantage be combined. The various forms of spastic paralysis, both spinal and cerebral, have also been treated by tendon transplantation with signal benefit. Of the cerebral cases only those should be chosen, however, in which the mental condition of the patient is good.

In the treatment of paralytic deformities already developed, the overcorrection of these should, as a rule, precede the operation upon the tendon. In any paralytic case transplantation should be considered only when likelihood of spontaneous improvement is no longer apparent.

Finally, the operation has been done for a number of deformities not of paralytic origin. Thus, to prevent the tendency to flexion after arthrectomy, or excision of the knee, or that which frequently occurs after the cure of tuberculosis or other severe arthritis of this joint, implantation of the hamstrings into the quadriceps tendon has been done with success. Likewise in severe cases of pes valgus or plano-valgus the operation has had its value demonstrated.

In order to decide upon a plan of operation it is necessary to know which muscles are paralyzed and which are not. This must be decided by careful observation of the patient and the voluntary movements of the part, and also by the electrical reactions. It is not to be forgotten, however, that the atrophy of disuse in certain muscles, caused by the paralysis of some of the more important ones of the part, cannot be recognized in this way; but for this purpose ocular inspection of the muscle substance is necessary. In contrast to the dark red of the normal, the paretic fibres of inactive but non-paralyzed muscles are pink of varying shade, while the paralyzed ones look yellow or yellowish-white, according to the amount of fatty degeneration. The complete design of the operation may have to be deferred for these reasons until such inspection has been made.

In the performance of the operation perfect asepsis is a prerequisite. When the tendons to be united are near to one another, a single incision parallel to them may suffice. When they are separated by a somewhat greater space, a slanting cut may be advantageous; but when the distance is considerable multiple incisions may be called for; these may also need to be made quite long for the inspection of the muscular substance. The tendon sheaths should be treated as conservatively as possible.

The combination of the tendons may be done in a number of ways. The simplest method is by lateral anastomosis. In this the continuity of both sound and paralyzed tendon is preserved; both are freshened and united by lateral apposition; tension being secured by drawing the paralyzed tendon proximally, the sound one in the opposite direction. The method is available only when the tendons lie in contiguity.

The second method is that of functional transfer (Figs. 4636, 4637, and 4638). In this the sound tendon is cut through completely, and is sewed to the whole or a part of the paralyzed tendon. This presupposes that the sound tendon is either useless or even harmful in its action, as by it the peripheral stump of the tendon is unused. This fault may, however, be overcome by uniting the distal end of the sound tendon with a sound neighbor. Finally we have functional partition, in which only a part of the sound tendon is joined to the paralyzed one (Figs. 4639 to 4642). This has the great advantage of conserving the function of the sound muscle through the uninjured part of its tendon. The figures show the methods by which functional transfer and functional partition may be achieved. The shaded tendon represents the paralyzed structure. Which of the methods will be chosen will depend upon the functional importance of the unparalyzed tendon which is to be used; upon its size, *i.e.*, whether a slip may be taken from it large enough to sew securely; and upon other conditions which present themselves at the time of choice. It is always preferable, when possible, to graft tendons of similar function; for example, an extensor upon an extensor. This need not of necessity be done, however. In doing functional partition it is desirable that the split in the tendon be made as near the muscle substance as possible, and that it be continued by blunt separation of fibres into the muscle belly for a short distance. This is done in order to achieve as much functional differentiation of the two parts as possible.

While the tendon is being cut through it should be held by means of clamp forceps, so as to prevent retraction into its sheath after complete division. In displacing the tendon from its old into its new position it is desirable that it shall be placed under the deep fascia, if possible, in order to minimize the likelihood of adhesions. Drobnik's suggestion to pass the tendon beneath the other tendons of the part may, however, be regarded as involving an unnecessary amount of disturbance. It is highly important that the new course of the tendon be a fairly straight one; this requirement should be borne in mind in choosing the tendon and the point at which it is cut

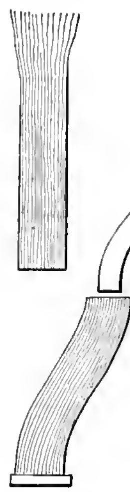


FIG. 4639.

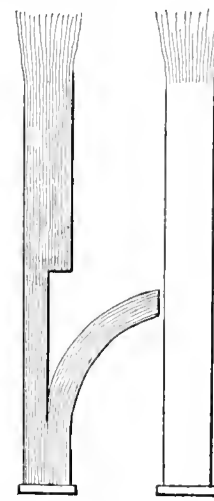


FIG. 4640.

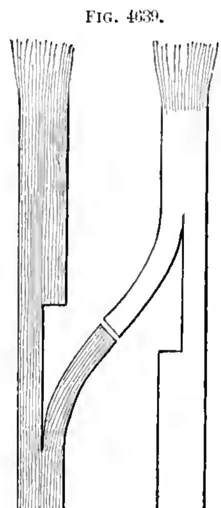


FIG. 4641.

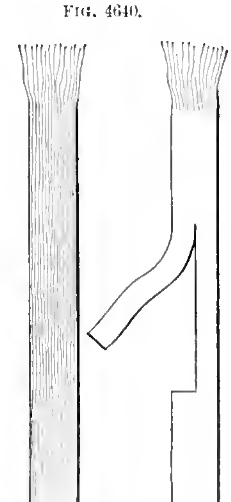


FIG. 4642.

FIGS. 4639 TO 4642.—Principal Modes of Functional Partition. (After Vulpius.) Shading represents paralyzed tendon.

through. In grafting extensors upon flexors, or the reverse, the tendon may in the forearm and leg be carried through the interosseous space instead of around the limb.

The suture should be made under a certain amount of tension, and should be capable of withstanding considerable force. This is best accomplished, ordinarily, by passing the end of the divided tendon through one or even two buttonholes in the other tendon and securing it by a number of sutures. When two divided ends are to be joined, this is done, as above described, under tendon suture. Silk is by all means the best material to use for the suture, as it can be made truly aseptic, and will retain its strength sufficiently long. In a small proportion of cases sutures will afterward work their way out without jeopardizing the result of the operation.

In order to satisfy the two rules, that the tendon suture should be under tension and that it should be done under slight overcorrection of any pre-existing deformity, it will often be necessary to do tendon lengthening on some contractured muscle, such as the tendo Achillis, and tendon shortening on others. Lengthening is done by means of the plastic tenotomy above described (Fig. 4635), while shortening is usually best accomplished by taking a fold in the tendon and maintaining it by sutures.

The proposals of Lange and Wolff to fasten the end of the active tendon into periosteum or bone, instead of into the paralyzed tendon, would seem to involve unnecessary complication, and the more so since the results of these procedures have not been shown to surpass those of the older ones. Lange's plan of using silk strands to connect a sound tendon with a bony insertion in order to avoid the necessity of incising or splitting the tendon has been proved by him to be perfectly feasible. It might be employed with advantage where the tendon graft cannot be made of sufficient length.

The operation upon the tendons having been completed, it is well to attempt to bring the wounds in the sheaths together, or at least to sew the fascia over them. In closing the skin wound drainage had best be dispensed with if possible. The part should be fixed in a plaster-of-Paris dressing, applied over the aseptic bandage; this should hold the joint in a neutral position, *e.g.*, midway between flexion and extension. In the absence of wound infection, the original dressing should be allowed to remain for from six to eight weeks. Suppuration will usually place the result in great doubt. It is not, however, incompatible with a successful issue. It is best to maintain the patient in complete recumbency for at least one month.

After the removal of the fixation dressing, warm baths, massage, passive and active, as well as resistive movements, must be employed with energy and skill if fullest success is to be obtained. In many cases a light brace should be worn during the first few months, so that the act of walking may not tax the muscles too greatly. This is especially true of cases in which a deformity had been corrected.

The number of combinations which may be made in the performance of tendon transplantations is so great that space forbids mention of them in detail. For this reason only a few of the commoner ones are given as examples.

Paralysis of Tibialis Anticus and Tibialis Posticus.—The foot is in position of equino-valgus. The extensor hallucis is cut through and the proximal end is sewed to the tibialis anticus. A slip is taken from the extensor communis and sewed to the tibialis anticus. The distal end of the extensor hallucis is attached to the extensor communis. The tendo Achillis is lengthened, and the peroneus longus is grafted upon the tibialis posticus.

Paralysis of Gastrocnemius.—The foot is in position of calcaneo-valgus. The proximal ends of peroneus longus, flexor digitorum, and a slip from the tibialis posticus are implanted upon the tendo Achillis, which itself requires to be shortened. The distal end of the peroneus longus may be attached to the tendon of the peroneus brevis.

Paralysis of Extensor Communis and Peronei.—The foot is in position of equino-varus. Redressement of the deformity. Extensor hallucis sewed to extensor communis digitorum. Tibialis posticus severed and proximal end attached to peroneus brevis. A slip from tendo Achillis is attached to the peroneus longus.

While tendon transplantation is by all means to be considered a very great advance in the treatment of partial paralysis and of paralytic deformities, unreasonable things should not be expected of it. The most satisfactory results by far are obtained when only one or two muscles are paralyzed, and here the cure may under favorable conditions be practically perfect. When a number of important muscles must be substituted for, much less is usually accomplished. A better position of the limb, making the wearing of apparatus easier, because of simpler needs for it, is all that is frequently accomplished, and it is likely that in some cases arthrodesis would be of more beneficent effect. The success of transplantation depends, however, not only upon the selection of the proper muscles for grafting and a correct operative technique, but in no less degree upon attention to even the minor details of the after-treatment. The full benefit of the operation is usually not to be observed until some months afterward, and the total improvement is sometimes not gained until a period of as much as two years has expired. Sometimes benefit from the operation is found to be transitory; a few months afterward the patient is found to be in the old condition. In this case careful investigation will sometimes disclose the cause of failure in improper selection of energizing muscles, and one may with hope of success resort to secondary operations. *Albert H. Freiberg.*

TERATOLOGY—derived from the Greek word τερατολογια (τερας, monster + λογια, tell)—in its broadest application is that department of biology which treats of the malformations or abnormal growths in both the animal and the vegetal kingdom. In the more restricted and usual sense of the term, as suggested by the elder Saint-Hilaire, in 1822, teratology includes the consideration of the graver malformations resulting from deviations in the normal development of man and other animals occurring at some period before birth.

It is evident that no sharp demarcation can be drawn between the many slight developmental variations giving rise to the numerous anomalies, or *hemiterata*, affecting various parts of the body and the more serious defects appropriately classed as malformations; with the latter, however, is associated the existence of disturbances of form and function which more or less profoundly affect the well-being of the organism.

Malformations may be grouped as *primary* and *secondary;* the former include those produced by arrest or deviation of the fundamental processes of development by which the animal body, or its parts, originates; the latter embrace those that result from disturbances of organs or parts, the early development of which has progressed normally until adversely impressed by some secondary influence.

Malformations presenting marked change or distortion from the normal appearance of the embryo or fœtus are termed *monsters*. In these the external characteristics are usually associated with structural defects of such gravity that the organism is incapable of maintaining an independent existence after separation from the sources of maternal nutrition. A conspicuous exception to such inability is seen in double monsters, which, notwithstanding their striking peculiarities, sometimes, as in the case of the famous Siamese twins, live, grow, and even thrive for years.

History.—An intelligent interpretation of malformations is so dependent upon an adequate knowledge of the processes of normal development that the evolution of teratology from the crude and fanciful speculations of the past into a recognized department of biology, founded upon a sound and rational basis, is largely the record of the progress of embryology itself.

The appearance, in 1759, of the epoch-making *Theoria generationis* of Caspar Friedrich Wolff marks the beginning not only of a true conception of normal development, as a progressive differentiation and specialization of a primarily simple germ-mass, but likewise of a just appreciation of the causes leading to abnormal formations.

From the earliest times the occurrence of congenital malformations may well be imagined as having arrested the attention and exacted the speculation of philosophers of all ages; objects of such deep general interest could not escape the keen scrutiny of Aristotle (384-332 B.C.), and to him we are indebted for the earliest discussions of the causes and the manner of production of such abnormalities.

Notwithstanding the interest with which these defective beings were regarded, over two thousand years elapsed before their true nature began to be suspected during the early half of the eighteenth century. Previous explanations of the production of monstrosities consisted of confused and fanciful assumptions, often grotesque in their absurdity, in which supernatural influences, the benign or baneful exercise of divine power, the impressions wrought by heavenly bodies, the blighting influences cast by unholy spirits and by witches, sexual congress with the lower animals or with Satan himself—"coitus cum diabolo" being an accepted factor even as late as Martin Luther and Ambrose Paré—all found accredited place in the category of potent causes of monstrous births. A detailed consideration of such idle speculation need not here detain us; the reader interested in a fuller account of these curiosities of medical literature may be referred to the interesting *résumé* of past theories contained in Ballantyne's paper on "Teratogenesis."[1]

Following, although tardily, the more accurate trend of anatomical investigation inaugurated by the genius of Vesalius and the enthusiasm of his pupils, the progress of teratology during the seventeenth and eighteenth centuries is marked by the passing of old traditions and the dawn of a rational conception of the significance of malformations as evidenced by the increasing number of accurate descriptions of these variations by competent observers. An adequate interpretation of malformations was manifestly impossible at a time when the fundamental facts concerning normal development were still to be recognized.

The discovery of the mammalian ovum by de Graaf, in 1672, and of the spermatozoa by Hamm, three years later, supplied the basis for the bitterly contested discussions of the two factions—the "ovists" and the "animalculists"—which, however, met on common ground in the acceptance of the doctrine of "evolution" which assumed that gestation resulted in the expansion and unfolding of the perfectly developed body, preformed but of infinitesimal size. These principles when directly applied to the explanation of malformations, as they were by many, led to the conclusion that such defects must result from malformed germs—an admission irreconcilable with the generally conceded adaptability to purpose of nature and a divine Wisdom. In order to meet these objections, the influence of mechanical disturbances, as well as of external pathological conditions, upon the unfolding germ was assumed by the more conservative. Even the philosophical Haller failed to appreciate the importance of the views advanced by Wolff, who, recognizing the fundamental truth that each new being is formed by individual development and differentiation of the primary simple germ, declared malformations to be the results of abnormal variations of the formative energy which under favorable conditions produced the perfect being. While in the main accepting the correctness of the then current doctrine of preformation, Haller presented for the first time a critical analysis of the relation of the known causes of abnormal development to the facts established by observation as gleaned from his own rich experience; he must be regarded, therefore, as one of the founders of scientific teratology.

The closing years of the eighteenth century, and the opening decade of the next, witnessed further advances in the study of malformations in the accurate investigations into the anatomical peculiarities of many abnormalities by Sömmering, Autenrieth, Tiedemann, Blumenbach, and others; Sömmering in particular was fortunate in recognizing the fact that congenital defects were not capricious aberrations, but that in their production they followed definite laws.

The services of Meckel to embryology in securing to Wolff's later papers their merited recognition, by translation into German, were also shared by teratology, since his keen appreciation of the truth of Wolff's "Epigenesis," as opposed to the long-accepted evolution theory, enabled Meckel to regard the production of malformations from an advanced standpoint. As an ardent believer in the dynamic causes of malformations, Meckel sought to explain the majority of defects as the result of disturbances of formative energy, attributing to an early arrest of development the prominence which his own researches suggested.

In 1822, four years after the completion of Meckel's "Handbuch der pathologischen Anatomie," the name of Saint Hilaire appears which, represented by father and son, has become inseparably associated with the study of congenital defects. The "Traité de Teratologie" of the younger, Isidor Geoffroy, Saint Hilaire, published in 1837, presented a most elaborate and systematic consideration of malformations in which the various forms of deviation are described and grouped with such completeness that even at the present day n ny of the features and names of St. Hilaire's classification find recognition by the latest writers. Although influenced by the opinions of his father to regard mechanical influences as the most potent cause in producing malformations, the fuller appreciation and the emphatic statement of the truth that certain typical forms of variation are continually repeated are among the benefits derived from the teachings of this eminent French teratologist.

Among the immediate results of the establishment of the cell doctrine by Schleiden and Schwann, in 1837, were not only renewed investigations and rapid advances pertaining to normal development, but also more searching inquiries into the mode of production of malformations in the light of these newer views. The contributions of Bischoff (1842), Vrolik (1849), Panum (1860), and Förster (1865) mark the beginning of a new era in teratological literature; the last-named author, in particular, proposed a classification upon an embryological basis which, in a modified form, may serve the purposes of today. Among the more recent systematic works on teratology may be mentioned those of Ahlfeld (1880), Taruffi (1881-95), Hirst and Piersol (1891), Guinard (1893), and Marchand (1897).

The deep interest which the causation of malformation has always excited could not fail to suggest attempts to produce artificially monstrosities as aids in solving the problems connected with the mode of production of these variations. Even before the appreciation of the fundamental truth that malformations arise as disturbances and deviations of the normal processes of development, the elder Saint Hilaire succeeded in producing abnormalities by incubating hens' eggs placed in unusual positions, thus meriting the distinction of being the founder of experimental teratology, to the results of which we are indebted to many most suggestive and important data. Liharzik, Panum, Dareste, Schrohe, Koch, Gerlach, O and R. Hertwig, and Richter are among the investigators whose experimental studies yielded positive proofs of the disturbing effects of mechanical, chemical, thermal, and other influences. Within the last ten years the important experimental studies of Roux, Born, Driesch, Wilson, O. Schultze, Windle, Morgan, Schaper, and others have added much valuable information relating to embryological mechanics and to the formation of developmental variations.

It will be seen from the foregoing brief historical sketch that the advancement of teratology as a science may be divided (according to the predominating influences) into three periods:

1. The descriptive—embracing the last half of the eighteenth and the first third of the nineteenth century, when the systematic grouping of the various malformations was based upon the apparent relationship, as exhibited by the characteristics of the completed defects.

2. The morphological—during which the anatomico-embryological details chiefly claimed attention.

3. The experimental—including the last ten years, during which the causation and the mode of production have been the subjects of inquiry rather than the structural peculiarities of the malformations. It is to the further achievements along the lines of experimental investigation that we must look for the advances in accurate knowledge necessary to place teratology upon a satisfactory plane as a department of biology.

In the limited space allotted to this article it will be impossible to present more than a brief account of the more important malformations occurring in the human subject. For a more detailed consideration of the particular defects, the reader must be referred to the special papers to be found in the publications noted at the end of this article.

Causation.—The etiology of malformations in many cases is still a matter of uncertainty; the causes, however, may be divided in general into two groups—*external* and *internal*. The latter, in contrast to external causes, may be held responsible for the production of spontaneous malformations in which influences acting from without are excluded; they comprise the defective constitution of the germ-plasm, whether the latter be modified by the inherent peculiarities of one or both parent cells, by pathological changes affecting the embryonic organism, or by impressions due to heredity or atavism.

The occurrence of defective conditions of the parental germ-cells, whether of father or mother or of both, is more a matter of *a priori* assumption than of positive demonstration, since it is impossible to detect structural variations which account for the often far-reaching impressions produced on the embryo.

The influence of heredity—whatever the limitations of our intimate understanding of the phenomena—in the production of malformations has long been recognized in those cases in which particular defects, as supernumerary fingers and toes, harelip and skin pigmentation, occur in certain families through successive generations. Even graver abnormalities, including hypospadias, imperforate anus, spina bifida, microcephaly, and partial absence of limbs, seem influenced by transmitted predisposition. An unbroken sequence of generations may be wanting, since the defects may be absent in one generation and again appear in the next, or a "reversion" may occur to an abnormality presented by some ancestor several generations removed.

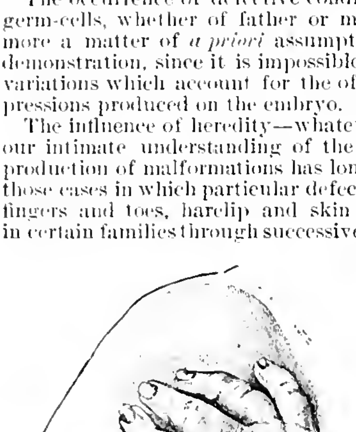


Fig. 4643.—Distortion of Upper Extremity Resulting from Amniotic Pressure. (Ziegler.)

The responsibility of one parent for the inherited defect has been repeatedly shown in families where the children of one father by two or more wives, or, conversely, those of one mother by different husbands, have presented similar malformations. A remarkable case in point is recorded by Meckel,[2] in which two children of a man by his first wife had harelip; of four children by his second mate, two had the same deformity, while a third had cleft palate. Two relations of the father also had harelip. Gade[3] reported the case of a woman who had given birth to three anencephalic monsters.

Notwithstanding the important investigations of recent years relating to the details of the union of the chromatin contributed by the male and female germ-nuclei that have given to our knowledge of fertilization an almost mathematical precision and supplied an accurate morphological basis for our understanding of heredity, the inscrutable variations in the ultimate constitution of the chromatin upon which depend the transmission of inherited characteristics must still remain subjects of speculation.

Pathological changes affecting the early embryo are sometimes indistinguishable, in their consequences at least, from true formative disturbances, since both may result in the arrested development and death of the embryo. Defective nutrition, whether due to diseased conditions of the maternal tissues or to defective development of the early circulatory system of the embryo itself, is responsible for the loss of many products of conception—probably of a far larger number than is usually appreciated, since these may be thrown off in the earlier weeks of gestation without attracting attention. The aborted "moles" so frequently encountered are the malformed and partly absorbed embryos of later, but still early, stages; the disproportion between the size of the embryo and the duration of pregnancy, so conspicuous in many cases, is accounted for by the fact that the death of the embryo takes place some time prior to its expulsion. In not a few instances, in which death occurs at a very early period, absorption has been so complete that even the most careful examination fails to locate the embryo within the enveloping sac.

We are indebted to His[4,5] for the first comprehensive study of these defective forms which, according to this authority, constitute at least forty per cent. of all early abortions. Giacomini[6] regards this estimate as too low, and declares that in less than twenty-five per cent. of abortions during the first month the embryo presents normal development. The last-named writer divides these abortive products into two chief groups: 1, the embyro is present; 2, the embryo is absent. When present, the embryo is represented by (*a*) atrophic forms, or (*b*) nodular malformations. When absent, the disappearance of the embryo may be due (*a*) to absorption, either with or without the retention of the fetal appendages, or (*b*) to complete or partial escape from its enclosing sac.

Mall[7] has also contributed an instructive paper relating to early malformed embryos. In all described, some fifty in number, he regards the abnormality as either primarily of the embryo or of the chorion. The term "vesicular" is suggested instead of His' nodular forms, all of which are earlier than the second week. Mall concludes that the cells which so conspicuously infiltrate the tissues of such malformed embryos are the blood cells that migrate from the vessels, which latter are left enlarged and empty. After the early formation of the amnion, the embryo may die while the amnion, chorion, and umbilical cord continue to grow for a time, thus accounting for the discrepancy between the development of the membranes and of the product of conception which may undergo partial or complete destruction. In certain cases the supposed vesicular embryo is really the remains of the yolk sac.

External causes adversely affecting the development of the embryo include *mechanical influences*, as traumatism and pressure, *physico-chemical influences*, as variations of temperature, electricity, deficient oxygen, toxics, and *maternal influences*. External violence, when not too overwhelming in its immediate effects, may bring about arrest of development and subsequent malformation by causing an impaired nutrition in consequence of the separation between the ovum and the maternal tissues due to extravasation of blood. The results of such nutritive disturbances may be death and subsequent expulsion of the embryo, or a malformation which may be retained until the termination of gestation.

Pressure is a potent source of defective development; and even when of slight degree, if long continued and exerted at an early period, is capable of producing profound changes in the young fœtus. Conspicuous examples of malformations due to such causes are seen in abnormalities of the extremities, congenital luxations and club feet, in the production of which unusual relations of the amnion, or malposition of the fœtus in utero, must be assumed as common sources of the undue pressure. Joachimsthal[8] further refers certain examples of spinal curvature, deep constrictions on the head, and flattened nose to such influences. The pathological conditions of the fetal membranes, particularly of the amnion, may be responsible for pressure-defects in cases in which the available space for the developing fœtus is reduced by hemorrhages either within or between the membranes.

Many malformations may be properly attributed to arrested or disturbed development induced by pressure in consequence of failure of the amnion to keep pace in its expansion with the growth of the fœtus. The close relation between the tubular amniotic envelope and the young human embryo, especially at its cephalic end, renders abnormal diminution of the amniotic space in the early stages a serious matter for the delicate product of conception. Under such unfavorable conditions profound changes may occur, which, when involving the head, may lead to defective development of various segments of the brain, the eyes (*cyclopia*) or the parts normally formed from the visceral arches. Certain types of deformities of the skull (*cranioschisis*) and of the spine (*rachischisis*) are probably expressions of later influences due to amniotic pressure.

Likewise the development and differentiation of the caudal end of the embryo may suffer and the immature lower limbs may remain stunted (*phocomelus*) or unformed, or early be so blended that their future development gives rise to a composite member (*symelus*).

In certain cases there is evidence that the pressure has been only temporary, the amnion after a time assuming a normal relation to the fœtus. Rarely the obliteration of the amniotic sac is only local, the membrane being closely applied to the fœtus over portions of its surface, while in others the amnion is separated and removed by accumulations of the amniotic fluid. Where tightly applied the investing membrane sometimes undergoes atrophy to such extent that the embryo appears to, or actually does, lie partially uncovered.

Amniotic adhesions are productive sources of malformations, especially of those parts, as the head and the extremities, which present prominences favorable to the attachment of the investing membrane during the early period of gestation when the amnion lies closely related to the embryo. The fact that both the exterior of the latter and the inner surface of the amnion are covered by the same layer, the ectoblast, is favorable to union of these surfaces when brought into unusual intimacy. Such adhesions may remain limited, or, when favored by mechanical influences, may become more extensive and firm. When, on the other hand, the amnion is later removed from the embryo, the adhesions may be reduced to a few delicate and attenuated strands, as occasionally seen attached to the fingers and toes. Sometimes the constriction due to an encircling band of amniotic tissue leads to amputation and loss of a larger or smaller portion of one or more limbs. Ridlon[9] describes a case exhibiting congenital amputation of both legs at the knee and of the left arm at the elbow. In another he noted a constriction around the middle finger on one hand; on the other the corresponding finger beyond the proximal phalanx was represented by a mere thread. On both feet the distal phalanx of the great toe and the distal and middle phalanges of the second toe were amputated, the third digits being also imperfect. The fact that the separated parts are never found is explained by their maceration and disintegration after constriction, since such amputations occur at a time while the limbs are still small and immature. Not infrequently the amniotic adhesions may disappear as gestation advances, and at birth their former existence may be indicated only by

FIG. 4644.—Results of Amniotic Adhesions. (Marchand.)

scar-like markings. It is often difficult or impossible to distinguish between primary unions and the results of secondary adhesions due to inflammatory processes, although according to Tesdorpf[10] the blood-vessels so characteristic of the latter are wanting in the simple primary attachments.

The prominence and irregularity of surface presented by the head offer especially favorable localities for amniotic adhesions. These may lead to profound disturbances in the development of the skull and brain, as well as to the more common defects in the formation of the face due to interference with the closure of the various clefts between the processes and arches which normally take part in completing the face. The unusual traction exerted by an attached amniotic fold may give rise to extensive facial clefts, or if attached in the orbital region defects involving the palpebral opening, together with those of the eyelid or eye, may occur. The accompanying illustration from Marchand is a remarkable exhibition of the defects produced by amniotic adhesions, including partial exencephalus, oblique facial cleft, disturbed and imperfect development of the right eye. A firm band connects the head with the thorax in consequence of which attachment closure of the ventral body wall has been incomplete. Additional manifestations of amniotic adhesions are seen in the constricted condition of two fingers of the right hand and the tail-like appendage attached in the lumbar region.

Ahlfeld[11] has pointed out that the oval areas of defective integument occasionally seen on the head are attributable to limited amniotic adhesion of tubular form.

The effects of *physico-chemical influences* upon development have suggested important themes for the experimental investigator who has subjected the ova of the lower types, as birds, amphibians, and fishes, to variations of temperature and to the action of chemical substances and of electricity. Interesting as the results of such investigations may be in connection with experimental teratology, it must be pointed out that our knowledge relating to the effect of these influences upon the human embryo is for the most part conjectural. The well-known adverse effects of certain febrile conditions of the mother in frequently producing abortions are attributable by no means exclusively to increased temperature, nor have we any evidence that the latter cause may produce malformations. The disturbances of development which follow artificially induced deficiency in the supply of oxygen in the case of the bird's ovum, may be assumed as taking place in the higher forms and man whenever the normal balance between the necessities of the fœtus and the maternal supply of oxygen becomes impaired, either by reason of imperfect connections between the fetal membranes and the maternal tissues, or of stasis and venous congestion of the maternal circulation; although such conditions may result in the death of the fœtus, we have no evidence that malformations may be so produced. In like manner fatal consequences may follow the introduction of toxic or infectious substances into the circulation of the fœtus.

Maternal Impressions.—The influence of impressions received by the mother during gestation has always been regarded by the laity, and, indeed, by not a few members of the medical profession as well, as a most potent cause in the production of malformations. Nor is it strange that this venerable and deeply rooted superstition should continue to be regarded with favor when we consider the widespread ignorance concerning the normal processes of development which prevails among otherwise well-informed persons. While appreciating the honest convictions of many in the belief of the power of such impressions, and in the sometimes seemingly convincing testimony adduced in support of such views, it must be borne in mind that the teaching of embryology and the verdict of unbiassed critical review of the evidence presented are irreconcilably opposed to such claims. Attention may be called once more to the significant fact that in a majority of cases the affected parts are well advanced in their development before the supposed impression occurs; in fact, not infrequently the developmental deviations necessary to produce the malformation attributed to the influence of the maternal impression take place before the existence of pregnancy is even suspected. Were the instances recorded in which no defective development follows the exposure of the mother to impressions to which malformations are attributed, the overwhelming majority of negative results would do much to lessen the effect now made on the popular mind by the carefully reported cases in which the real or imaginary coincidences are cited as positive proofs of the sufficiency of maternal impressions as a cause of deviations in embryogenesis.

Although, as again emphasized by Ballantyne,[12] it cannot be admitted that an unusual impression upon the mind of a pregnant woman is capable of producing defects in the fœtus closely resembling the object responsible for the impression, there are sufficient grounds for believing that the mental state of the mother may indirectly influence the development of the offspring by inducing changes in nutrition leading to congenital debility, retarded growth, and even death. Conceding that certain defects may result from nutritive changes arising in consequence of profound nervous impressions on the mother, nevertheless, to those familiar with the embryological significance of malformations, the basis of the popular belief in the potency of maternal impressions will appear as depending upon the very natural desire to find an explanation for unintelligible misfortunes in coincidental circumstances rather than upon well established and accurately observed phenomena.

Frequency of Malformations.—The earlier attempts to determine the relative frequency of malformations resulted in widely differing estimates. The most trustworthy figures are those supplied by Winckel,[13] who found in Dresden, covering a period of eleven years, in 10,056 births 156 abnormalities, or 1:64; the same authority, however, records the occurrence of 232 malformations in 8,149 births, or 1:35, in Munich during ten years. The latter proportion agrees closely with the results of Förster, whose observations gave 1:36 based upon the examination of 1,000 cases.

Classification.

All attempts to divide malformations into systematic groups must be regarded as more or less provisional in the present state of our knowledge concerning the mode of their production, since it is evident that an entirely competent classification must be based upon their origin and true nature rather than upon the external peculiarities of the abnormalities. The elaborate classification devised by the younger Saint Hilaire attempted to provide for all forms of variation, but notwithstanding its apparent completeness many incongruities became evident as an embryological foundation for teratology became more secure. The artificial divisions set up by many proposed classifications based upon external characteristics separate abnormalities which are closely related, and, on the other hand, place in intimate relation defects depending upon entirely different causes. The early attempt by Bischoff to formulate a division based upon the embryological significance of the variations was supplemented with greater success by the classification of Förster,[14] in which malformations are considered from the standpoint of their development. More recently Marchand[15] has adopted Förster's classification which, in a modified form, has been likewise followed in this article.

Abnormal Development Affecting the Entire Embryonic Area.—In addition to the disturbances due to pathological conditions of the amnion and the chorion which so often result in the defective development, early death, degeneration and partial or complete absorption of the embryo, already described in connection with the various forms of "moles," the changes affecting the entire embryonic area may be considered as (1) *abnormalities of size*, (2) *abnormalities of position*, (3) *duplicity*.

Congenital Abnormalities of Size. These may be either (*a*) *excessive* or (*b*) *defective*.

1. *Excessive size*, giant growth, or *macrosomia*, is characterized by a general increase of the entire organism which may be manifested at, or shortly after birth, or be developed later, especially about the time of puberty. True giantism is to be distinguished from the excessive size observed in consequence of pathological conditions (*acromegaly*). While slight manifestations from the normal average length (50.5 cm., or about 20 in.) and weight (3,250 gm., or about 7.2 lbs.) of the new-born infant constantly occur, well-substantiated instances in which these figures are exceeded to any marked extent are by no means frequent. Among the instances of new-born children of excessive weight is the case noted by Eddowes[16] of a male child weighing twenty pounds two ounces, and measuring twenty-three inches in length. Dickinson[17] reports the case of a woman whose first child weighed nine pounds, the second twenty, and the third sixteen. Rice[18] mentions a neonatus weighing twenty and a quarter pounds, Baldwin[19] one that weighed twenty-three.

It is worthy of note that children of extraordinary size are usually offspring of parents of average stature. A striking exception is presented in the case reported by Beach,[20] since the father measured seven feet two and one-half inches and the mother seven feet five and one-half inches. Their first child, immediately after birth, weighed eighteen pounds and measured twenty-four inches, while the second turned the scales at twenty-three and three-quarter pounds and was thirty inches long. The assumption of an excessive amount of formative material or genetic force, in an attempt to find an explanation of these instances of unusual growth, must be unsatisfactory, and it must be admitted that our knowledge is altogether conjectural as to the cause of these cases.

Equally uncertain is the etiology of the curious partial excessive growth limited to some particular part of the body, as where one-half of the body, one extremity, one hand, or even a single finger or toe, attains unusual dimensions without participation of the adjacent parts. As with a general giantism, so here, the affected parts may for some time after birth present no unusual characteristic, the tendency to extraordinary growth first becoming noticeable at a later day. These instances of hemihypertrophy must be carefully distinguished from enlargement, the result of inflammatory processes or other pathological conditions.

It may be of interest to note incidentally the excessive stature of a few famous "giants," although it must not be forgotten that in the majority of these individuals the undue proportions are expressions of pathological conditions (acromegaly) rather than true giantism, the conspicuous stature depending largely upon excessive growth of the lower limbs. The accounts of individuals over nine feet in height are to be regarded as apocryphal, very few well-authenticated cases exceeding eight feet. Measurements by Topinard on Austrian soldiers gave eight feet four and one-half inches as the extreme height. The giant Winckelmeyer is said to have attained a height of eight feet six inches. O'Brien, the famous "Irish Giant," whose skeleton was secured for the museum of the Royal College of Surgeons, London, by John Hunter, measured eight feet four inches at the age of twenty-four; his successor, Patrick Cotter, was of similar height.

Women of unusual stature have become famous, from time to time, as "giantesses"; among the most noted of those accurately measured in recent years may be mentioned "Leah," an American, who at nineteen years of age measured seven feet two inches, and the giantess, Miss Marian, eighteen years old, who was exhibited in London as possessing a height of slightly over eight feet. The "Kentucky Giant," Captain Bates, and his wife, the "Nova Scotia Giantess," measuring seven feet two and one-half inches and seven feet five and one-half inches respectively, enjoyed the distinction of having a combined stature of fourteen feet eight inches and of being the tallest married couple known. The excessive size of the children springing from the union of these giant parents has been noted above in the case recorded by Beach. These giants themselves were the offspring, in both cases, of parents of usual stature.

2. The second group of abnormalities of size includes those exhibiting *defective growth*. These may be divided into (*a*) early defects arising from impaired nutrition, represented by the embryos whose arrested growth usually results in death and abortion during the first weeks of pregnancy; (*b*) fœtuses which complete their development, but in which growth has been defective so that at the close of gestation the new-born child is conspicuous for small size, constituting a congenital dwarf.

True dwarf growth, or *microsomia*, in which completed development is associated with insufficient growth, is to be distinguished from the not infrequent cases in which the diminutive size is due to the acquired influence of disease, as rachitis, caries, or inherited constitutional vice. True dwarfs of conspicuously diminished stature are extremely rare, their essential differential characteristic being that all parts of the body, including the head and the brain, are properly proportioned, although reduced in size. In the dwarfing due to pathological influences, on the contrary, the reduction in size is confined to certain parts, as exemplified in the shortened extremities of rachitic subjects. Such disproportion results in marked preponderance of the unaffected members, as often observed in the unduly large head of children affected with disease of the skeleton. Heredity plays an unimportant rôle in the production of dwarfs, since usually the parents are of normal size, and, further, frequently dwarfs during early infancy do not differ from other children of similar age, the diminutive size, which later renders them conspicuous, attracting attention only as age advances. The history of the celebrated dwarf, Gen. Tom Thumb, is an interesting case in point. At birth he weighed rather above the average, but ceased growing when about five months old and less than twenty-one inches in height. He lived until nearly sixty years of age, having had one child by his dwarf wife, Lavinia Warren. "Princess Paulina," described by Nagel,[21] measured nineteen inches in height at nineteen years of age, when she died. She was perfectly developed in every way, and very intelligent, speaking four languages. At birth she measured twelve inches.

Among the instances of full-term children of exceptional smallness may be cited the case, noted by Home,[22] of a living child which weighed one pound and measured less than eight inches in length. At the age of nine years, when it died, the child had attained a height of twenty-two inches. Mursick[23] mentions a living infant weighing one and three-quarter pounds at birth; Baker[24] another of the same weight and fourteen inches long when fifty days old. In 1871, at Kalamazoo, Mich., occurred the birth of twins, a boy and a girl, weighing one and a half and one and three-quarters pounds respectively, their combined weight reaching three and one-quarter pounds. They were perfectly formed and, while less than eight inches, unusually active. Another case of diminutive twins, both girls, twenty-two and one-half and twenty-four ounces in weight, is interesting from the fact that both lived to adolescence.

Abnormalities of Position.—Congenital deviations from the normal position present differing degrees of displacement, varying from involvement of a single organ, as a depressed kidney or an undescended testicle, to the complete transposition of all the thoracic and abdominal viscera, as sometimes seen in marked examples of *situs inversus viscerum*.

Fig. 4645. Complete Transposition of Viscera. (Rüdinger.)

Since variations extensively involving the primary embryonic mass alone claim attention at this place, consideration of the minor deviations of position exhibited by organs, as well as the malpositions affecting the extremities, will be deferred until the description of the malformations of special parts.

Transposition of the organs (*situs transversus, inversio viscerum*) may be so complete that even the slight asymmetries which are usually observed on the two sides are all repeated, in reversed order, in the new arrangement, the functions of the organs remaining unimpaired. Complete situs transversus has been noted in about two hundred subjects, the two sexes being about equally represented. The case reported by Caton[25] presents a typical picture of this condition. The brain was normal, but the convolutions of the right Rolandic area were remarkably complex on the right side, the subject having been left-handed. The superior longitudinal sinus joined the left lateral sinus. The apex of the heart lay about four inches to the right of the mid line and a right aortic arch passed back to the right of the vertebral column and continued downward in that relation to the spine. A left innominate artery, right common carotid and subclavian sprang from the aortic arch. The left lung consisted of three lobes, the right of two, and the bronchi were transposed, the right passing beneath the aortic arch. The liver lay on the left, the stomach protruding to the right, while the spleen enjoyed its usual but reversed relations on the right. The duodenum, pancreas, cæcum, sigmoid flexure, and rectum were all transposed. The left kidney was lower than the right and the right testicle lower than the left.

The explanation of the production of situs transversus shares the uncertainty of our knowledge concerning the cause of the asymmetry which normally affects the heart and great blood-vessels and other organs. The early primitive heart, as is well known, after fusion of the two isolated primary heart tubes, for a short period occupies a median position as a straight canal which receives the vitelline veins at its caudal end and gives off the truncus arteriosus from its cephalic extremity. Very soon, however, marked flexion toward the right takes place and inaugurates the conspicuous asymmetry which henceforth distinguishes the heart and later involves the large arterial trunks.

In seeking an explanation of the constant flexion of the growing heart tube toward the right, the facts presented by the development of the chick are very suggestive. The earliest deflection of the heart takes place while the embryo lies extended upon the vitelline sac and before the torsion of the head toward the left has occurred; the primary cause of the cardiac expansion toward the right, therefore, cannot be referred to the twisting of the head and the application of its left side to the yolk sac. On the contrary, it is probable that the tendency of the rapidly increasing head to seek support for its broad lateral surface on the left side rather than the right is influenced by the development of the heart. The preponderance of the left vitelline, or omphalo-mesenteric vein, which normally is larger than the right in consequence of the greater development of the corresponding half of the vasculosa, has been regarded by Dareste and by Martinotti as the primary factor in causing the deflection of the heart tube in the opposite direction. Indeed, no one can carefully study the relations and evident impression of the left vitelline vein to the early heart in the chick embryo without recognizing the direct influence of this vessel in producing the right-sided expansion of the heart loop. The subsequent suppression of the right vitelline vein still further aids the early influences of the larger left vessel. It is not improbable that similar influences affect the development of the mammalian heart, although the inequality of the vitelline vessels, as shown by van Beneden in the rabbit, is conspicuous in the secondary changes which lead to the preponderance of the left vitelline artery.

The commonly accepted view that deflection of the primary heart toward the left is the initial morphological factor in producing transposition of the viscera finds support in the observations of Kölliker, Dareste, and others, as well as in the experiments of Fol and Warynski. These investigators likewise show that the reversed position of the early heart is associated with reversed torsion of the cephalic segment, so that the embryo rests with the right side of its head upon the yolk. While we may accept, therefore, unusual size and persistence of the right vitelline vein, associated with a corresponding diminution and suppression of the left, as the immediate cause of a reversed torsion of the heart tube and the subsequent situs inversus, we are compelled to recognize further influences to account for the fact that the abdominal viscera may be transposed, although the thoracic organs retain their normal position.

In seeking an explanation of such conditions, an examination of the causes leading to the normal asymmetry of the abdominal viscera will furnish suggestive facts. Kölliker, and especially His, have shown that the changes affecting the umbilical and the vitelline veins have much to do in determining the relations of the liver and the stomach. In the early embryo, the vitelline veins return the blood from the vascular area and, as a common trunk, open into the primary auricular extremity of the heart. After the establishment of the allantoic circulation, the two umbilical veins course in the lateral belly walls, passing beneath the diaphragm and over the primary liver anlage, to empty into the *sinus reuniens*, a transversely placed venous channel, which receives all the principal venous trunks—the vitelline, the umbilical, and the ducts of Cuvier. After a time the connection of the umbilical veins with the sinus renniens is broken when the formation of a vascular network within the rapidly growing liver takes place. The right umbilical vein, always less well developed than the left, subsequently largely undergoes atrophy, while the left umbilical vein increases and becomes the channel for the blood returned from the now rapidly augmenting placental circulation. The vitelline veins, which ascend at first in front of the intestinal canal and, higher up, lie on either side of the duodenum and the stomach, form transverse communications which thus enclose the duodenum within two vascular rings. The latter undergo partial atrophy in such manner that the right half of the lower and the left half of the upper annulus disappear, the remaining parts forming the upper part of the portal vein. The primary relations of the persistent portions of the venous rings to the primitive gut tube are preserved in the spiral course of the portal vein around the duodenum; the stomach lies to the left of the portal vein.

Since, in general, the usual situation of the liver and stomach are influenced by the persistence of the left venous trunks, the effect of the exceptional retention of these stems on the right side offers an intelligent explanation of the conditions producing transposition of these organs, the relation between a transposed stomach and a reversed portal vein being particularly intimate. Lochte[26] has emphasized, and we believe rightly, the responsibility of the omphalo-mesenteric and the umbilical veins in the production of transposition of the abdominal viscera, in this manner accounting for the reversed position of these organs when associated with normally disposed thoracic contents.

While the heart tube is extremely sensitive to influences inducing transposition, the impression of the vitelline veins on this organ is exerted only so long as these vessels have a direct communication through the sinus reuniens with the primitive heart. After these veins suffer interruption by breaking up into capillary networks within the primary liver, their influence no longer directly affects the heart, but, in conjunction with that of the umbilical veins, is expended upon the abdominal organs, which may be regarded, in a measure, as having an independent development. Since the modifications of the veins occur relatively late, and after the definite relations of the heart are established, the transposition of the abdominal organs may take place subsequently to the normal development of the heart and other thoracic viscera. Regarding the primary cause, which results in the persistence of the right venous trunks of the embryonic area, nothing is known. The very common, but not invariable (Koller[27]) transposition of the viscera observed in the right member of monomphalic double monsters is referable, according to Lochte, to the reversed relations which the right fœtus bears to the umbilical vein.

Duplicities.

The conspicuous malformations embraced in this group have attracted the study and the speculation of the most competent observers from the days of the Greek philosophers to the present, and even to-day, notwithstanding the advances in our knowledge of the primary phases of development, no problem of teratology calls forth more divergent opinions than the production of double monsters.

The salient peculiarities of these malformations readily suggested an origin by union, Aristotle holding that double monsters in viviparous animals were due to fusion of two yolks. Such views held sway for many centuries as the generally accepted doctrine, until the bitter discussions of ovists and animalculists, regarding the relative importance of the ovum and the spermatozoa, were extended to the production of duplicities by the rival schools. Lemery, in 1724, first advanced the opinion that double monsters resulted from the union of two embryos within the uterus—a theory, however, that met many opponents, among whom were Haller and Wolff. The objections of the latter were based upon his insight into the normal processes of development which his observations had taught him were incompatible with the assumption of a fusion of embryos already well advanced in their formation. Wolff pictured the possibility of a double monster arising within an originally single anlage* as the result of divergent growth due to "surplus vegetation."

During the first half of the nineteenth century the writings of the foremost authorities, among whom were I. F. Meckel, Johann Müller, Geoffroy St. Hilaire, Gurlt, Otto, Bischoff, and others, indicate an abandonment of the older conception of fusion as the union of two ova or of well-advanced embryos and the acceptance of the doctrine of fusion in a modified sense, it being recognized that the union must take place at a very early stage. Meckel, however, dissented from the generally accepted explanation of double monsters, as the result of the union of embryonic areas primarily distinct, and held, on the contrary, that such malformations might be produced by the excessive growth of the component halves of a single embryo due to unusual formative energy. Meckel thus appears to have first suggested the theory of fission, which subsequently had, and still has, many enthusiastic supporters.

The later writers who have busied themselves with the discussion of the production of double monsters constitute two schools: the one regarding the duplicity as the result of the union of two primary anlages in a single ovum; the other, as the result of a cleavage of a single anlage. Among the supporters of the first view may be mentioned Panum, Foerster, Dareste, Rauber, Gerlach, Marchand, Ziegler, and others, while the "fission" theory has been defended by Dönitz, Dittmer, Oellacher, Ahlfeld, and not a few later followers.

In considering the merits of these opposed views concerning the production of double monsters, it may be accepted as a fundamental principle that the initial changes leading to duplicity occur during the very earliest stages of development, an assumption of either fusion or cleavage of advanced embryos being untenable. The present conception of *fusion* recognizes the presence of two originally distinct anlages within a single ovum; these may remain separate and develop independently, leading to the formation of twins, or they may come in contact during growth and undergo more or less extensive union, thereby producing some variety of double monster. The fact that in such unions fusion occurs always between parts which are identical in character, as skull with skull, or liver with liver, although not necessarily at points identical in situation, has been advanced as an argument of weight against the acceptance of the fusion theory. It must be remembered, however, that equally remarkable exhibitions of selective affinity (*Loi d'affinité de soi pour soi* of St. Hilaire) are displayed during the normal processes of development, in the approximation and fusion which the somatopleura, splanchnopleura, and other originally separate parts undergo in the evolution of the body walls, the gut tube and organs developed from symmetrical halves.

* The writer adopts the convenient German word, "Anlage," as indicating the primary formative area of an organ, or of the embryo, as more satisfactory than any of the numerous English synonyms that have been suggested.

The explanation of the union of similar parts in double monsters is to be found in the extremely early age at which junction is effected and the inherent attraction of the subsequently produced differentiating tissues for their own kind, muscle seeking muscle, connective tissue joining connective tissue, and epithelium fusing with epithelium. The experiments of Born,[27] in which he succeeded in grafting portions of one amphibian larva upon another, afford many suggestive facts bearing upon the malformations under consideration. Examination of the artificially produced composite larvæ showed that in consequence of the tissue affinity, like organs became united by the fusion of their specific components; thus, the spinal cord of the anterior segment of one larva joined the like structure of the posterior part of a second; the sectioned immature digestive tubes united into a common canal, the Wolffian ducts sought each other, while among the simpler fusions were liver with liver, cartilage with cartilage, cutis with cutis, and epidermis with epidermis. Gemmill[29] confirms the law of union of homologous structures and points out that the primitive embryonic axis, the notochord, is tardier in uniting than either the neural or the digestive tube. It is to be noted that such direct unions are possible only in the early formative condition of the tissues; when once matured, union is effected only by means of comparatively elaborate reparative processes.

The *fission theory*, as presented by its most enthusiastic supporter, Ahlfeld, regards the duplicity as the result of cleavage of a single anlage during the very earliest stages of development, before the formation of the primitive streak. The earlier the cleavage, the more complete the division of the anlage, or, conversely, the longer deferred, the more incomplete the fission. The cleavage force is probably expended earliest and most forcibly upon the cephalic pole of the anlage, from which it follows that partial division of the upper half of the body is so commonly encountered. According to Ahlfeld, the immediate agency in producing the cleavage is to be sought in the mechanical resistance offered by the zona pellucida in consequence of an abnormal increase of the formative material. Since the greatest force exerted by the zona pellucida will be expended on the most prominent part of the embryonal mass, later the cephalic portion of the embryo, the early and profound cleavage affects this segment. Ahlfeld's conception of the results of cleavage so induced includes an associated secondary rotation and divergence of the separated segments of the anlage in proportion to the extent of the fission. If the cleavage be complete and the pressure of the zona pellucida be exerted equally on all portions, the segments will separate but remain parallel; if the cleavage be incomplete, and, therefore, the anlage be still undivided throughout part of its extent, the separated portions will bend in opposite directions, or diverge, thus producing anterior or posterior duplicity. In case the cleavage is complete, with the exception of a limited undivided portion at either cephalic or caudal pole, the segments may diverge and rotate until their axes form a straight line, as in the conspicuous examples of craniopagus, where head is attached to head and the body axes coincide.

The ingenious theory advanced by Ahlfeld, as sketched above, in support of the fission doctrine does not stand the test of embryological criticism, since, as pointed out by Gerlach and emphasized by Marchand, the assumption, that the early embryonic anlage, constituting a part of the delicate and yielding blastodermic vesicle, can be influenced by the attenuated zona pellucida to the extent of inducing a mechanical cleavage, is not in accord with the facts of development.

Although neither the theoretical views of Ahlfeld concerning the production of double monsters, nor the universal application of fission in explaining all forms of duplicity accorded by this author, can be accepted without challenge, yet it must be admitted that certain types of anterior incomplete duplicity are accounted for more satisfactorily by an assumption of cleavage of the anterior end of a primarily single anlage than by fusion.

Were two separate anlages to unite to an extent necessary to produce an anterior doubling of the form shown in Fig. 4655, it is difficult to admit that the anterior ends of the primary embryonic areas would fail to become likewise blended during the development of the prominent cephalic segments. We are compelled, therefore, to seek an explanation of anterior incomplete duplication in some process resulting in the doubling of the early head end to a greater or less degree.

Gerlach, who presents in his admirable monograph[30] a critical analysis of the various theories regarding the production of double monsters, suggests a modification of the usual conception of fission which has much to recommend it. According to the later views of this author,[31] incomplete anterior duplication results not in consequence of a fission of the anterior end of the anlage, but is the result of "bifurcation" accompanying the development of the cephalic end of the young embryo along diverging axes. Bifurcation in this sense fundamentally differs from fission, since the former is the product of active formative processes, the latter the passive result of mechanical forces. Whether the duplication and divergence of the axes are the direct result of mechanical influences, as held by Klaussner,[32] or whether bifurcation occurs independently of such forces, as assumed by Marchand,[33] it is certain that the impression inducing the division affects the anlage at an early stage, and that the degree of duplication is directly proportionate to the time at which the influence was exerted—the earlier its action the more profound the impression and the more extensive the anterior duplication. Examples of comparatively late impressions are seen in the slight duplicity involving limited parts of the head.

The suggestive facts contributed by the results of the interesting investigations in experimental embryology by O. Hertwig, Roux, O. Schultze, Driesch, Wilson, Morgan, and others, are of importance in adding to our understanding of the fundamental principles of both normal and abnormal development. These investigations have shown that in the segmenting ova of amphibian and lower forms the first cleavage virtually establishes a differentiation into right and left body halves, since under normal conditions from each of the two segmentation cells, or blastomeres, a half embryo arises. Under modified conditions, however, each blastomere is capable of producing an entire perfect, although undersized, embryo. The conditions necessary to secure the latter result seem to be such that bring about a readjustment of the egg materials contained within the blastomere to correspond, in a sense, in arrangement and equilibrium to the entire ovum. Morgan[34] discovered that according to the position of the blastomere half-embryos, or whole dwarf embryos, could be produced at will. If, after destruction of one blastomere of the two-celled stage, the other be retained in its normal position, a half-embryo resulted; if, on the other hand, the blastomere be inverted, either a half-embryo or a whole dwarf was produced. These observations are in accord with the discoveries of O. Schultze,[35] who found that by fixing a frog's ova in an inverted position for about twenty hours he obtained, with remarkable regularity, double malformations instead of the usual simple embryos. It is of interest to note that the experiment was successful only when the eggs were inverted as soon as the first cleavage had been completed; double monsters were never produced when the misplacement was effected before or after this stage. The resulting malformations presented various arrangements in the relation of their axes; sometimes one blastomere developed into a complete dwarf, while the other produced only the anterior segment. In some cases the dwarf embryos were united along their ventral surfaces, or back to back; in others a common trunk terminated in two distinct diverging heads; exceptionally, the cephalic segments were directed in opposite directions.

These experiments point to the important conclusion that each of the two primary blastomeres contains the materials necessary to produce an entire body, although under usual conditions of development each contributes but half. O. Hertwig[36] has recently expressed his belief that duplicity is associated with the occurrence of double gastrulation, such variation resulting in the production of the double malformations conspicuously seen in the lower vertebrates. He also regards the duplicities among the amniota as referable to a modification of the same process.

Etiology.—The complete or partial symmetrical duplicity, whether produced immediately by fusion or cleavage, is evidently the result of primary disturbances or unusual conditions affecting the primitive germ mass. The determination of the initial causes which bring about double malformations has been, and still is, one of the most difficult and vexed of teratological problems toward the solution of which little more than speculation can be offered with our present imperfect knowledge.

A. The assumption of inherent peculiarities within the unfertilized ovum, while perhaps of much importance for the current theories concerning the causes leading to the production of double monsters, is speculative and incapable of direct demonstration by the means at the disposal of the biologist.

Suggestive facts, pointing to the possibility that at times the peculiarities of the ovum may be responsible for the production of double monsters, are afforded by the observations of Rauber and of Born. These experimenters showed that the eggs of certain individual fishes were conspicuous by reason of the frequency and repeated occurrence of double malformations arising from their development. It cannot be assumed, however, that the existence of such predisposition can be discovered in any recognizable morphological peculiarity in the ova.

The presence of more than one nucleus, or germinal vesicle, within the ovum has long been regarded as a condition favoring the production of double malformations. The observations of Féré[37] on the hen's eggs show that while in certain cases the development of such ova leads to the formation of two distinct embryos, in others fusion of the early embryonal areas takes place and duplicity results. Wetzel[38] describes interesting examples of multiple areas originating in snake eggs, and regards the evidence convincing in establishing such origin for certain types of duplicity. In addition to the many instances encountered in the eggs of birds and of the lower forms, a number of observers, Franque, Stöckel, Rabl, and Schumacher and Schwarz, have noted human ova containing more than a single nucleus. The last-named authors[39] regard such eggs as capable of giving rise to duplicities. Blanc[40] agrees with Dareste in holding that all double forms originate from ova with two nuclei. O. Schultze,[41] while less radical, regards the presence of two nuclei as one of three possible sources of double malformations.

The most serious obstacle in accepting such origin of duplicities is the difficulty of explaining satisfactorily the fertilization of the double ova. According to our present conceptions relating to the higher animals, fertilization implies the addition to the egg of a definite number of paternal chromosomes and a centrosome through the entrance of the spermatic filament and the formation of the sperm-nucleus. Since the quota supplied by a single spermatozoon is sufficient to unite with only a single egg-nucleus, it follows that no provision is made for the fertilization of the second germ. The assumption, frequently accepted, that fecundation in these cases is accomplished by the entrance of more than a single spermatic element—polyspermia—seems very doubtful when applied to the human species, since it is probable that this never takes place so long as the ovum is healthy and capable of developing. Sobotta,[42] one of the most recent writers who has reviewed the merits of the double-nuclei theory, rejects the latter as insufficient to account for double monsters. Broman,[43] in meeting these objections to the foregoing theory, holds that certain double-tailed forms of spermatozoa (more fully described under the next heading) are capable of fertilizing the two nuclei, since by this means two centrosomes,

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as well as a double quota of paternal chromosomes, are introduced into the egg.

B. Peculiarities of the male sexual cell, when assumed as inherent predisposing influences, are as much a matter of speculation in relation to the production of double monsters as are similar causes attributed to the ovum. The aberrant forms of spermatozoa, described by many observers and regarded by some [44] as physiological, have been considered as directly connected with the production of duplicity, being looked upon as homologous with the ova with two germinal vesicles. Retzius,[45] however, inclines to the view that doubling of the tail results from separation of the two filaments, which, probably, normally constitute the axial filament. Broman has exhaustively studied these atypical forms and divides them into:

(*a*) Spermatozoa presenting deviations in size—giant and dwarf cells.

(*b*) Spermatozoa with a single head, but with two or more tails.

(*c*) Spermatozoa with two or more heads with one or more tails.

(*d*) Spermatozoa deviating from the normal in the form.

Of these, the variations included within groups (*a*) and (*b*) are those accredited as being most closely related to the production of double monsters as assumed by Ballowitz [46] and Broman. The latter excludes the influence of the double-headed forms since their morphological peculiarities impede progress to such extent that the handicap precludes victory in the race toward the ovum with the normal competitors. The double-tailed spermatozoa, on the other hand, possess an advantage both in their more efficient propelling apparatus and in the double centrosomes which the filaments convey. Broman regards the double-tailed forms as important factors in producing duplicities, not only since they may possibly lead to fertilization of ova with double nuclei, but also since, according to this author, they may supply the impulse resulting in the later subdivision of the segmentation mass into two germ centres.

Abnormal segmentation, as an assumed distinct cause of duplicity, is closely related to the foregoing group, since polyspermia is regarded as a potent factor leading to such variation. The considerations weighing against the latter assumption, as applied to the higher animals, are, as already noted, the improbability that more than one spermatozoon gains entrance to a normal ovum and the probable inability of an ovum so invaded to undergo development, since the lessened resistance implies diminished vitality.

Although abnormalities of segmentation *per se* cannot be regarded as playing an essential rôle in producing double malformations, the nearly related condition, in which more than a single formation centre is established, must be regarded as the most important immediate forestep of duplicity.

The difference between the results of the development of the separated first or second pair of segmentation cells and of the subdivided germ mass originating from the normal cleavage of the ovum must be distinguished. The first conditions would probably give rise to two entirely distinct individuals; under the second would follow the production of two closely related germinal areas capable of undergoing fusion.

The most important influences leading to double monsters are, therefore, those that are expended upon the segmented ovum during its early differentiation and result in the establishment of two centres from which development proceeds. Windle [47] regards such condition as dependent upon superfluity of germ-plasm attributable to faulty extrusion of the polar bodies following the entrance of double-headed or atypical spermatozoa [48] or of polyspermia. The latter is also accepted by Duval [49] as the chief cause of the redundant development. Laguesse and Bué,[50] incidental to the description of an early anterior duplicity of only 19 mm. length (probably the smallest human double monster ever recorded), follow Duval in assigning to polyspermia an important rôle.

Although little more than speculation, the most plausible view concerning the origin of the two formative centres, in the light of the more recent experimental studies upon segmentation, attributes the division of the blastula to influences which impress the ovum before their effects are manifested in the appearance of the two germs. That these influences may at times be external is suggested by the experiments of Schultze, Wetzel, Wilson, Loeb, and others with the eggs of the lower forms under modifying conditions. Regarding, however, the development of the higher animals, the assumption of influences dependent upon internal causes seems more plausible. That such may be paternal, as well as maternal, is supported by direct observation. The period at which the deviation from the normal development first becomes definite probably varies, in some instances closely following the early stages of segmentation, in others not until the blastodermic vesicle has been formed.

In connection with the production of true parasitic duplicities, distinguished by great primary inequality of the two anlages, the possible importance of a polar body as the origin of the parasite has been suggested. In our present knowledge, the polar bodies must be regarded as ova of greatly reduced size, but capable of being fertilized (Sobotta [51]). The development of such cells into an imperfect blastula, and later parasite, has been assumed by Marchand [52] as a plausible explanation of the origin of the lesser embryo. These true parasitic duplicities must be distinguished from those in which the disparity between the germs is due to differences in growth and nutrition of what originally were equal anlages.

Classification of Duplicities.—Any adequate grouping of double forms must take into account the developmental as well as the morphological characteristics of the malformations, hence the classifications proposed by different teratologists from time to time have exhibited, more or less markedly, the impress of their views regarding the production of these abnormalities. Although the influence of the teachings of St. Hilaire, and especially of Foerster, is evident in the classifications suggested by later writers, the extent to which the theory of fission or of fusion is accepted as sufficient for the explanation of duplicities largely determines the classification adopted. That proposed by Ahlfeld represents a fission-grouping of the most pronounced type, while the elaborate classification advanced by Taruffi is based upon the opposite assumption of fusion.

In view of the probability, now admitted by many, that although some forms of duplicity are attributable to fission, in many others fusion occurs, a classification is desirable which shall take into account the possible variations in the mode of production. This necessity was recognized by Cleland, who, although accepting fission as the primary process, included in his grouping secondary unions. The division of duplicities adopted by Marchand, which includes the best features of the classifications of St. Hilaire and of Foerster, presents a happy compromise in accordance with recent opinion; this classification, therefore, forms the basis for the grouping here followed.

Duplicities fall into two chief divisions: those in which the two primary germ masses, or anlages, are originally *symmetrical*, and those in which, from the beginning, marked discrepancy exists; the latter are, therefore, *asymmetrical*.

Symmetrical Duplicities.—These may be either *complete* or *incomplete*, the former group including the double forms in which the bodies of the two embryos are entirely distinct, as in twins developed from a single ovum, the latter group embracing the double forms which present more or less extensive union, as exhibited in the various types of double monsters.

Twins developed from a single ovum are distinguished from those originating from different eggs by the possession of a common chorion, although an amnion and an umbilical vesicle are usually formed for each; such twins are said to be *monochorionic*. They are further distinguished by remarkable similarity in their physical, as well as mental, characteristics, being always of the same sex, complexion, and feature. In recognition of these close resemblances, and of their assumed origin by complete fission of the original anlage, Ahlfeld applied the name, "homologous twins" to these duplicities. The only suggestion of union presented by such fœtuses is the single placenta which serves as the common source of nutrition. The conditions of nutrition and the rate of growth of one-egg twins may be so similar in both individuals that their development is *equal*. In exceptional cases the one may exactly correspond with the other in length and weight, as shown by the careful observations of Schatz.[58] More commonly, however, the development of such twins is *unequal*, as evidenced in the more or less marked discrepancy in their size and weight. If the difference is slight, the less favored individual suffers only to an unimportant degree and after birth is fully able to maintain an independent existence. If, on the other hand, the nutrition of one fœtus becomes seriously impaired, its death may occur and its body be subjected to pressure by the increasing bulk of the more fortunate companion. When such conditions arise during the earlier months of pregnancy, the dead product of conception is pushed against the wall of the enveloping sac and later the uterus, and subjected to gradual compression, which results in flattening and distortion to such extent that it is known as *fœtus papyraceus*.

The intimate relations between the placental circulations of monochorionic twins include not only a common placental area containing anastomoses of the capillaries of the chorionic villi, but also, with few exceptions, a superficial anastomosis between the smaller twigs of the umbilical vessels.

The most constant and important of these direct communications between the circulatory systems of the twins is that formed by the capillaries within certain villi to which the blood is supplied by vessels from one fœtus and carried away by those from the other. These areas of *capillary transfusion* usually occur along the blending line of the two placentæ and are designated by Schatz as the *third placental circulation*. This author concludes from his careful observations that the most common type of placental anastomosis is where, in addition to the constant communication existing within certain villi, a single, seldom double, *arterial* anastomosis is formed between the superficial vessels. The next most frequent type is distinguished by a single, rarely double, superficial anastomosis of both the *arteries* and the *veins*. The additional possible relations of the superficial vessels, *venous* union and *absence* of anastomosis, are comparatively rare.

In consequence of the communications within the villi common to both circulations, it follows that in some villi the blood supplied by one fœtus, A, passes into the vessels of the other, B, and, conversely, blood contributed by B enters the circulation of A. The transfusion is, therefore, opposed. Although an accurate balance of these contrary blood streams is supposable, in fact a greater or less discrepancy exists with few exceptions. In many cases this difference is compensated by the superficial anastomosis, but in others this means does not suffice, and the adjustment of the dynamic asymmetry must be attempted by functional changes within the fœtuses. The necessity thus established may be productive of only inconsequent alterations; on the other hand, when associated with obstruction of the blood current within the umbilical vein of one twin, it may result in profound and even disastrous change.

Unequal Monochorionic Twins.—Since equal growth of one egg twins implies an equal apportionment of the placental area, any condition that materially disturbs the nutritive balance tends to affect adversely the less favored fœtus. Among the early sequelæ of such disturbances are the impaired, or even arrested, growth of the heart and the appearance of symptoms resulting from the stasis induced by obstruction of the blood stream within the weaker fœtus, expressed by the hepatic congestion and subsequent atrophy, œdema, and ascites.

When impairment of the circulation of the weaker fœtus occurs at an early period, the heart may suffer to such extent that not only is its development arrested, but atrophy and even disappearance of the organ may follow, thereby contributing to the malformation known as *acardius*. The loss by the affected fœtus of its capability of maintaining an independent nutrition is compensated, to a greater or less degree, by the stronger twin, which, by means of inosculations established between its placental vessels and those of the impaired fœtus, assumes the nutrition of its weaker mate. By virtue of such arrangement the blood current within the latter suffers reversal, usually a single umbilical artery conveying the blood to and a corresponding vein from the body of

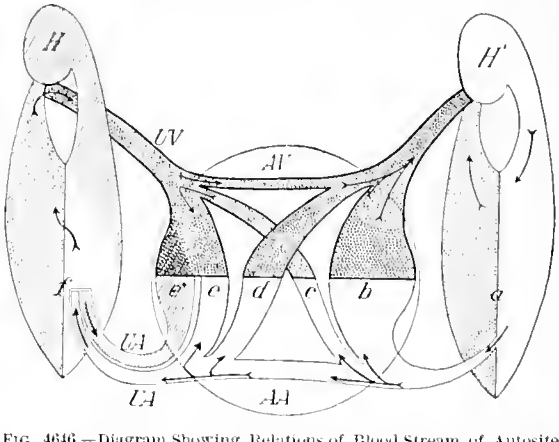

FIG. 4646.—Diagram Showing Relations of Blood Stream of Autosite and Parasite in Acardius. Circle indicates fused placental areas. Blood passes from autosite (*a*) by umbilical arteries to placenta (*b*); in addition to returning to heart of autosite (*H'*), part enters circulation of parasite by villous (*c*) and by arterial anastomoses (*AA*), following the paths indicated by arrows. The reversed current passes by umbilical artery into arteries of parasite, finding its way into the venous stems in consequence of obstruction and obliteration of heart (*H*) and associated large vessels, and returns to placenta by umbilical vein and thence by venous anastomoses (*AV*) into circulation of autosite. Unshaded areas represent arterial paths; light stipple, venous circulation of fœtus; dark stipple, venous paths; lined areas, obliterated tracts. (After Schatz.)

the dependent fœtus. Under such conditions of unequal development one twin becomes in a sense a parasite, since the continuance of its life may be entirely dependent upon the circulation of the other.

The period at which the fœtus becomes thus dependent exerts a profound influence upon the general development which it attains. Occurring early, before the organs and definite form of the fœtus are well established, the formation of such parts may be rudimentary or entirely suppressed. In consequence of the inadequacy of the donated circulation, which at best is only an imperfect substitution, it is usual to find acardius associated with conspicuous deficiencies of other parts of the body. The head particularly is imperfectly formed, often bearing little resemblance to the normal part. When partially developed, the condition is known as *paracephalus*, in which the brain is very rudimentary or entirely wanting, the eyes are imperfect or absent, and the face is malformed. Total absence of the head constitutes *acephalus*. These deformities of the head are usually associated with malformations of the trunk and limbs, the former being abnormally small, contracted, or misshapen, the latter defective or partially suppressed. The upper extremities are particularly prone to suffer, not infrequently being entirely wanting, although the lower limbs, by reason of their more favorable relations to the nutritive vessels, may be fairly well developed. In rare cases even these suffer, so that only a rudimentary single inferior extremity is present.

The internal organs, especially those closely related to the vascular system, are profoundly affected. Thus, in addition to lack of development of the heart, the liver is usually wanting, and, further, the lungs are more or less rudimentary. Defective development of the digestive tube, the kidneys, and other abdominal organs often coexists.

When the arrest of development is of the highest degree, the body of the dependent twin becomes reduced to a misshapen mass presenting slight resemblance to the human form. Such monsters, which may be little else than irregular nodules invested with œdematous skin and attached by an umbilical cord, constitute the form termed *amorphus*.

Acardiac Monsters.—Reference has been made to the occurrence of acardiac monsters in consequence of impairment of the placental circulation of one of monochorionic twins. It will be desirable, therefore, to consider more fully the group of malformations in which partial or complete absence of the heart is often a conspicuous, but by no means essential, feature. The distinguishing characteristics of a true acardius include not only the impaired development of the heart, but also a circulation dependent upon a stronger fœtus and a *reversal of the blood current*.

The views regarding the production of acardius held during the middle and immediately succeeding decades of the last century by many teratologists, including H. Meckel, Dareste, and Panum, assumed primary defect or death of the heart as the essential factor in bringing about this condition, the cardiac imperfections, in the first place, being caused or accompanied by primary defects of the entire embryo.

Claudius, however, opposed this opinion and maintained that in placental anastomoses lay the chief factor, since, according to this author, the arteries of the two fœtuses united and thus brought the two blood streams into direct opposition. Assuming that the heart of one twin acted less vigorously than that of its mate, Claudius held that the blood current propelled by the stronger heart overcame the circulation of the weaker and reversal of the blood stream within the latter followed. In consequence of this change in the direction of the blood current, Claudius assumed that the heart of the weaker fœtus becomes embarrassed and impaired, and is brought to a standstill, followed by atrophy and final disappearance. Absence of heart was regarded, therefore, by this author as a constant condition of all forms of acardius.

The particular service of Claudius was to emphasize the important fact, originally observed by Hempel, of the reversal of the blood stream and to contradict the assumption of an inherent defect of the heart as necessary for the production of acardius. The effects attributed by Claudius to the arterial anastomoses and the supposed struggle for supremacy between the blood currents are less happy, since, as pointed out by Schatz, the assumed opposition does not exist, for instead of being driven against the stream propelled by the heart along the umbilical arteries, the blood entering the circulation of one fœtus from that of the other must pass in the direction of least resistance. This being toward the placenta, and not toward the heart, the transferred blood will join that already journeying along the umbilical arteries to the placenta, and within the latter pass into the returning veins, and so on to the heart to the nutrition of which it will contribute instead of impair. Ahlfeld has championed the views advanced by Claudius and attempted by new assumptions to strengthen their defective arguments. Thus, this author regards the capillaries of the placental villi as the seat of the reversal of the blood stream, and suggests that from the beginning the acardius may be regarded as an "allantoic parasite" in consequence of the tardiness with which it forms its placental attachments. According to Ahlfeld, during this late development, the allantois of the weaker fœtus grows into that of the stronger, in the course of which process anastomoses become established between the two circulations; as a result, that of the less vigorous twin is overpowered by the blood stream propelled by the stronger heart.

Although recognizing, as all now must, that the explanation advanced by Ahlfeld is incompatible with our present knowledge concerning the formation of the early attachment of the human embryo to the serosa by means of the belly stalk and the absence of a free allantoic vesicle, Marchand inclines toward a modified acceptance of somewhat similar views. This authority assumes a primary inequality of the two embryonic anlages with a corresponding discrepancy in the development of the mesoderm, belly stalk, amnion, and umbilical vesicle of the two embryos. In consequence of this unequal growth, asymmetry results by which the smaller fœtus becomes united by its belly stalk to that of the larger in such manner that they represent a form analogous to double monsters with posterior union and diverging axes. The anastomoses between the blood-vessels of the dissimilar placental areas furnishes the path through which the circulation of the weaker fœtus is overpowered and replaced by the extension of blood stream of the stronger. The defect of the above theory lies in its inapplicability to the explanation of the important group of hemiacardii in which the changes may appear so late in intra-uterine life that the heart and other organs closely associated with the development of the circulation are affected to only a relatively slight degree.

It is to the careful investigations of Schatz that we are indebted for a comprehensive view of the acardii and the related forms of malformation. The conclusions of this author form the basis of the opinions here expressed. Before entering upon a consideration of their production, it will be of advantage clearly to appreciate the groups into which these malformations fall. They are: *holoacardius*, in which the circulation is derived *entirely* from the stronger twin, irrespective of the presence of a more or less perfect heart in the affected fœtus; *hemiacardius*, in which only a part of the fœtus is supplied by the stronger heart, the remainder being nourished from the circulation of the affected fœtus. It is sufficient for the production of a hemiacardius that the reversed blood current is limited to one umbilical artery and only a lower extremity is supplied by donated blood. On the other hand, the entire body of the hemiacardius, with the exception of a small part, may be nourished by the reversed blood stream. Schatz recognizes an additional group of analogous malformations, *pseudoacardii*, in which reversal of the circulation never occurs and placental anastomoses are wanting. *Microcardius* and *macrocardius* are conditions of under- and over-weight of the heart depending upon the variations of nutrition associated with modifications of the placental circulation of monochorionic twins.

Reversal of the circulation, therefore, is the one condition constant in all forms of true acardius, complete or partial alike. Absence of the heart is not, since in hemiacardius developed at a late period this organ may be present and even functionating; conversely, single, unassociated embryos sometimes possess hearts no more perfectly developed than those of recognized acardii.

The periods at which acardii may originate are:

1. *Before the heart has developed.* The heart is formed, as well known, by the fusion of two heart-tubes which are developed independently of the vessels of the vascular area, the latter vessels subsequently growing toward the embryonic axis and joining the primitive heart. When, for any reason, the development of this organ is arrested and the vascular areas of the two embryos lie in close relation, the vitelline circulation of the impaired embryo may form anastomoses with that of the normal twin so that the latter assumes, as far as possible, the nourishment of both embryos. Under such conditions, the embryo, which if unaided would necessarily die, continues its development and becomes a parasitic acardius.

2. *After the heart has developed*, but before the establishment of the allantoic or placental circulation. In case heart-death occurs, either primary or secondary, at a time when the vitelline circulation is still formative, anastomoses may still occur in sufficient number to provide succor for the imperilled embryo, which under such conditions may become a parasitic acardius. Since the

development of the allantoic circulation does not take place under such circumstances, a placenta and cord are not formed.

3. *After the establishment of the allantoic or placental circulation.* This period produces the forms usually included as acardii in the origin of which defects of the placental circulation play an important rôle. Mention has already been made of the fact established by Schatz, that the placental circulations of monochorionic twins are united by two forms of anastomoses—the constant communication effected by the chorionic villi common to the vessels of both fœtuses and the more variable communication effected by the superficial anastomoses, at times limited to the umbilical arteries, at others involving both artery and vein, less frequently only the umbilical vein.

In exceptional cases, which may, however, occur at any time between the completion of the placental circulation and the middle of gestation, acardius may arise in consequence of primary heart-death followed by transfusion of the blood within the umbilical arteries of the stronger fœtus into the corresponding vessels of the impaired twin in consequence of the diminished blood pressure within the latter. The blood thus contributed by the stronger fœtus flows both to the placenta and to the body of the weaker; should the nourishment be insufficient to maintain both placenta and body, the one or the other suffers unless the meagre supply is equally shared.

Although in these comparatively rare cases the placental anastomoses, following the primary heart-death, directly produce the acardius, such communications in themselves are incapable of originating these malformations, the reversal of the blood stream being dependent upon a cause to which the failure of the heart and the subsequent change in the direction of the circulation are secondary.

The investigations of Schatz render it highly probable that this primary cause lies in obstruction along the course of the umbilical vein, either within or without the body of the fœtus, at any point between the heart and the placenta. In consequence of the gradual narrowing of the vessel returning the blood from the placenta, the amount passing to the heart is correspondingly diminished until, sooner or later, this organ is more or less completely deprived of the supply necessary to maintain its nutrition and function. The result of this restriction is increasing impairment of the heart's strength and consequent diminution of the blood pressure within the umbilical arteries. When the resistance offered by the failing powers of the impoverished heart is reduced to a sufficient extent, the blood stream conveyed through the placental anastomosis from the stronger twin overcomes that within the weaker fœtus and reversal of the circulation within the latter gradually takes place. In consequence of this reversal the weaker heart, sooner or later, is brought to a standstill and an acardius results. The rapidity with which these changes are effected depends upon the rapidity and the extent with which the venous obstruction develops. Although the superficial placental anastomoses suffice to compensate for inequality in the transfusion taking place between the twins, such communications are powerless to neutralize the effects of the hindrance caused by stenosis of the umbilical vein. On the contrary, they aggravate the untoward transfusion inequality, since the superficial venous anastomosis offers a ready escape for the retarded blood current into the circulation of the unaffected fœtus, and the arterial anastomosis provides the channel by which the blood from the vigorous heart passes into the reversed circulation of the acardius.

After the establishment of the acardius, the obstruction within the umbilical vein may remain stationary, or after a time it may decrease, since the returning blood current, which now passes along the vein, is under higher pressure than before the assumption of the circulation by the stronger heart. In those cases in which the narrowing of the umbilical vein is permanent, at a time very shortly after the appearance of the budding limb, the meagre supply of blood suffices for the imperfect development of the embryo into the globular amorphus type of acardius, in which the retarded return of the blood from the fœtus results in œdema and failure of development of the internal viscera. When the obstruction appears relatively late, the deficient development may result in producing an œdematous acephalus instead of the more typical amorphus.

It may be emphasized that, in general, the acardii are formed from normal embryos, and, further, that the time of their production may be at any period of gestation, from the early relations of the embryonic areas resulting in the development of a parasitic acardius, on the one hand, to the conversion of a hemiacardius into an acardius near the close of pregnancy on the other.

Although at times the reversed blood stream and the impaired heart are the only defects, in other cases conspicuous malformations are associated with the acardia. These defects may be grouped as *primary* and *secondary*, the former including such as exist prior to the acardia, the latter after its appearance.

The primary defects, again, embrace those which are *intrinsic* and those which are *accidental*. Among the intrinsic primary defects may be mentioned irregularities in the development of the venous system associated with *situs transversus*, absence of the ductus venosus, faulty formation of the liver and its veins, or malformation and stenosis of the umbilical vein. The accidental primary defects are such as have no connection with the condition of acardia, as spina bifida.

Regarding the grouping and the fundamental circulatory conditions of the several types of acardiac monsters, the conclusions of Schatz may be followed with advantage.

I. *Acardii completi*, in which a fairly well-developed trunk and head are present, the limbs being represented by the full complement or by the members remaining after the suppression of one or both upper or lower extremities. The various degrees of development of the head are expressed by the terms *holo-*, *para-*, *oma-*, and *hemicephalic*. Since the different types of acardii depend for their production largely upon the amount and character of the blood supply derived from the stronger twin, it is of interest to consider the probable relations existing in the complete acardii. Bearing in mind the fact that, even under the most favorable conditions, the nutritive requirements of the dependent twin must always remain insufficient, it will be appreciated that in order to secure the degree of development sometimes seen in the complete acardii, the fœtus has enjoyed the most advantageous conditions possible under the circumstances. This implies an approximately sufficient nutrition by means of a well-balanced circulation, the blood stream entering by the umbilical arteries being carried away from the fœtus by venous channels of adequate capacity to insure the necessary blood pressure, and at the same time to prevent stasis. The general development of the acardius depends upon the sufficiency of the blood supply forced into its various parts by the active heart; the occasional instances in which the affected fœtus is relatively well-formed are possible because of the ample and direct anastomosis between the placental circulations.

II. *Acardii acormi*, which possess only the head, with possibly traces of the trunk and limbs, constitute a conspicuous group of monsters depending for their production upon the effects of unusual combinations in their venous channels.

The remarkable acormous acardius represented in Fig. 4647, carefully recorded by Barkow, may serve to illustrate the manner in which, as interpreted by Schatz, such rare malformations originate. The production of an acormus implies a close and intimate primary anastomosis between the vitelline circulation of the fused embryonic anlages. Although the communication between the two vitelline veins at first consists of numerous vessels, during the subsequent development of the embryos the inosculation is reduced to paths forming a single main channel, the *common vitelline vein*. Under usual conditions, this vessel becomes impervious and atrophies upon the establishment of the allantoic circulation. In response to the imperative necessities of impaired nutrition, however, it may remain and take an important part in the nourishment of the acardius.

In consequence of early obstructed circulation due to stenosis or arrest of development of the allantoic vein of

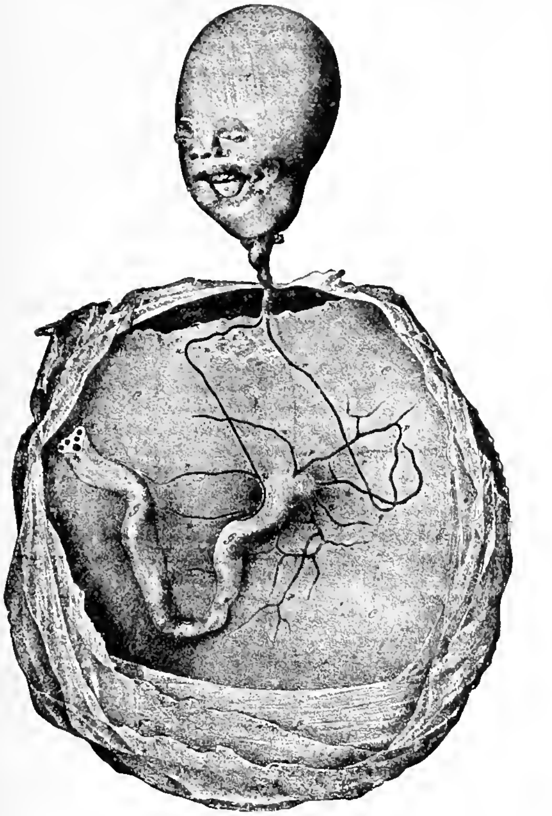

FIG. 4647.—Acardius Acormus. Rudiment of left upper extremity and of digestive tube. (Barkow.)

the subsequent acardiac fœtus, the blood pressure of the latter becomes lessened, followed by the passage of the blood from the systemic veins of the stronger twin into the weaker fœtus by way of the still present common vitelline vein. Notwithstanding the improved nutrition thus secured, the heart sooner or later becomes enfeebled in consequence of the inadequate blood supply and the greatly increased length of the circuit through which the blood passes. With the development of the umbilical cords, the common umbilical vein is included within both, and hence the blood which is carried to the placenta by the umbilical arteries of the future acardius must pass, in order to return to the latter, through the placental villous anastomoses into the umbilical vein of the normal fœtus and thence to the point of entrance of the common vitelline vein; then along the entire length of the umbilical cord back to and across the placenta, into and along the entire length of the cord of the second fœtus to the overburdened and under nourished heart—the blood being propelled by the latter through a course over three times the length of its normal circuit. In consequence of these demands, the insufficiently nourished heart gradually becomes more and more enfeebled, until a period arrives when the reduced blood pressure within the weaker fœtus is overcome by the circulation of the more fortunate twin, and the blood of the latter passes, by means of the superficial placental anastomosis, from the umbilical artery of the stronger into the corresponding vessel of the weaker twin. The reversal of its circulation so induced, following the heart-death, affects not only the blood current within the umbilical arteries, but also within the extended path formed by the common vitelline vein, the typical condition of acardia being now established. Since the vitelline vein affords a ready exit for the blood carried by the superior vena cava, the circulation supplying the cephalic end of the fœtus is comparatively well maintained, and hence the conspicuous development of the head and immediately succeeding part of the trunk, and the suppression of those portions of the body not in relation with the superior vena cava.

III. *Acardii acephali* form a group in which the lower or pelvic portion of the trunk constitutes the chief representative of the body of the malformed fœtus, to which other parts of the trunk, together with all, some, or none of the limbs, but no head, may be added.

In considering the anatomical factors active in the production of such headless forms, the importance of the collateral venous anastomoses, by which the obstruction in the umbilical vein is partially compensated, becomes evident. The most important collateral path, probably, is that afforded by the enlargement of the veins of Burow, small branches within the abdominal wall connecting the umbilical and deep epigastric veins. Since the most active circulation, and hence most efficient nutrition, is determined by the position of the channels affording the readiest return of the blood, those portions of the acardius affected by the blood current established by means of the collateral vessels will be most favorably

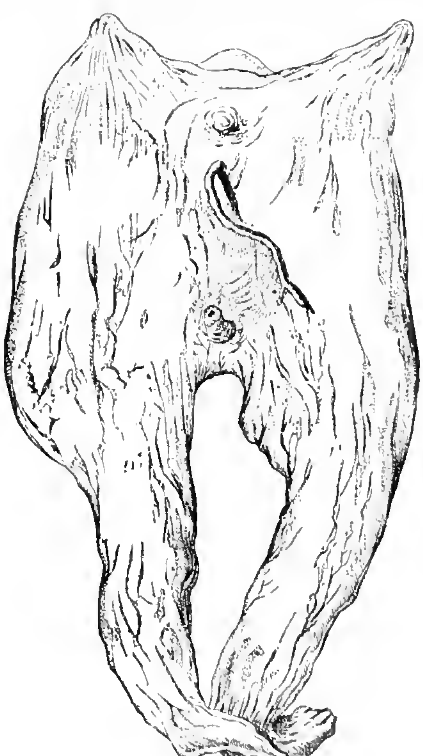

FIG. 4648.—Acardius Acephalus. (Herholdt.)

influenced. These parts will be evidently primarily the lower part of the trunk and the inferior extremities, which are preserved and undergo further development. At times additional veins within the body walls are included within the collateral circulation, the favorable influence of which is thus extended to a larger part of the trunk. The common vitelline vein not being available, either by reason of the late period at which the acardius was developed, or because the formation of the vein never took place on account of separation of the embryonic areas, the head remains unprovided with an active circulation, and hence fails to develop, the result being the production of the acephalic type of acardius.

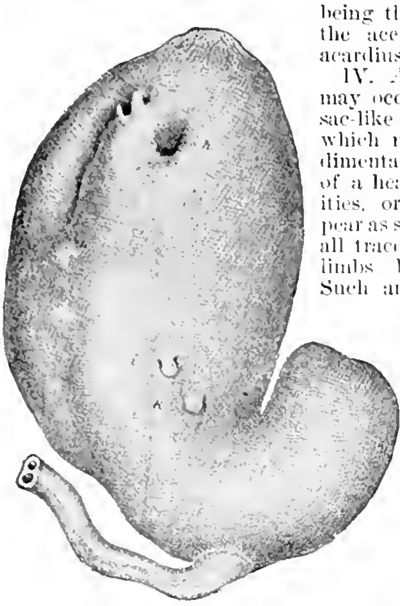

FIG. 4649.—Acardius Amorphus. (Barkow.)

IV. *Acardii amorphi* may occur as irregular sac-like masses, from which may project rudimentary suggestions of a head or of extremities, or they may appear as spherical masses, all traces of head or of limbs being wanting. Such amorphous forms probably originate under conditions due to early obstruction of the allantoic veins, followed by insufficient nutrition and subsequent death of the impaired heart, associated with an inadequate centrally located channel for the return of the blood. In consequence of the stasis so induced, marked œdema of the entire acardius occurs, followed by arrested development or degeneration of the organs; in extreme cases the globular, skin-covered mass retains little resemblance to the fetal form.

DOUBLE MONSTERS.—These malformations constitute a class of joined twins (*gemini conjuncti*) in which the union involves a part of the axial portions of the two bodies. The latter may be *equal* in their development, or one twin may be so retarded in its formation and nutrition that the united individuals are conspicuously *unequal*, even to the extent of the less favored becoming a parasite.

Equally developed united twins present three types:

1. *Anterior duplicity*, or *posterior union*, in which the junction is limited to the lower end of the body axis.

2. *Posterior duplicity*, or *anterior union*, in which the embryos are connected at their cephalic extremities; either the head alone, or in conjunction with a variable part of the adjacent trunk, is involved, leaving the posterior or inferior end of the bodies free.

3. *Middle union*, in which the junction extends from the umbilicus upward for a variable extent.

ANTERIOR DUPLICITY, in which the junction involves the pelvic region, occurs in two forms: (*a*) with *dorsal union*, (*b*) with *ventral union*.

(*a*) *Pygopagus*, the term applied to anterior duplicity with dorsal posterior union, presents a rare form of double monster characterized by a connected pelvic region, with the dorsal surfaces of the twins directed toward each other. The navel is double, the umbilical cords converging toward a common placenta. The axial skeleton of such monsters includes a single coccyx and sacrum common to both individuals, from which spring two spines; rarely the upper part of the sacrum is also double. The innominate bones and the pubic symphyses of the two pelves are present in normal number. In consequence of the obliquity of the dorsal surfaces of the two bodies, the lower limbs, usually fully formed, are so disposed that one pair, belonging to both individuals, lies ventrally and more closely placed than the other. The digestive tubes remain distinct until near the termination of the large gut, where the two recta join and open by a common anus located between the more dorsally situated pair of lower limbs. The spinal cords unite at their inferior extremities to form a common conus with filum terminale. The urogenital tracts show slight fusion of the lower segments; thus associated with a single vulva, the urethra, bladder, vagina, and uterus remain separate. The fact that within a single scrotum four testicles have been found, is readily explained by recalling the original intra-abdominal location of the early sexual gland and its subsequent descent. In a pygopagus examined by Marchand, the abdominal aorta and the venæ cavæ of the two fœtuses joined.

This form of double monster is of especial interest on account of the possibility of life being continued for years, as in the instances of the sisters Christine and Millie, who were born in 1851 and are still alive. A number of pygopagi have been described, of which the most remarkable are the "Hungarian sisters," the "North Carolina twins," and the "Bohemian twins."

The "Hungarian sisters," Helen and Judith, were born in Szony, Hungary, in 1701. They were united at the second sacral segment, below which the sacrum and coccyx were single. The common anus lay between the right thigh of one and the left of the other, and was the termination of a single rectum. In front was a common vulvar orifice, into which two vaginæ opened; the clitoris, nymphæ, and urethra were distinct for each body. Inclination to evacuate the bowels affected both twins at the same time, but urination was effected separately. The great blood-vessels, the aortæ and inferior venæ cavæ, were fused in the region in which the arterial stems bifurcated. Judith, in consequence of illness, remained permanently backward in strength and general development in comparison with her sister. While the two suffered from smallpox and measles at the same time, they contracted other diseases separately. Menstruation began at sixteen, but subsequently the two sisters menstruated at different times and with varying profuseness. When in their twenty-third year, Judith was seized with convulsions and became unconscious, shortly after Helen was in a condition of collapse, and expired a few minutes before her sister.

FIG. 4650. — Pygopagus. Sacrum, from second segment, and coccyx single. *c*, Fused umbilical cords. (Marchand.)

The "North Carolina twins," Christine and Millie, were born in 1851 of negro parents. The union extended from the first sacral segment to the coccyx. There are two recta having a common anal opening, defecation occurring at different times. There are two urethræ and two vaginæ, the labia blending at the posterior margins to give the impression of a single vulva. Menstruation takes place at the same time in both. Common sensibility exists to a limited degree, since one sister can recognize and imperfectly locate touch on the lower extremity of her mate; likewise each knows when the other moves her leg without being able to decide which limb it is.

The "Bohemian twins," Rosaline and Josepha Blazek, were born in 1878. The union is latero-posterior and involves sacra and the lower lumbar vertebræ. The two anterior legs are much closer together than the posterior, the former being moved forward with the outer sides of the feet first, to be followed by the posterior pair with the inner sides of the feet directed forward. In this manner the twins are capable of rapid locomotion or even a quick run, although the stronger girl is able to walk naturally forward and draw after her the weaker sister, who then walks backward.

(*b*) *Ischiopagus*, anterior duplicity with posterior ventral union, is characterized by junction in the pelvic region so related that the right pubic bone of one pelvis fuses with the left pubic bone of the other, the ventral surfaces of the two sacra facing each other. The common pelvic ring thus constituted may be subdivided by an osseous bridge formed by the united coccygeal bones. The body axes may correspond in position, thus forming a straight line, or they may be placed so as to include a very obtuse angle. The continuous ventral body surface contains a single navel. The pelvic organs are often fused and the anus may be single or double; likewise the genital organs. When, however, the latter are in duplicate, they are so placed that each is common to the two bodies, the right and left parts belonging not to one individual, but one to each.

FIG. 4651.—Pygopagus. "Christine and Millie." (Pancoast.)

The lower limbs may be well developed and, when the body axes correspond, are placed at right angles to the latter. When, however, the axes of the two individuals are placed at an angle, the consequent approximation of the lower limbs on one side may result in more or less complete fusion, or these members may be entirely suppressed, and only two lower extremities be developed. In such cases, one limb belongs to each body. Gemmill [54] has very carefully described the anatomical details of the ischiopagus tripus represented in Fig. 4653. Atresia of the urethra and anus, on one or both sides, is common in these malformations, in consequence of which defects ischiopagi seldom survive for any length of time. Sometimes conspicuous discrepancy marks the development of the twins, one remaining very rudimentary, the thorax and head being wanting, although the extremities are present. Such forms constitute the *ischiopagus parasiticus* of certain authors.

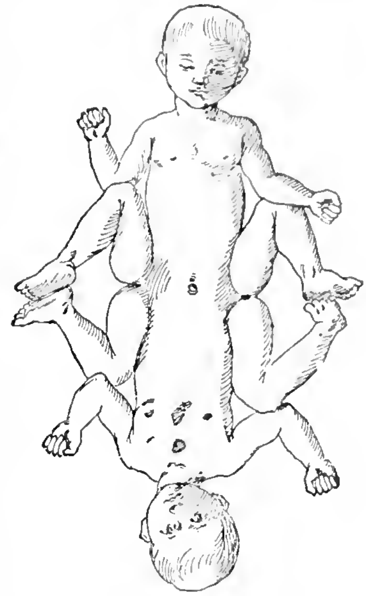

FIG. 4652.—Ischiopagus. (Levy.)

Ischio- or *ileo-thoracopagus* is the name applied to double monsters in which the ventral or latero-ventral union includes the entire trunk. While the presacral portions of the spines are double, the heads being always separated, the pelves are so united that the more approximated ilia are rudimentary or are entirely absent, in which case the two sacra are fused. The more ventrally situated iliac bones, together with the corresponding lower limbs, are well formed. The thoraces of the twins are conjoined ventrally by means of a common sternum, while they are continuous on the dorsal aspect. The upper limbs may all be present (*ischio-thoracopagus tetrabrachius*); or those most closely approximated may be fused into a single member, which may be well developed or very rudimentary. In other cases these limbs fail to develop, thus producing the dibrachial type, one of the remaining pair belonging to each body. The lower extremities are subject to the same arrangements, varying from the full complement to a single pair. The external genitals and the anus are single and common to the two bodies, notwithstanding the presence of double uteri; likewise the bladder is single. The digestive tube exists in duplicate until toward its lower end, the two stomachs being arranged with pylori converging. The thoracic viscera remain partially double, although at times the two hearts are enclosed within a common pericardial sac. An interesting case in the Wistar Institute of Anatomy possessed a heart of which the two sides were contributed each by one fœtus, an intermediate rudimentary auricle and ventricle being the common possession of both. There were three lungs, the intermediate or middle one possessing five lobes. The kidneys in this case were represented by two large and a small intermediate organ. The ischio thoracopagi type of duplicity is not incompatible with prolonged life, as conspicuously shown by the Tocci brothers, who have survived since 1877. According to Virchow, who carefully examined these united twins, it is probable the spinal cords

FIG. 4653. — Ischiopagus Tripus. (Gemmill.)

were separate. The functions of the two children were entirely independent, as well as the reflex movements and sensation of the two lower limbs, one of which belonged to each body. Rita-Christina (1829) and Marie-Rose Drouin (1878) are other noted examples of this form of duplicity; they survived eight and seventeen months respectively.

FIG. 4654.—Ischio-thoracopagus. "Tocci Brothers." (Hirst and Piersol.)

INCOMPLETE ANTERIOR DUPLICITIES include a group of malformations distinguished by partial doubling of the cephalic extremity. Although here conveniently noticed in connection with the forms of anterior duplicity already described, the duplications under consideration probably differ materially from the former in their mode of origin, since there is good reason for regarding them as the results of a dichotomous growth involving the cephalic end of a single embryonic anlage, and not, as in the case of the other anterior duplicities, of the posterior union of two distinct embryos.

The malformations in question present varying grades of duplicity from the mere suggestion of doubling to almost complete separation. The most usual condition is that of doubling of the anterior part of the medullary tube and the chorda followed by duplication of the secondarily derived structures.

Diprosopus is the term applied to partial duplicity where two faces are present. While almost the entire cranial portion of the skull may be simple, the facial part is duplicated and so disposed that the faces are turned more or less toward opposite sides. The divergence depends upon the degree of separation, as does likewise the condition of the eyes, ears, and mouth. Where the duplicity is very slight, the more nearly related eyes may be represented by a single organ (*D. triophthalmus*), or the approximated eyes may later entirely disappear (*D. diophthalmus*). On the other hand, four distinct visual organs may be present (*D. tetrophthalmus*). More rarely the mouths may be fused (*D. monostomus*), although they usually remain distinct. In cases in which two complete faces are present, four ears may remain distinct; frequently, however, two fuse, or are suppressed. The nervous axis also shows more or less extensive duplication, although parts which normally occur in pairs, as the cerebral peduncles, frequently suffer reduction in number by the formation of a common mesially situated structure in place of two distinct, closely placed members.

Dicephalus implies a more extensive and complete duplication of the head, and possibly also of the upper part of the vertebral column. When the spine is involved to a considerable extent, the double-headed monster properly belongs rather to the results of extensive posterior union than to partial anterior duplicity, the differential test being the single or doubled condition of the pelvic end of the spine and the pelvic organs. Frequent examples of dicephalic monsters are seen in the doubled-headed calves of the popular museums, in which the duplication involves, in addition to the head, only the cervical region. In man a true dicephalus is comparatively rare, since the apparent examples of this malformation are really cases of extensive posterior union.

POSTERIOR DUPLICITY with anterior union occurs in two forms: (*a*) *dorsal union*, limited to the head; (*b*) *ventral union*, involving to a greater or less extent the trunks of the two embryos as far as the umbilicus. Both embryos may undergo full development, or one may remain stunted.

(*a*) *Craniopagus*.—This form of monstrosity is characterized by dorsal union involving the heads alone, the

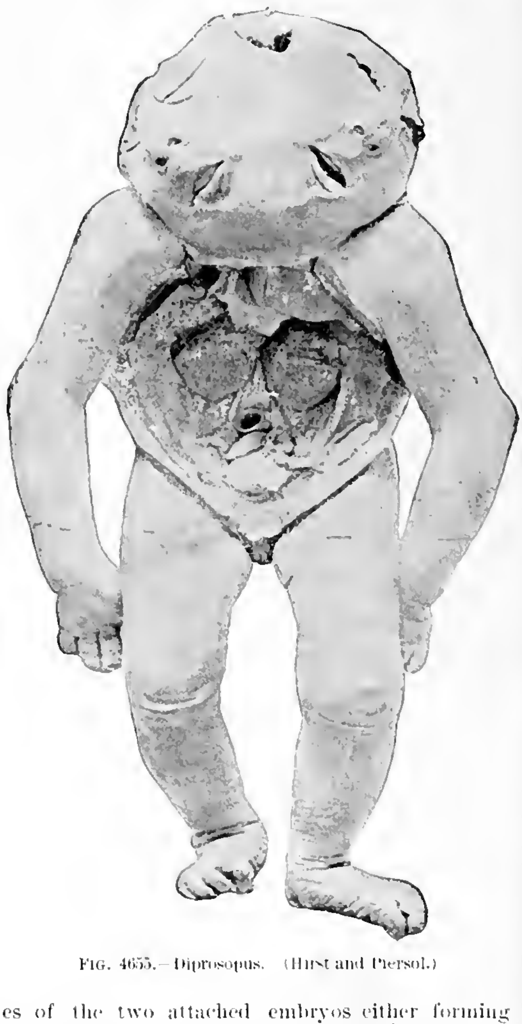

FIG. 4655.—Diprosopus. (Hirst and Piersol.)

axes of the two attached embryos either forming a straight line, or lying at varying angles with each other. The junction may correspond in position with the frontal, parietal, or occipital regions, and usually includes only the integument and cranial vault, the two brains remaining separated by their membranes within a common cranial cavity. It is of interest to note that identical parts of the united skulls are by no means always opposed. This is conspicuous in those rare forms in which partial rotation of the body axes occurs, in consequence of which the faces are turned toward opposite sides. Craniopagic monstrosities are rare and usually short-lived; an exceptional case of craniopagus occipitales, however, is reported as having survived ten years.

FIG. 4656.—Diprosopus. (Ziegler.)

The development of the united embryos may vary so that marked difference is presented in their general growth. This lack of correspondence may be so considerable that the one fœtus becomes an appendage to the more favored, giving rise to a very rare form of head-joined twins, known as *craniopagus parisiticus* (Fig. 4659). One individual is finally represented by a head, alone or in connection with part of the trunk, fused to the autosite, as the better developed fœtus may be termed.

(*b*) *Cephalo-thoracopagus*, or *syncephalus*, applies to posterior duplicities where the union is ventral or latero-ventral and involves the head and the thorax, the pelvic ends of the joined embryos remaining free. The early united twins pass through their development in common, each contributing its quota to the formation of the composite individual. Two faces are formed, each of which belongs half to each embryo. When they are exactly opposite and equally developed, the condition is known as *Janus symmetros*, one face looking ventrally, the other dorsally. More usually there is some lateral misplacement and unequal development as seen in *Janus asymmetros*, in which one face alone is well formed, the other presenting a pair of closely approximated ears. This discrepancy may result in cyclopia, synotia, or obliteration of the oral opening, as well as in suppression or fusion of various parts of the skull. The internal organs of syncephalic monsters present various degrees of union, corresponding in a measure with the extent of the external fusion. In general, however, the viscera retain their independent arrangement. The cerebral divisions may be fully represented, or the adjacent hemispheres may be fused, although the cerebelli, pontes, and medullæ are separate. The two hearts are often so disposed that one lies in relation to the common ventral, the other to the dorsal body surface.

FIG. 4657. Craniopagus. (Barkow.)

MIDDLE UNION.—The ventral or latero-ventral attachment of the embryos forming such malformations extends for a variable distance from the umbilicus upward, at times as far as the head; the pelvis, however, always remains uninvolved. The resulting anterior and posterior duplicity, with intermediate union, suggested the term *duplicitas parallela* applied to these monsters. The umbilicus is single, except in rare cases in which the cord is formed by short converging limbs from the two individuals.

THORACOPAGUS embraces two subdivisions of middle union involving the thoracic region: (*a*) *Xiphopagus* and (*b*) *Sternopagus*. The former presents an attachment at the xiphoid processes, the latter along the sterna of the two embryos.

Xiphopagus is characterized by a more or less extensive epigastric bridge which connects the opposed ventral or ventro-lateral surfaces of the two bodies. The inferior limit of the attachment is the common umbilicus, the upper being marked by the united, usually elongated, xiphoid processes. The thoracic cavities are entirely separate, and divided from the peritoneal sacs by intervening diaphragms. The two livers are usually connected by a bridge of hepatic tissue, although they may remain ununited. In the former case the peritoneal cavities may communicate. The digestive tubes may also open into each other in the vicinity of the stomach or small intestine; in other cases the canals remain entirely distinct.

FIG. 4658.—Craniopagus. (Sanne.)

In a number of xiphopagic twins life has continued for many years. The most noted of these, the Siamese Twins, Eng and Chang, attained the ripe age of nearly sixty-three years before their death in 1874. They were of Siamo-Chinese parentage, being born near Bangkok in 1811. The mother, thirty-five years of age, presented a remarkable predisposition toward multiple births, of the fourteen children which she bore ten being twins. Four daughters preceded the birth of Eng and Chang. The twins were united by a bond extending from the common umbilicus to the xiphoid cartilage, measuring three and one-quarter inches vertically. The connection was of greater length above (one and one third inches) than along its lower margin where it measured almost three inches. The circumference was nine inches, the bridge being broader above than below. Eng, the stronger and better developed of the two, was upon the right, Chang upon the left. Their bodies lacked symmetry, since the inclined and opposed parts were generally less well developed than those turned away. The opposed thoracic surfaces were lacking in rotundity, the outer exhibiting unusual fulness. Chang's chest was deflected to the left owing to marked lateral spinal curvature. The outer arms and legs were stronger than the opposed members

FIG. 4659.—Craniopagus Parasiticus. (Dönitz.)

The brothers were married when thirty-two years old and became fathers of large families, Eng having twelve and Chang ten children; of these twenty-two children all were normal except two of Chang's, who were deaf-mutes. Three years before Chang's death he was stricken with hemiplegia of the right side, from which he never entirely recovered. In January, 1874, Chang developed bronchitis which, aggravated by imprudent exposure, led to pulmonary oppression and inability to lie down without discomfort. After both had fallen asleep, Eng awakened to find his brother dead. Within a little more than two hours of this discovery Eng's death quietly ensued, consciousness being retained almost to the last.

FIG. 4660.—Cephalo-thoracopagus with Janus-Head; other face presented malformed eyes, nose, and mouth. (Hirst and Piersol.)

The autopsy disclosed the bond of union to consist, in addition to the integument, connective tissue, fat, and aponeuroses, of a bridge of hepatic tissue, three inches long, one-half inch wide, and one-quarter inch thick, which arose on both sides, directly above the longitudinal fissure. Two peritoneal pouches on each side, extended transversely until separated by a vertical median septum. Extensions of muscular tissue of both diaphragms were represented by a broad slip from Chang, which was inserted into ensiform process of Eng, and a similar but smaller band which passed to Chang, supplemented by two additional slips extending from Eng's diaphragm to that of Chang. The blood-vessels within the bond of union included a terminal and

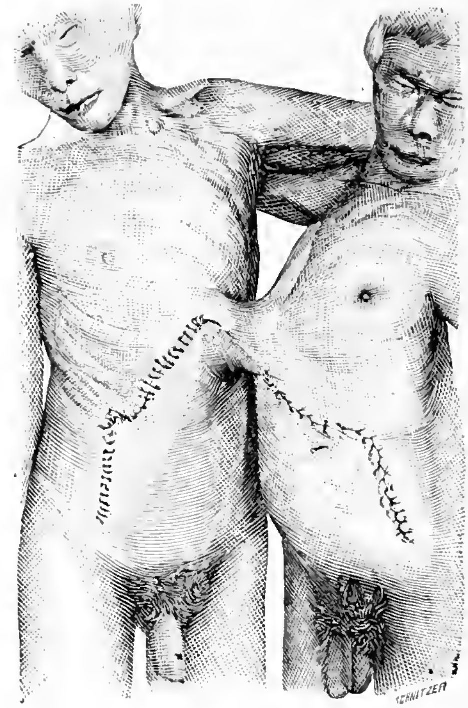

FIG. 4661.—Xiphopagus. "Siamese Twins." (Pancoast.)

an extrahepatic branch of the portal vein, branches of the hepatic artery, and some terminal twigs of the right internal mammary artery of Eng.

In this connection it may be of interest to note the operation undertaken by Prevost for the separation of the Brazilian xiphopagic sisters, "Rosalina" and "Maria." According to the letter published in the *Medical Record* (vol. lviii., 1900, p. 108) one sister, Rosalina, entirely recovered from the operation, the other succumbed.

FIG. 4662.—The Hepatic Isthmus across the Connecting Band of "Siamese Twins" Eng and Chang.

Sternopagus implies an upward extension of the attachment, so that the sterna are fused into a single bone at the upper border of the common thorax. In cases in which the union is very intimate, the manubrium may receive the four clavicles of the two individuals.

The hearts may remain distinct, or they may be fused to form a single tubular organ, from either side of which the great vessels are given off. When two hearts are present they usually are enclosed within a single peri-

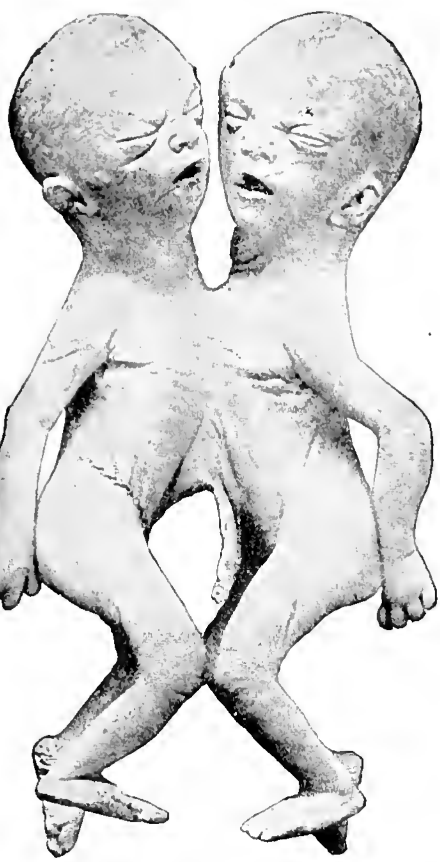

FIG. 4663.—Thoracopagus. (Hirst and Piersol.)

cardial sac. The common thoracic cavity is separated from the abdominal space by a single diaphragm. The middle portion of the digestive tube, including the greater part of the jejunum and ileum, is single. Above the jejunum, embracing the duodenum, the stomach and the œsophagus, and likewise below the position of the vitelline duct, the digestive canal is double. The livers are blended, more or less, into one common mass. The genitalia are separate and distinct, each body having its own set.

While the limb complement of the sternopagic twins may be normal, deviations from a ventral toward a ventro-lateral type of union, due to convergence of the spinal axes, sometimes result in the blending of the approximated upper extremities, the third arm thus produced being the joint contribution of the two embryos. Such limbs are sometimes very rudimentary. Sternopagi are usually born dead; if alive, they survive only a short time in consequence of their defective heart development.

MODE OF PRODUCTION OF DOUBLE MONSTERS.—Apart from the more speculative considerations of the causes leading to double monsters which have already been briefly sketched, the manner in which duplicities are formed calls for notice. Attention has been directed to the two prominent opposed views—fission and fusion—which have prevailed, and the arguments have been reviewed that have influenced the adoption of the fusion theory as offering the most plausible explanation of the production of double monsters. With the exception of the dicephali, in which dichotomous growth of the head end of the anlage may consistently be regarded as the mode of production, early union, more or less extensive, of the originally distinct but closely related, anlages seems most worthy of acceptance as the principle upon which double monsters originate. The accompanying diagrams have been suggested by Marchand as hypothetically illustrating the most plausible genesis of the anterior and posterior types of duplicity. In Fig. 4664, *A* represents the assumed early stage in which the two closely related anlages lie upon the common embryonic area, united to the chorion by the diverging belly stalks. With advancing development the latter become more widely separated, while the cephalic ends approach until they meet and union takes place; the umbilical vesicles meanwhile have become defined as two conspicuous sacs, one largely occupying the ventral surface of each embryo. The common amnion invests the dorso-lateral surfaces of both embryos and grows between their diverging belly stalks. *C* represents a later stage in which more marked fusion of the head ends has taken place, while at the same time the belly stalks are more widely separated, thus foreshadowing the later diomphalic or independent condition of the umbilical cords.

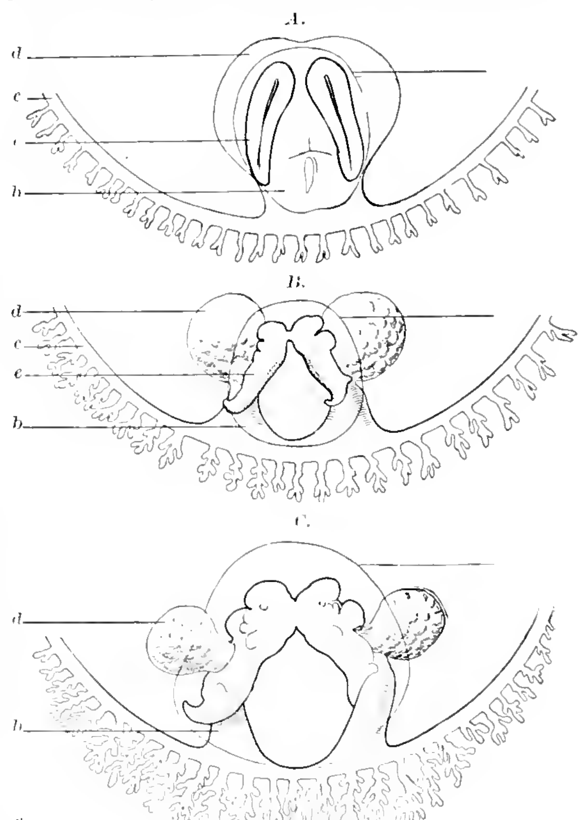

FIG. 4664.—Diagrams Illustrating Production of Hypothetical Double Monster with Anterior Union. Cephalopagus. *A*, The two embryos, on a common germinal area, are almost in contact with cephalic poles; united to chorion by closely placed belly stalks. *B* and *C*, later stages after union has been effected. *a*, Common amnion; *b*, belly-stalks; *c*, chorion; *d*, yolk-sac; *e*, embryo. (After Marchand.)

Rapid and extensive early separation of the belly stalks, together with rotation of the embryos, accounts for the various types of craniopagic twins.

In a similar manner the formation of the opposite condition of posterior union may be assumed to take place. (Fig. 4665.) The production of pygopagic twins, however, assumes the continued close relations of the belly stalk, with more or less divergence of the cephalic poles until, in certain cases, the axes of the two embryos correspond. The rotation and ventral type of union is associated with the retention of a common umbilical vesicle

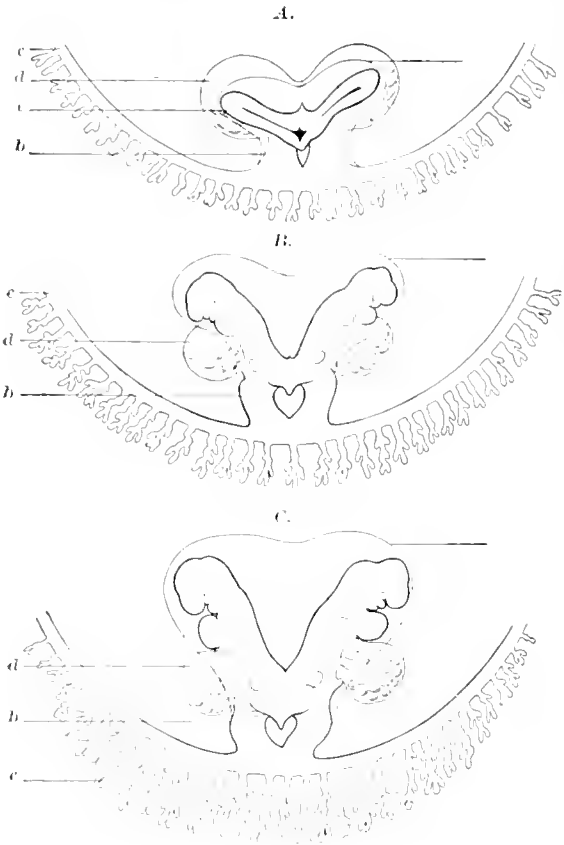

FIG. 4665.—Diagrams Illustrating Production of Hypothetical Double Monster with Posterior Union. Pygopagus. *A*, Very early stage; at caudal end primitive streaks fused into common tract; cephalic ends diverge. United embryos fixed to chorion by closely placed belly stalks. *B* and *C* later stages. *a*, Common amnion; *b*, belly stalk; *c*, chorion; *d*, yolk sac; *e*, embryo. (After Marchand.)

(vitelline sac) and single umbilicus. The assumption of these stages is hypothetical, and based upon theoretical possibilities rather than direct observation.

Multiplicities.

A systematic classification of pleural conceptions (including the cases of three, four, five, and possibly six at one birth) would call for the recognition of *complete* and *incomplete* multiplicities. The former again embrace the *monochorionic* group, of which the *equal* and *unequal* triplets are the best known representatives.

Monochorionic triplets are very infrequent, although a number have been described. The common chorion may enclose the three separate amnionic sacs, the umbilical vessels anastomosing within the placenta. Two authentic cases of monochorionic quadruplets have been recorded and an observation of five fœtuses within a common chorion has been credited to Pigné. Other instances of quintuplets have been reported, but these, as in the case reported by Kölliker, include the association of monochorionic triplets with similar twins. The example of plural births reported by Vassali in 1888 recording the extraction of six fœtuses, four males and two females, probably falls within this category. Kerr and Cookman have recently reported (*Medical Press and Circular*, May 27th, 1903) a remarkable case of six at one birth to which they were called. The mother, a native woman of Accra, West Africa, gave birth to five boys and one girl; all were alive when born, but succumbed between the second and fourth day. The girl and one boy had a placenta each, the remaining four children being attached to two placentæ. The mother, who recovered, exhibited a noteworthy predisposition toward pleural conceptions, three former pregnancies having yielded four, three, and three children respectively, making a total of sixteen in four confinements. The evidence sustaining a reputed instance of the birth of seven children, two boys and five girls, at Hameln in 1600, to which Barfurth[55] has called attention, is too uncertain to be convincing. Were the case satisfactorily authentic, here, too, the presence of more than one ovum and chorionic sac must be assumed as probable.

FIG. 4666.—Tricephalus. (Reina and Galvani.)

The occurrence of a malformed fœtus in company with two or even three others within a single chorion is extremely rare, only three trustworthy cases being recorded. That described by Soemmering presented four female fœtuses within a common sac, three being normal while the fourth was an acephalus.

FIG. 4667.—Dipygus Parisiticus. "Laloo." (Hirst and Piersol.)

Triple Monsters represent the rarest of all malformations. While a small number of such abnormalities have been observed among the lower animals, only a sin-

Fig. 4668.—Dipygus. (Hirst and Piersol.)

gle well-authenticated example of a human triple monster has been recorded by Reina and Galvani. The deformity was born in 1831, after a difficult labor lasting four days, necessitating the perforation and amputation of the first and second heads and the perforation of the third. Two spines were present bearing one and two heads respectively; the spinal columns were separate to their lower ends, although the sacra were very closely related. The pelvis included four iliac, two ischiac, and two pubic bones, the poorly developed medianly placed ilia being united by cartilage. The thoracic cavities were separated by a thin septum, each enclosing a heart. The abdominal cavity was large, the contained organs included a single stomach and an œsophagus that divided a short distance above its lower end; one of the resulting branches again divided, each head thus being provided with its own œsophagus. A similar arrangement was present in the trachea. The separation was apparent externally only on the neck and head, the unusually broad thorax seemingly being single. A third rudimentary upper extremity projected dorsally. The lower half of the body was normal, as were also the male genital organs.

The interpretation of the triplicity just described is to be found in the assumption that the anterior end of one of the primary anlages, which have undergone posterior fusion in the production of the ischiopagus, has been affected by dichotomous growth. The result of the latter is seen in the closely associated heads surmounting one spine.

Asymmetrical Duplicity.—Attention has been already called to the possibility that one of originally equal embryos which unite to form double monsters may suffer impairment of nutrition to such extent that its further imperfect development depends upon connections with the more fortunate mate. Such "parasites," therefore, result from secondary changes which affect embryos which were at first symmetrical. The continued nutrition and development of a part of the parasite, with the atrophy and disappearance of those parts less favorably situated, account for the remarkable cases in which a well formed head is attached to that of the autosite. In other instances the cephalic end of one embryo becomes atrophic and is drawn within the body of the other, surrounded by the ventrally closing parietal plates.

Mention may here be made of two conspicuous examples of asymmetrical duplicity. The one, "Laloo"—familiar to many on account of his museum notoriety—represents the type of unequally developed thoracopagus, termed *dipygus parasiticus*, or gastro-thoracopagus dipygus. The "parasite," attached from the umbilicus to the xiphoid process of his host, exhibited neither voluntary movements nor responded to Laloo's will. An anus is not present, but a small penis occasionally voids small quantities of urine. The other malformation (Fig. 4668) is a remarkable instance of the rare form of posterior duplicity known as *diphygus*. In the case figured the duplicity begins at the third lumbar vertebra. She was married and became pregnant on the left side, both sets of organs being, however, functionating. Micturition and defecation take place independently on the two sides, but menstruation occurs at the same time. Anterior fusion of two closely placed converging embryonic anlages probably accounts for this rare type of malformation.

The asymmetrical duplicities now to be considered include, on the contrary, the *true parasitic double monsters* which result from anlages in which primary inequality and subsequent asymmetry of form and size are characteristic features. The inequality of the anlages may be so marked that the parasite presents little or no external resemblance to a fœtus; in other cases the dependent embryo may develop parts, as extremities, which are fairly well formed. In addition to such external attachments, or *implantations*, other parasites exist as *inclusions* within the autosite, having been drawn into the latter by the closure of the body walls, or lying from the earliest stages within the mesoderm.

As introductory to the consideration of the rudimentary fœtal or parasitic growths encountered in various parts of the body, distinction must be made between der-

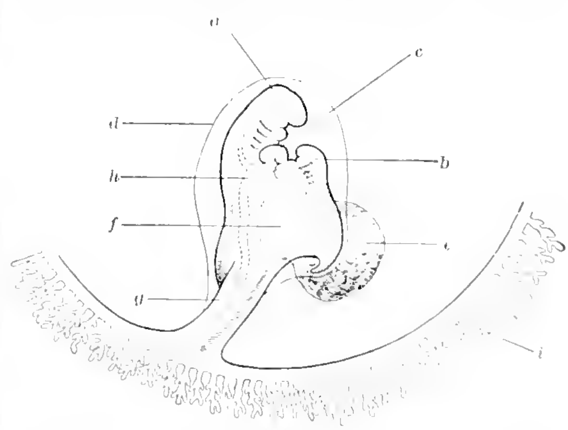

Fig. 4669.—Schematic Representation of Relations of Embryos of about Third Week in Production of Parasitic Duplicity. *a*, Autosite; *b*, parasite; *c*, heart of former; *d*, common amnion joining common yolk sac (*e*) around *f*; *g*, common belly stalk; *i*, chorion. (After Marchand.)

moid cysts, arising from invagination and displacement of portions of the elements from the neighboring skin, and the true parasite tumors or *teratomata* originating by differentiation of tissues from the three germ layers derived from the independent although imperfect development of a separate anlage. In the former case the tissues of the skin cyst include only those that ordinarily may

FIG. 4670.—Epignathus. (Ahlfeld.)

develop from the integumentary layers, their position being unusual owing to the dislocation of the aberrant cells ("Keimverirrung").

It is necessary, therefore, to recognize that simple dermoid cysts occur in many localities which may be the seats of true fœtal growths. The distinction between the latter and the simple skin cysts is by no means always easily made. In doubtful cases, in which evident fœtal structures are unrecognizable, the crucial test in establishing the parasitic nature of the growth is the presence of tissues and structures derived from all three germ layers, which cannot be attributed to transplantation of neighboring structures.

Although differing little in the principles governing their genesis, it is convenient for description to group parasitic duplicities according to the region of the autosite to which they are attached.

CEPHALIC PARASITES.—*Epignathus* is the term applied to a well-known group in which the rudimentary parasite is attached to the base of the skull or the palate and appears as a mass protruding from the mouth. The parasitic tumor is usually enclosed within an envelope of skin containing hair bulbs and sweat glands. When of small size, however, the tumor may lie almost entirely or wholly within the oral cavity, in which case a covering of mucous membrane replaces more or less completely the integument. The mass most frequently consists of cysts, cavities, and intervening slightly differentiated embryonal tissue. In other cases the tumor contains easily recognized fœtal structures, including perhaps skin, epithelium, hair, teeth, cartilage, bones, fat, and brain substance. Parts of a rudimentary intestinal canal, as well as normal hepatic tissue, have been found as constituents of epignathic parasites.

In contrast to the amorphous types are the rarer instances in which the parasite presents conspicuous fœtal characters, such as partly developed inferior extremities. Krentzmann[56] described an epignathus in which a tumor depended from the cleft hard palate of the autosite, being united by a stalk to the vomer and base of the skull. The tumor, the size of a fist and covered with hair, at one point bore an imperfectly developed set of external female genitalia, possessing labia majora and minora and a tube representing the vagina. These lay between two rudimentary lower extremities.

As a great rarity the parasite may be attached to the region of the orbit from which a tumor-like mass protrudes. Ahlfeld[57] has described and figured (Fig. 4671) a remarkable case of this kind in which a buttock and left lower extremity protruded from the left orbit of a well-formed child. In the vicinity of the left oral angle projected an additional tumor. Broer and Weigert[58] also record a case in which the right eyeball was connected with a tumor, the "size of an orange," that extended outward from the orbit. Microscopical examination revealed within the orbital fat the presence of cartilage, bone, epidermal masses, mucous gland cysts, portions of the digestive and respiratory apparatus.

Encranius embraces a group of fœtal inclusions in which the parasitic anlage lies partly or wholly within the cranial cavity of the autosite. Based on their mode of origin (see page 693) and the position of the anlage, as within or without the skull, the intracranial parasites may be divided into *primary* and *secondary inclusions*. The former undergo but slight development and remain rudimentary, appearing as irregular tumors attached often in the vicinity of the sella turcica or beneath the dura in other localities. The immediate neighborhood of the pituitary body is a favorite location, not only for dermoid cysts derived from aberrant cells which have gained the interior of the skull by means of the early invagination producing the oral portion of the pituitary body, but also for growths which contain rudiments of various tissues and organs. Beck[59] found a tumor, the size of a walnut, on the sella turcica which contained cartilage, bone, myxomatous tissue, cyst lined with ciliated epithelium, and fourteen teeth; structure resembling thyroid gland was also present. Such tumors may remain for years without further growth, as in the case recorded by Eberthr,[60] of a woman of seventy-five, in whom the teratome contained nervous, muscular, and lymphoid tissue.

It may be assumed that parasitic anlage, are drawn into the interior of the future skull during the early closure of the neural canal, to become later enclosed by the brain mass. Strassmann and Strecker[61] described a teratoma in the right lateral ventricle which probably thus gained early access from the dorsal surface. The tumor was of the size of a walnut, riddled with spaces, contained a cyst lined with simple and stratified epithelium, nervous

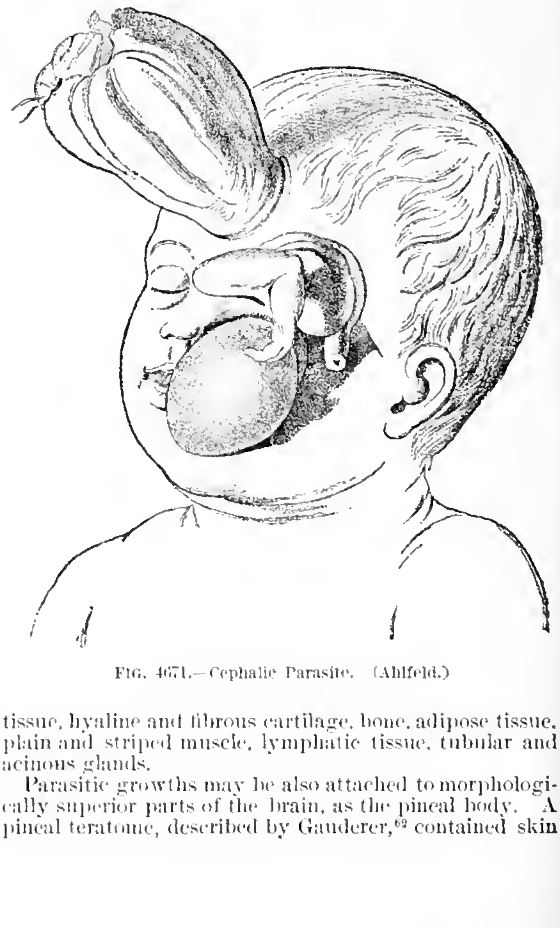

FIG. 4671.—Cephalic Parasite. (Ahlfeld.)

tissue, hyaline and fibrous cartilage, bone, adipose tissue, plain and striped muscle, lymphatic tissue, tubular and acinous glands.

Parasitic growths may be also attached to morphologically superior parts of the brain, as the pineal body. A pineal teratome, described by Gauderer,[62] contained skin and sebaceous glands, cartilage, bones, plain muscle, adipose tissue, and columnar epithelium.

The *secondary inclusions* may present externally fœtal characters, such as more or less developed limbs attached to a rudimentary trunk. The escape of the inclusion may be through the base of the skull into or beyond the mouth, the protruding mass then resembling an epignathus. In rare instances the parasite may project from the cranium of the autosite. Aretaos[63] described a very remarkable case in which, in addition to a rudimentary inclusion, an acephalic parasite protruded from the skull of the autosite.

Lovett and Councilman[64] have also recorded an instance of multiple inclusions in a child of three weeks, which presented a scrotal and intracranial teratoma containing representations of all three blastodermic layers.

The encranial parasites above described imply the production of more or less characteristic fœtal structures from the development of independent anlages capable of giving rise to all types of tissue. The inclusions from such anlages may, therefore, be regarded as true parasites, although they may remain rudimentary. To be distinguished from the latter are the intracranial dermoid cysts originating from the isolated and transplanted masses of epidermal elements, which ordinarily produce the prototypes of the tissues found within the intracranial growths. The latter should not be included within the true parasitic inclusions.

Cervical Parasites or Teratomata comprise the true fœtal inclusions attached to some part of the region formed by the visceral arches. Such parasitic growths appear as cystic tumors, covered with integument and extending a variable distance along the neck and lower jaw. In addition to the cysts usually present, the tumors contain more or less developed fœtal structures, including bones, teeth, parts of the head, and extremities. A cervical teratome in a child of two years, described by Brunker,[65] extended from the zygoma to the third rib and contained brain tissue, fat, cartilage, striated muscle, glands, and a rudimentary eye. Usually the seat of the growth is less extensive and is limited to the lateral cervical region. Instances are recorded of attachment to the parotid and the oral region, the latter cases forming a transition between the cervical and epignathic groups. Gurlt and Slomann both have described cases in which teeth were conspicuous; in one instance in a child of five years, both milk and permanent teeth were present and corresponded in form and size to the age of the patient.

Thoracic Parasites.—Closely associated with the teratomata of the cervical region are the dermoid growths occasionally encountered within the anterior mediastinum in the vicinity of the thymus gland or its remains. That the migration of this organ from its original relation with the third pharyngeal pouch to the mediastinal space is the probable means of transplantation of the primary tissues giving rise to the dermoids under consideration is suggested by the intimate relations between the outer and inner germ layers in the occluding membranes closing the visceral clefts in mammals. Although the primary thymus anlage is entodermic in origin, the proximity of the ectoderm lining the external furrows and the important changes in the relation of the arches effected by the formation, and later closure of the sinus precervicalis render the transportation of ectoblastic and mesodermic tissue in connection with the migration of the thymus highly probable. Additional evidence of close association is had in the presence of thymus tissue in cases reported by Marchand and by Pinders.

As shown by the series of forty cases tabulated by Christian,[66] the great majority of mediastinal dermoids are to be regarded as tumors of ectodermal origin, since of these cases only two can be classified as true teratomata, the derivatives of all three germ layers. These conclusions agree with the results of the studies of Pflanz[67] and of Wilms.[68] A few cases, however, such as recorded by Virchow,[69] Marchand,[70] Ekehorn,[71] and Fletcher,[72] give evidence of being true teratomata. The possibility of other congenital tumors of the lower anterior mediastinum being the result of inclusions at the time of the closure of the ventral body walls cannot be ignored, although a branchiogenetic origin is undoubtedly the more common. Extensions to the neighboring lung constitute the pulmonary dermoids sometimes described.

Although among the lower animals examples of parasitic anlages attached to the dorsal body surface are occasionally observed as rudimentary limbs projecting from

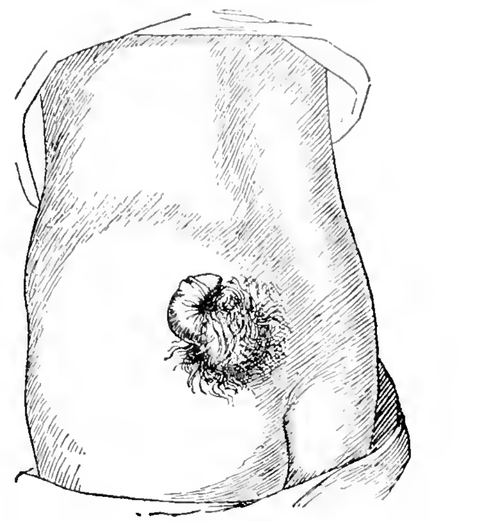

Fig. 4672.—Supernumerary Penis on Back. (Windle.)

the back, such malformations have not been encountered in the human subject. In this connection mention should be made of the remarkable case (Fig. 4672) described by Windle[73] of a young man who, in addition to normal genitalia, possessed over the lumbar vertebræ an elevation similar to a mons from which projected a small but well-formed penis, capable of erection, although imperforate. Windle refers to a somewhat similar case, recorded by Tsortis, of a soldier of twenty-one, who bore, below the left scapula, an almost complete set of female external genital organs. A small cavity between the labia resembled a rudimentary vagina, above which was a clitoris-like tubercle. These cases can be explained only on the assumption of the partial development of a second, originally independent embryonic anlage.

Sacral Parasites and Teratomata.—Of all forms of parasitic inclusions those occurring in the sacral and perineal regions are most frequent. They usually appear as cystic tumors attached to the sacrum, on either the anterior or posterior surface, or to the coccyx. The tumor is covered with integument directly continuous with that of the autosite, and consists usually of several cysts. Not infrequently the position of the teratome is not median, but to one side; in such cases often a second enlargement, consisting of a simple cyst, lies at the side of the larger nodulated parasitic growth, the two tumors sometimes occupying the opposite sides of the coccyx. Within the compartments of the teratome are found more or less striking evidences of its fœtal origin. These may include various epidermal structures and connective tissue, cartilage, bone, muscle, and nervous tissue, as well as parts of the spine, the digestive tract, and glands. In exceptional cases rudimentary extremities, both upper and lower, may be present and even free, being dependent from the tumor. In the classic and unique case of Anna Przenosly described by Ammon, in the third year a small congenital tumor opened and revealed a supernumerary leg which after seventeen years was removed by amputation. The presence of considerable masses of muscular tissue within the sac surrounding the inclusion may give rise to movements as in the two instances recorded by Preuss and by Ahlfeld. In the infant observed by the latter, the motion was produced by contractions of a sheet of striped muscle beneath the covering of the tumor and not by true fœtal movements.

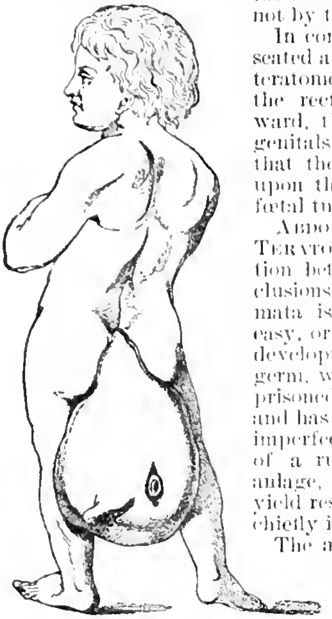

FIG. 4673.—Child with Sacral Tumor. (Löffler.)

In consequence of the deep seated attachment of the sacral teratomes, the perineum and the rectum are pushed forward, the anus and extended genitals being so displaced that they usually lie directly upon the anterior part of the fœtal tumor.

ABDOMINAL PARASITES AND TERATOMATA.—The distinction between true parasitic inclusions and embryonal teratomata is by no means always easy, or indeed possible. The development of an independent germ, which has become imprisoned at an early period and has undergone only a very imperfect evolution, and that of a rudimentary embryonal anlage, producing a teratoma, yield results which often differ chiefly in degree.

The anlage of the parasitic inclusion may lie, theoretically at least, embedded within the abdominal wall of the autosite, or it may be included within the body cavity. The entire number of adequately described and undoubted abdominal fœtal inclusions is small, probably less than forty. As an example of the very rare intraparietal type of inclusion the case mentioned by Himly [74] stands almost alone. Autopsy of a female child of two and one-half years revealed a cystic tumor in the epigastrium which contained a fairly well-formed fœtus, with, however, defective extremities and head.

The intra-abdominal inclusions, or *epigastric parasites*, are found most commonly in the vicinity of the lesser peritoneal sac, between the layers, or at the root, of the transverse mesocolon, being an especially favorite location. Since, as shown by Paquy,[75] the true fœtal inclusions always lie supra-umbilical and closely connected with the alimentary canal, Lexer [76] regards their usual intimate relation to the lesser peritoneal sac as due to migration induced by the increasing volume of the liver and the transverse displacement of the stomach. The fœtal parasite is usually enclosed within an envelope, composed of mesenteric or retroperitoneal tissue, to which the rudimentary embryo may be attached. Sometimes the fœtal characters are so well pronounced that spine, head, and extremities are recognizable; in other cases only rudimentary organs are present. The sac surrounding the inclusion is closely united with the adjacent organs, the blood-vessels of which communicate with those of the parasite and provide for its nutrition. Not infrequently the rudimentary fœtus exhibits distortion, the result of progressive mechanical disturbances as well as of faulty development. Under such conditions the inclusion may become pressed into a shapeless mass.

Spontaneous movements have been noted within the cyst containing the parasite. Klebs [77] describes a case of an infant in which independent motions were noted within an abdominal tumor. The child died a few weeks after birth, and presented, on post mortem examination, a cyst composed of peritoneum and amnion beneath the transverse colon. An artery passed from the aorta of the host to the cyst and thence by a short umbilical cord to the parasite. The latter was of an irregular ellipsoidal form and consisted of an imperfect spine and pelvis, a skull of considerable size containing a distinct brain mass, a digestive tube with unusually wide, large intestine, a liver, and rudimentary lungs and heart. The extremities were represented by poorly developed and stunted limbs. External genitals were absent.

Another remarkable instance of abdominal fœtal inclusion is the classic case recorded by Highmore.[78] The subject, when a boy of seven, developed a marked abdominal swelling attended with severe pain. Succeeding a period of temporary relief until the fifteenth year, the distress returned, death occurring in consequence of intestinal hemorrhage. During life marked pulsations were recognizable in the tumor, sensitive on pressure; the movements were felt by the patient, who declared that his abdomen contained something living. The autopsy disclosed an irregularly oval, sack-like tumor, weighing over four pounds, attached along the entire extent of the duodenum, which freely communicated with and formed a part of the sack. The latter contained an imperfect fœtus with stunted trunk, two upper and one lower extremities, and a very rudimentary head consisting of scalp to which hair a foot long was attached. The nutrition of the parasitic fœtus was maintained by a short cord which established the connection with the vascular walls of the sack.

Ballantyne [79] describes an abdominal teratoma in a child of three months, the parasite being connected with the lesser peritoneal sac. At one point there was a projection resembling a pair of rudimentary digits; pieces of intestine, teeth, and fragments of bone and cartilage were also present. Paquy records a somewhat similar case in which the omentum was occupied by a tumor consisting largely of cartilage, glandular elements, and abundant blood-vessels.

Although children bearing fœtal inclusions are often still-born, the possession of the parasite is not incompatible with prolonged, and even extended, life, since such inclusions have been discovered in subjects of advanced years. Usually, however, the presence of the parasite induces, after a time, fatal peritonitis.

EMBRYONAL TUMORS OF THE SEXUAL GLANDS.—The sexual glands are the seats of fœtal tumors of great interest by reason not only of their relative frequency, but also of the interesting problems concerning their production. Disregarding for the present the latter, these tumors may be divided into *cystic dermoids* and *teratomata* according to their consistence—sac-like or solid respectively—and the degree of development which they present.

FIG. 4674.—Sacral Teratoma Containing Extremities (*a*, *b*, *c*) of Parasite. (Ziegler.)

Ovarian cystic dermoids, the more common variety of the first group, appear as tumors varying in size from a pea to a child's head. These consist of a tough-walled sac enclosing a fatty mass and hair. The seat of the dermoid is nearly always the sexual gland, the tumor being attached to the adnexa of the uterus by broad adhesions. The ovarian tissue immediately surrounding the growth usually undergoes partial or complete degeneration, although in exceptional cases the dermoid may be almost isolated and connected with the ovary by only a slender stalk. Wilms [80] has established the important fact, confirmed by a number of competent observers, that the embryonal tumors of the sexual glands contain derivatives of all three germ layers, and further, that the development proceeds in general, although modified, in a way similar to that followed under normal conditions.

The inner surface of the dermoid cyst at some point exhibits a projection, villous or less abrupt, which usually bears hairs and also not infrequently teeth. While the more superficial layer of the projection contains the constituents of the integument, including hair follicles and sebaceous and sweat glands, the deeper parts may enclose cartilage, bone, muscular tissue, nervous substance, mucous glands, or suggestions of the digestive and respiratory tubes. Rudimentary mammary glands with nipples, fingers with nails, and retinal pigment are among the rarer additional organs that have been observed in ovarian dermoids. Hepatic, renal, and cardiac tissue, on the contrary, are among the few structures not represented in these tumors. The explanation of these exceptions, as suggested by Wilms, lies in the early assumption by the autosite of the nutrition of the parasitic embryo, which results, after a possible abortive effort at heart formation, in a very imperfect independent circulatory apparatus. In consequence of this relation there is no necessity for the formation of excretory organs, hence the liver and kidneys remain undeveloped and are never found.

Although most frequently encountered in middle life, ovarian cystic dermoids occur at all ages from early childhood to extreme old age.

Ovarian teratomata, or solid tumors, are of much greater rarity than the cystic dermoids. As the latter, so also the teratomes always contain the representatives of all the germ layers. The tissues and rudimentary organs, however, present much less regularity in order and arrangement and hence less resemblance to the fœtus on account of their confused and indefinite disposition and generally less perfect development. These characteristics are due to the mechanical disturbances induced by limitations of space, in consequence of which there follows a displacement of the cells resulting in loss of relations in the anlage and the institution of a process of tumor formation. As shown by Wilms,[81] the solid ovarian teratomata correspond in genesis with the cystic dermoids and differ only in the degree to which the fœtal structures are developed. In view of the slight resemblance that these growths bear to the normal products of conception, Wilms has appropriately named them *embryonoid tumors*.

The *fœtal growths of the testicle* constitute a group homologous with those of the ovary already discussed, in conjunction with the latter forming the distinct class of rudimentary parasites of the sexual glands. Wilms conclusively proved that these growths originate from the testicle and correspond in all important features with those of the ovary. As in the latter so also in the testicle dermoid cysts and solid teratomes both occur; in the male gland, however, in contrast to the female, the cystic dermoids are of extreme rarity, the solid tumors being the form usually encountered. Even these are of great infrequency when compared with the ovarian teratomata. As pointed out by Wilms,[82] in the testicle the conditions favorable for the development and growth of fœtal structures are seldom present on account of the anatomical construction of the organ and its position, hence the formation of rudimentary parasites but rarely takes place, the solid embryonoid tumors being the usual expression of the repressed development.

Dermoid cysts of the testicle, although of great infrequency, occasionally present marked fœtal characters, as in the remarkable case reported by Répin[83] in which an almost complete skeleton, with four limbs, was present. The more usual teratomes evince their embryonal nature by the presence of tissues derived from the three germ layers rather than by an orderly disposition suggesting parts of a fœtus.

These tumors vary greatly in size, the largest being in volume equal to a child's head. They may be entirely solid or contain cysts which may be lined by simple or stratified cuboidal or cylindrical epithelium; in rare cases pigmented as well as glandular cells have been found. The derivatives of the mesoblast are conspicuous in these tumors, being represented often by considerable masses of connective tissue and cartilage, less frequently by bone; adipose and muscular tissues are also not uncommon. The teratomata of the testicle, therefore, are usually met with in the form of adenocystoma, chondroadenoma, chondrosarcoma, adenorhabdomyoma, or other type of composite tumor.

The studies of Wilms leaves no doubt that these teratomata are to be regarded as imperfect expressions of an independent development, and that they in principle are to be regarded as extremely rudimentary parasitic malformations modified by the influence of mechanical disturbance.

Origin of Parasitic Duplicities.

The condition of true parasitic duplicity, as distinguished from dependence secondarily acquired by one of the united twins in consequence of unfavorable conditions of development, implies *primary inequality* of the anlages.

In all forms of double monsters the allantoic circulation of one individual may become impaired or interrupted to such extent that the affected embryo succumbs unless its nutrition is assumed by the more fortunate mate. The donation by the latter may so far suffice that a considerable part of the dependent embryo is maintained, thereby producing such striking forms as "Laloo." When, on the other hand, the union is cranial and the donated nutrition insufficient, only the cephalic end may remain, as in the classic case of Home, in which a well-developed head, attached to the vertex of the autosite, alone represented what was at one time a complete embryo.

The secondary and acquired nature of such parasites is conclusively demonstrated by the presence of the remains of an atrophic umbilical cord attached to the trunk. Since the nutrition of the affected embryo is early assumed by the stronger, the heart of the former atrophies, although instances have been noted in which the hearts of both parasite and autosite have existed within the thorax of the autosite.

The true parasitic duplicities are from the first conspicuously asymmetrical, the dependent embryo being rudimentary or incompletely developed, and more or less enclosed by the body of the autosite. These inclusions present two groups: (*a*) those which are partially surround and hence appear as an external appendage to the host, or are drawn within the body and lie beneath the integument of the autosite; (*b*) those which develop entirely within the autosite, especially in relation to the abdominal cavity. Examples of the first group are seen in the epignathi and the sacral tumors; of the second in the ovarian dermoids.

The exact manner in which the weaker and rudimentary anlage becomes surrounded by the stronger can only be surmised, but it may be assumed with probability as intimately related with the migration of the external layer of the autosite which takes place in connection with the invaginations and the closures incidental to the normal development of the stronger embryo. Such closures occur at the cephalic pole and along the dorsal and ventral surfaces, while the primary oval and branchial invaginations are additional means of transportation. We may reasonably conceive the anlage giving rise to the future parasite as being fixed to the surface and within the amnion of the autosite in the immediate vicinity of such migratory areas; subsequently it is carried within the body and more or less surrounded by the tissues of the autosite to produce a true fœtal inclusion, or *fœtus in fœtu*.

The production and relations of an epignathus or encranius can be clearly referred to the inclusion of anlages which have suffered displacement during the formation

Teratology.

of the primary oval invagination and of the brain case respectively. In other cases, however, the location of the fœtal inclusion is probably acquired secondarily in consequence of changes occurring during development, as in the case of sacral teratomata on the ventral aspect of the sacrococcygeal region in which the anlage was

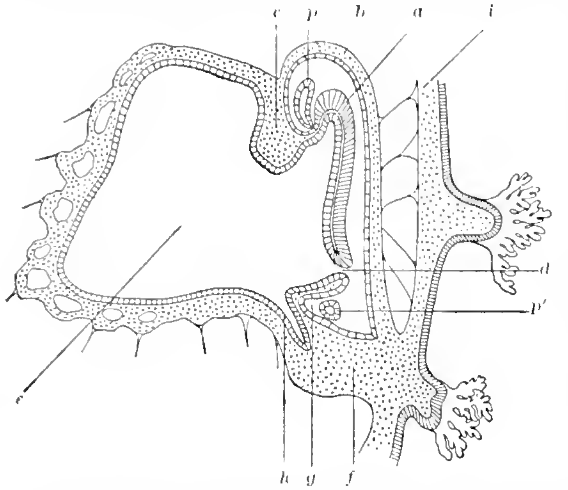

FIG. 4675.—Schematic Representation of Relations of Parasitic Anlage in Epignathus (*p*) and Sacral Teratoma (*p'*), based on sagittal section of Spee's early human embryo. *a*, Neural plate; *b*, amnion; *c*, heart area; *d*, neurenteric canal; *e*, umbilical vesicle; *f*, belly-stalk; *g*, region of anal membrane; *h*, allantoic duct; *i*, chorion. (After Marchand.)

primarily attached in the vicinity of the hind-gut and carried ventrally by the flexure of the autositic axis.

In contrast to the primary independence of the nutritive apparatus of both embryos in the case of parasites arising from symmetrical double monsters, the rudimentary anlages producing true fœtal parasites present little evidence of having had separate chorionic attachments. It is doubtful whether such parasites ever possess rudiments of true umbilical cords or allantoic attachments, notwithstanding their reported presence in certain cases.

In attempting to arrive at some conclusion regarding the vexed question concerning the origin of the rudimentary anlage producing the parasite, it may be assumed that the latter represents the development of a germ-cell or cell mass that progresses independently in the earliest stages, although later dependent for its nutrition upon the autosite. Reviewing the established facts relating to the origin and early changes of the ovum leading to the formation of the blastoderm from which the embryo proceeds, two possible sources of the rudimentary anlage may be suggested that are not incompatible with the known facts of embryology. These are: (1) that the rudimentary anlage may be the product of the imperfect development of a fertilized polar body; (2) that the parasite may arise from the differentiation of a special or an isolated group of segmentation cells.

The significance of the polar bodies as abortive or rudimentary ova, liberated during the process of maturation of the female sexual cell, is admitted by all. These rudimentary ova, the polar bodies, contain the same morphological constituents and therefore the same potentialities as the larger matured oöcyte, only in diminished force. Usually the polar bodies remain for a time beneath the egg envelope, or zona pellucida, closely related to the early segmentation spheres, later disappearing.

Since the occurrence of segmentation and formation of the blastoderm in vertebrates implies the development of a fertilized ovum—a true parthenogenetic development not occurring among the vertebrated animals—it is of interest to note that in addition to the direct observations of Platner and of Kostanecki on the fertilization of the polar bodies of lower forms, the older observations of Bischoff, proving that in the segmenting ovum of mammals (rabbit, dog) the living spermatozoa may exist beneath the zona pellucida in the vicinity of the polar bodies, have been confirmed by Assheton[84] and by Bonnet.[85] In view of these investigations it is highly probable, at least not improbable, that in exceptional cases the polar body may undergo fertilization and enter upon a development which may produce a small blastodermic vesicle and rudimentary anlage capable of giving rise to the parasite. The anlage so arising lies closely related to the blastoderm developed from larger egg. When that derived from the polar body retains the usual primary relations of the latter it will lie in proximity to the first plane of cleavage, which corresponds with the later axis of the embryo as established by the notochord and the medullary furrow. Since the last-named structure becomes the neural tube, it is evident that the rudimentary anlage may become attached in the vicinity of the medullary folds and be drawn within the larger embryo to become an encranius. It is, however, well established that the polar body may lie in relation to other portions of the segmenting mass and hence become attached to various parts of the larger anlage. When related to the ventrally approximating somatopleuric folds, the rudimentary anlage may be enclosed within the later abdominal walls or carried into the body cavity to form an inclusion.

The possibility of the rudimentary anlage being early included between the segmentation cells of the larger anlage has been shown by the observation of Assheton on the rabbit in which the polar body was found between the blastomeres. Assuming that the ferilized polar body suffers such displacement it follows that the resulting rudimentary anlage may obtain later an intramesoblastic position and may become an inclusion in some deeply seated organ, including the sexual glands. In such manner the existence of the ovarian dermoids and the teratomata of the testicle find a plausible explanation.

The important fact that the embryonoid growths of the sexual glands consist of derivates of all three germ layers was emphasized by Wilms in the papers already quoted. Other investigators, including Pfannenstiel, Krömer, Mertens, Arnsperger, Franzen, and Emanuel, have confirmed these views, which may be regarded as established. Bandler,[86] however, challenges these conclusions and denies that the entoblastic derivatives take part in the formation of these growths, the origin of which he attributes to possible cell dislocations occurring during the complex development of the Wolffian body, kidney, and sexual glands. The formation of such growths implies development of a sexual cell. The necessity of accounting for such process has led to many theories as to the possibilty of development proceeding from sexual cells within the ovary and testicle without the influence of the male element. The well-known existence of parthenogenic development among certain invertebrates suggested the possibility of the occurrence of a similar process in the higher animals; parthenogenesis, therefore, has been accepted as an explanation of the congenital tumors of the sexual glands by many authors, some going to such length that they accept the radical proposition that the sexual cells within the testicle are capable of producing the teratomes of that organ. Additional support for such views has been claimed from the interesting experiments with unimpregnated eggs of certain invertebrates which under particular conditions undergo cleavage and attempt the earlier phases of development. Somewhat analogous changes have been observed in the ova of vertebrates resulting in an imperfect segmentation, or more accurately "fragmentation." The conclusion of Bonnet,[87] that there is no justification for assuming the occurrence of parthenogenesis among the vertebrates, may be accepted as a reliable verdict founded upon an exhaustive and critical review of the evidence presented by the literature of this interesting problem.

Beard[88] has suggested an explanation of the congenital tumors of the sexual glands, as well as of other regions, based upon his investigations on the early embryos of the skate. In these he found that particular blastomeres are very early set apart for the formation of the sexual cells of the embryo and take no part in its general development. The descendants of these special *primary germ-cells* constitute the sexual elements of the ovary and the testicle. Beard regards the embryonal tumors as derived from aberrant members of this group of primary germ-cells, which differ from the generations of secondary germ-cells, represented by the ova and the spermatozoa, in not having undergone the cytological changes incident to maturation, extrusion of the polar bodies, and reduction of chromosomes. The primitive germ-cell, as Beard regards it, is the sister, not the derivative, of the embryo, and therefore capable of giving rise to a rudimentary twin — the included parasite or embryoma. As Beard admits, he establishes only the existence of the vagrant primary germ-cells and does not explain their spontaneous development. He regards these cells, however, as endowed with an inherent potentiality which may institute independent formative processes, so that "neither a congregation of germ-cells nor a parthenogenetic development of such is needed to account for dermoids."

A possible source of the rudimentary anlage producing the parasite has been suggested by the interesting experiments relating to the development of separated segmentation spheres, carried out by various investigators during the last decade. The observations of Driesch, Born, Wilson, Morgan, O. Hertwig, O. Schultze, Herlitzka, and others, have shown that artificially separated segmentation spheres may develop into perfect although small embryos, the size, within certain limits, being determined by the proportionate value of the isolated cells to the entire segmentation mass. The observations of Roux [69] upon young frog larvæ seem to warrant the assumption that groups of segmentation cells may become disconnected and displaced and finally enclosed within the derivatives of the blastodermic layers. Bonnet assumes, and with reason, that such inclusions may later undergo further differentiation and become congenital fœtal growths. Coley and Buxton conclude, after reviewing the various theories, that the separation of segmentation cells offers the most satisfactory explanation.

There are, therefore, two plausible sources for the rudimentary anlage producing the parasite, the one being the fertilization of an abortive ovum (the polar body), the other the tardy differentiation of a group of vagrant segmentation cells. There seems no reason for regarding either of these possibilities as the exclusive mode of production, and it may be assumed with probability that both methods may contribute to the various types of parasitic duplicity. The observed attempts, in certain instances, at the formation of imperfect fœtal membranes may be related, possibly, with an origin from a fertilized polar body, the development of which abortive ovum would be more favorable to the formation of such structures than that of included segmentation spheres.

The foregoing considerations emphasize the common origin of cystic dermoids and teratomes of the sexual glands and of other fœtal inclusions, the sharp lines drawn by Wilms being justly regarded by Marchand and by Bonnet as unwarranted.

The causes determining the period at which the fœtal inclusion shall develop within the surrounding tissue remain unknown. In general it may be assumed that conditions affecting nutrition and tissue activity are responsible. The fact that the ovarian inclusions usually develop during the period of sexual activity may be attributed to the stimulus incidental to the well-known periodical congestion of the ovary and associated parts. On the contrary, the fact that teratomata of the testicle are more frequently encountered in young subjects may be connected with the more favorable conditions of active nutrition presented by the young organ than during the later years where the imprisoned anlage suffers compression and arrest.

Malformation of the Organs.

The malformations described in the foregoing pages are the expression of influences affecting more or less profoundly the entire organism; it remains briefly to discuss the more limited developmental defects that are encountered in the individual organs.

Defects of the Cerebro-Spinal Axis.—The early appearance, exposed position, and delicate walls of the neural tube render it especially liable to unfavorable influences affecting its growth which result in malformations of the spinal cord and brain and their membranous and bony envelopes.

It will be recalled that the cerebro-spinal nervous axis is the direct transformation of the neural tube, the latter first appearing as a groove along the dorsal surface of the early embryo. The ectodermal medullary folds bounding the intervening neural groove approach and gradually convert the furrow into the neural tube, the expanded cephalic segments of which form the brain vesicles. Following the closure of the neural tube by fusion of the medullary folds, the surface ectoderm becomes separated from that lining of the neural tube by the ingrowth of the surrounding mesoderm. The latter subsequently undergoes differentiation into the meninges and the vertebral column and brain case. Each segment of the spine, consisting of a body and a pair of neural arches, is developed within the mesoblast, supplied by the somites as the skleratome, from three chief centres. The latter are: one for the body and one on each side for the corresponding half of the arch. Failure of the arches to unite dorsally in the midline may result in a more or less conspicuous cleft associated with developmental disturbances of the spinal cord and its membranes.

Defects Caused by Imperfect Closure of the Spinal Canal.—Clefts of the vertebral canal may be divided according to their relations with the exterior into two chief groups, *open* and *covered*. The former, termed *rachischisis*, present an open furrow-like defect at the bottom of which may be seen the vertebral bodies. The covered clefts are distinguished by the presence of a more or less prominent sac, hence the names *spina bifida cystica*, or *rachischisis cystica*, by which this group is properly known, although the less specific term *spina bifida* is often used instead. Both forms of cleft may occur in any part of the spine, and may be limited or very extensive.

Rachischisis.—The deformity included under this name is due to faulty development and imperfect union of the neural arches. When well marked it appears as a widely open groove bounded by rudimentary processes on each side representing the imperfectly formed arches. The skin being absent, the vertebral bodies are covered by the dura and the ventral portion of the pia, with, perhaps, remains of the atrophic spinal cord and the associated nerves. The cleft may involve the entire canal (*holorachischisis*), and is then frequently associated with an analogous defect of the skull; or it may be limited to one part of the spine (*merorachischisis*). The usual seat of the latter defect is the lumbo-sacral region, although clefts in the cervical portion of the spine occasionally occur. The intervening thoracic region is seldom involved. Rachischisis is usually attended with spinal curvature; the total and cervical clefts are associated with lordosis and those of the lower segment with kyphosis. In the latter cases, other profound defects of the ventral body wall, as eventration or ectopia of the bladder, are often also present.

Viewed from behind, the centre of the defect is occupied by a soft red membrane; this represents the flatly expanded pia enclosing the remains of the rudimentary spinal cord which has succeeded the unclosed neural tube. When the rachischisis is total, the cord is practically absent (*amyelus*); when less extensive, the cord may be present as a plate-like strip of loose, highly vascular tissue fused with the pia. This mass, the *area medullo-vasculosa*, may form a continuous structure, or be broken up into a delicate veil-like tissue. Remains of nerve cells and nerve fibres may be recognizable. At its margin the central area becomes continuous with the surrounding integument, the epidermis of the latter extending for a variable distance upon the pia. This boundary ring is

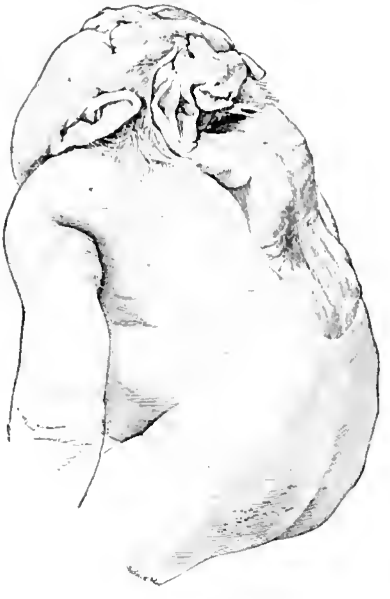

FIG. 4676.—Cranio-rachischisis with Absence of Brain and Spinal Cord. (Ziegler.)

termed the *zona epithelioserosa*, outside of which lies the *zona dermatica*, as the thicker margin of the surrounding integument is called.

The ventral relations of the meninges are more normally preserved, the anterior part of the subarachnoidal space being represented by the cleft between the pia and the subjacent arachnoid attached to the dura. This space sometimes becomes distended by accumulation of fluid. The rudimentary spinal nerves are attached to the ventral surface of the vascular membrane and may at times be followed into the atrophic nervous mass. In rare cases the vertebral bodies themselves may be imperfect and cleft, thereby giving rise to *rachischisis anterior*.

Spina Bifida Cystica.—The covered forms of spinal cleft are distinguished by the presence of a cyst, which protrudes through the fissure in the spine, and is externally evident as a saccular protrusion of variable size. Depending upon the structures involved, these defects are divided into three chief groups: (1) *myelomeningocele*, in which both the spinal cord and its membranes are included within the sac; (2) *meningocele*, in which only the spinal membranes compose the cyst; (3) *myelocystocele*, in which the spinal cord itself undergoes dilatation.

Myelomeningocele of the lumbo-sacral region is the most common form of spina bifida; much more rarely are the cervical and thoracic segments of the spine the seat of this defect. In rare cases the entire sacral region may be involved. Usually a rounded tumor, varying in size from a nut to an apple, appears in the midline about the juncture of the lumbar and sacral regions. When the child survives, it gradually increases and may attain the dimensions of a child's head.

The tumor is fluctuating, tense, and elastic, and often overhangs the lower margin of the cleft. When entirely covered by skin, the latter is attenuated and frequently cicatricial in appearance. More usually, however, the most prominent surface of the tumor is wanting in integument and invested by a smooth, soft, vascular membrane which is separated from the surrounding and elevated skin by a sharply defined boundary zone, covered with epidermis, and of a pale or bluish tint. The central part, uncovered by skin, is usually somewhat sunken and corresponds to the *area medullovasculosa;* the *zona epithelioserosa* and *zona dermatica* mark the intermediate and outer tracts of the tumor respectively. Pressure during labor, or the increasing tension following growth, may affect the nutrition of the integument and give rise to ulceration or gangrene, which results in perforation, destruction of the sac, or secondary cicatrices.

The defects of the skeleton include arrested development of the spinous processes and adjacent parts of the neural arches, the deficiency being most marked in the vertebræ contributing the lateral boundaries of the cleft. The latter may be limited to two, or even a single lumbar vertebræ; usually it involves the upper part of the sacrum, and may extend as far as the sacral fissure.

The spinal cord is commonly bent strongly backward and attached to the middle or upper part of the sac, the associated spinal nerves being correspondingly displaced. When the fissure lies near the lower end of the spine, the extremity of the cord may be drawn entirely into the sac, ending possibly in a flat expansion and without a conus. In many cases the cord extends lower in the spinal canal than normal. The pial investment is complete, and, in conjunction with the arachnoid, forms the sac enclosing the spinal cord; the dura, due to its imperfect development in association with the defective vertebræ, is always absent over the most prominent part of the tumor. In the much rarer and usually smaller thoracic and cervical examples of myelomeningocele, the spinal cord commonly protrudes less from the vertebral canal, being attached to the sac by a band-like fold. In exceptional instances the sac may escape through a ventral fissure, then constituting the rare defect *myelomeningocele anterior*.

Meningocele, in which the cyst is formed by the spinal membranes alone, occurs less frequently than sometimes assumed, since ordinarily the protruding membranes are closely associated with displaced nervous tissues. Uncomplicated spinal meningocele is encountered almost always at the lower end of the spine, the defects at the upper end of the column existing commonly in conjunction with hernia of the brain membranes.

The opening through which the meninges escape is not necessarily a posterior median cleft, since the sac may at times protrude between the arches, or through the intervertebral foramina or the sacral canal; rarely imperfections of the vertebral bodies allow the escape of the membranes anteriorly.

The sac of the meningocele appears oftener at the side, or downward, than in the midline. Since this defect is less unfavorable to prolonged life, the tumor not infrequently attains considerable dimension, at times increasing from the size of a hazelnut at birth to that of a man's head. The fluctuating cyst, filled with clear fluid, is covered with integument that may differ little from that of the surrounding parts; in other cases it may be tense and even gangrenous and rupture when subjected to unusual pressure. The wall of the sac consists principally of the abnormally distended arachnoidal supplemented by an imperfect dural layer which blends with the integument. The cavity of the cyst presents a smooth inner surface and communicates with the spinal subarachnoidal space; it is sometimes traversed by one or more spinal nerves, which otherwise run in the cyst wall, and may be secondarily subdivided into several compartments.

Myelocystocele or *syringomyelocele* implies a local dilatation of the central canal of the spinal cord, in consequence of which a larger or smaller segment of the cord, with the surrounding pia and arachnoid, becomes converted into a cystic tumor. The dura does not extend beyond the spinal canal. Since the sac represents the enormously dilated central canal, its lining consists of the ependyma cells and is, therefore, a layer of cylindrical epithelium. The remains of the compressed and atrophic nervous matter are seen on the ventral wall of the cyst as an area medullovasculosa to which rudimentary nerve roots may at times be traced.

Myelocystocele is often associated with lateral fissures and asymmetrical defects of the spine, especially shortening of the trunk. It may occur in any region, and is sometimes connected with anterior vertebral clefts.

When the dilatation of the cord is associated with distention of its membranes, the condition is termed *myelocystomeningocele*, a defect that may, when extensive, be mistaken for myelomeningocele. The differential diagnosis can be made by observing the character of the lining of the cyst, cylindrical cells being never found unless the sac is derived from the central canal of the cord.

Spina bifida occulta is the term applied to cases in which neither a cleft nor cystic tumor is externally visible. Such masked defects are usually of small extent and of sacral or lumbo-sacral origin. The position of these hidden imperfections is often indicated by a somewhat depressed or cicatricial area, or by a small cutaneous tumor. In other cases an unusual tuft of hair alone marks the location of the deeply seated defect, which on pressure may be detected as a minute opening in one or more vertebræ. In the cases carefully studied the greatly elongated spinal cord extended into the sacral canal and was connected with the external soft parts by a fibrolipomatous mass. The spinal canal may, however, be dilated by the presence of such tumor, and the nerve roots forming the cauda equina may be unfavorably affected, resulting in considerable motor and sensory disturbance in one or both lower extremities. Paralytic club-foot and derangement of the functions of the bladder are among the consequences of these defects of the neural canal and its contents.

Doubling of the spinal cord (*diastematomyelia*) is an occasional accompaniment in rachischisis, more rarely in myelomeningocele; the duplicity consists in the cleavage of the immature cord, which is then represented by two usually atrophic or rudimentary bands, seldom by nervous cords of more perfect development. The presence of a thorn-like spur or process in certain cases suggests that the doubling of the cord may sometimes depend upon mechanical disturbance.

The *genesis* of spina bifida was formerly regarded as closely related to an accumulation of fluid within the spinal canal leading to rupture of the distended sac. Such origin of the defects under consideration is now generally considered untenable. The present views, however, are far from settled. According to v. Recklinghausen, whose classic investigations have greatly advanced our understanding of spinal clefts, the defective median union is occasioned by inadequate development, or aplasia, of the spine, due to deficient growth of the blastoderm as a primary cause. The observations of Tourneux and Martin, on the other hand, point to an incomplete separation between the medullary folds and the adjacent ectoderms as the immediate factor, in consequence of which the lips of the neural groove never become united. The surrounding mesoblastic tissue, the skleratome, in which the vertebræ develop, fails to produce arches which unite. Ziegler inclines to the view that the defective or arrested development is due to a "primary agenesis" affecting the germ, regarding the symmetry of the malformation as evidence opposed to the assumption of mechanical impressions from without. The marked differences in these defects as to the extent, situation, and details suggest the probability that their mode of production is by no means always the same. In complete rachischisis the rudimentary condition and incomplete separation of the medullary folds which preclude the closure of the neural groove not unlikely are associated with abnormality or excessive narrowness of the amniotic sac, whereby the arrested growth and nonunion of the medullary folds are favored. The explanation of the favorite location of myelomeningocele in the lumbo-sacral region is found in the fact that this part of the spine not only corresponds to the area in which closure of the neural canal is longest delayed, but is also subject to the disturbing influence of a too closely applied amnion, on account of the flexure which here is more pronounced than in the thoracic segment. The upper cervical region, occasionally the seat of spina bifida, is also involved in the marked flexure at the cephalo-cervical juncture. The observations of v. Recklinghausen have established the fact that in many cases, the length of the spinal cord is relatively excessive, a condition favorable to the production of kinks which at the points of least resistance may become additional factors in causing protrusion of the cord and its membranes. Hertwig, basing his conclusions on experimental studies on frog's ova, regards spina bifida as indicative of faulty closure of the blastopore, ascribing the arrest of development to influences which very early affect the germ-mass. That this malformation may arise apart from mechanical disturbance due to the amnion is shown by its occurrence in the *anamnia* (fishes and amphibians) in which fœtal membranes are never formed.

Defects due to Arrested Development of the Cranial Vault.—The defective formation of the vault of the skull presents a series of malformations which affect not only the brain case, but also the enclosed nervous mass. Since the arrest of development involves those parts of the skull which are analogous to the neural arches of the vertebræ, these malformations of the skull may be appropriately termed *cranioschisis*, of which two chief groups—*acranius* and *hemicranius*—are recognized; these depend upon the degree of the defect, and vary from total absence of the vault to partial arrest of development. The associated defective conditions of the brain mass include *anencephalus*, *exencephalus*, and *cephalocele*.

Acranius.—This malformation is distinguished by very slight or totally deficient development of the bones comprising the cranial vault, resulting in a skull in which the base is often the only part present. The brain shares in the defective development and is frequently wholly lacking, or at best represented by rudiments of nervous substance contained within a richly vascular spongy mass of connective tissue which forms a membranous covering for the base of the skull. This structure, the *area cerebrovasculosa*, corresponds to the area medullovasculosa already noted in connection with the defects of the spine, and consists of the remains of the pia and the nervous tissue.

Hemicrania implies a partial development of the vault bones, which, although producing more of the skull than present in acrania, results in an imperfect closure, principally in the posterior segment. This condition is often attended with protrusion of the brain substance (*exenceph-alus*) which may rise above the imperfect skull as a crowning mass or form a pendulous sac-like tumor over the occipital region. The protruding brain, although commonly uncovered by integument, is invested by a soft and yielding membrane representing the pia and arachnoid.

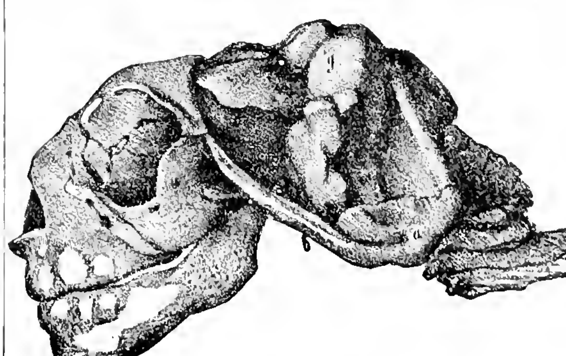

Fig. 4677.—Acranus Exencephalus. (Vrolik.)

The defective development resulting in cranioschisis frequently affects also the adjacent cervical vertebræ, thereby giving rise to the condition known as *craniorachischisis*, in which a cleft extends from the posterior part of the skull onto the upper part of the spine. The lordosis following the shortening and distortion of the vertebræ markedly influences the position of the head, the occiput being bent backward and the face thrown upward. This, in conjunction with the flattened cranial vault, deficient brows, and the consequent seemingly excessive protrusion of the eyes, gives to these malformations the peculiar appearance described as "toad-headed."

Cephalocele.—Associated with partial defects of the skull, but antedating the bony deficiencies, protrusions of the cranial contents may occur as various forms of cerebral hernia. The fallacy of regarding cephalocele as secondary to and dependent upon the defect in the brain case is suggested when we recall the time (end of the third month) at which ossification begins—a date manifestly too late for the production of changes so profoundly affecting the brain. The tumor escaping through the limited area of defective skull may consist of brain substance, only of its membranes, or of both. When composed of brain substance, the hernia is termed *encephalocele; hydrencephalocele*, or *hydrocephalus*, implies an accumulation of fluid within the ventricles and a more or less extensive prolapse of the dilated brain. Should, however, the accumulation of fluid take place after the development of the skull has well progressed, the condition may result in the general enlargement of the cranium, with the attendant alteration in the brain, seen in congenital hydrocephalus. The excessive production of the intraventricular fluid, which may reach a litre in quantity, takes place from the choroidal plexus, the lateral and third ventricles especially undergoing marked dilatation, while the surrounding nervous substance usually suffers greatly. The cranial vault shares in the expansion and becomes excessively thin, the fontanels being abnormally large and the sutures wide and ununited. When the hernia contains only the distended arachnoid and pia the condition is known as *meningocele*, or *hydromeningocele*. In case the brain substance is at the same time involved, as frequently it is, *meningo-encephalocele* is the appropriate designation for such deformity.

The most frequent seats for cerebral herniæ are the occipital region immediately above the foramen magnum and the vicinity of the root of the nose. The seats of the herniæ are indicated in the forms variously described as naso-frontal, naso-ethmoidal, naso-orbital, or, exceptionally when at the base or side of the skull, as spheno-pharyngeal, spheno-orbital, spheno-maxillary or lateral.

Iniencephalus.—In rare instances the cranial defect includes a combination of hydrencephalus and encephalocele with fissure of the adjoining cervical vertebræ. The distended occipital tumor overhangs the spine, the encephalocele being received in the vertebral cleft and the integument of the head, passing directly into that of the back.

Microcephalus and Micrencephalus.—These conditions, distinguished by abnormal smallness of the cranium and the enclosed brain, represent defective development of the nervous mass, the arrested growth of the latter probably preceding, not following, that of the skeleton. In contrast to the etymological comprehensiveness of the term, as including all forms of diminished head, microcephalus, as at present understood, implies the associated presence of a brain which, with the exception of its abnormally small size, may not be materially deformed. Further, that the diminished brain case is part of a body of usual stature, thus excluding the microcephalus seen in dwarfs (*nanocephalus*).

The decrease in the microcephalic skull affects especially the cranium, the facial portion often suffering but little arrest in its development. Assuming the average cranial capacity as 1,500 and 1,300 c.c. and the average horizontal circumference as 52 and 50 cm., for the adult male and female skull respectively, in extreme cases of microcephalus the cranial capacity may be diminished to little more than one-fourth of the normal, and the circumference may reach only two-thirds of the normal measurement. The unusual closeness, although not necessarily disappearance, of the sutures and the absence of the fontanels are among the characteristic features of the young microcephalic skull, the cranial vault, both in its sagittal and frontal curvature, being decidedly diminished. In consequence of the slight involvement of the face the narrowing of the cranium becomes conspicuous and confers upon the microcephalus a simian type, since the skull seemingly possesses a median crest. An additional peculiarity is also seen in the forward bend of the outer surface of the occipital bone, the external protuberance apparently being displaced upward. The partial or complete obliteration of the cranial sutures, upon which much emphasis was formerly laid, is far from constant, since synostosis in young microcephalic skulls is unusual, such crania even in later life occasionally exhibiting persistent sutures. Union of the sagittal suture, however, is not infrequent; since arrested growth of the brain occurs early, the elongation of the skull usually associated with such synostosis is not observed.

The *micrencephalus* associated with the diminished cranial capacity presents wide variations of brain weight (from 200 to 800 gm.), the loss being chiefly due to that suffered by the cerebral hemispheres, although usually the cerebellum is also under the normal weight. While in micrencephalus of low degrees the fissures and convolutions are practically normal, in the higher forms the frontal, parietal, and occipital lobes may be greatly distorted and disturbed. Often along with simplification of the gyri unusual prominence and partial exposure of the central lobe, or island of Reil, are highly characteristic in the more marked grades of micrencephalus.

Malformations of the brain, depending upon arrested development, affect chiefly the cerebral hemispheres, since these represent the more highly specialized portions of the encephalon, although the cerebellum and the brain stem are at times also involved. The defects of the cerebrum include irregularities, simplification, and suppression of the convolutions, imperfect development of the olfactory lobes, corpus callosum, basal nuclei, and other parts derived from the subdivisions of the primary anterior cerebral vesicle. The lateral and third ventricles sometimes become the seat of abnormal accumulations of cerebro-spinal fluid, followed by distention and more or less unfavorable change in the surrounding parts. To such congenital defects, when not sufficiently grave immediately to endanger life, although always productive of impaired intellect, the term *porencephalus* has been applied as distinctive from hydromicrencephalus, in which the defective features are more exaggerated. The former condition may be associated with extensive involvement of the adjacent frontal and parietal lobes, the affected convolutions and fissures presenting a characteristic radial disposition. In consequence of the impairment of the cortical motor areas contractions and atrophy of the limbs of the opposite side are frequently observed.

Cyclocephalus.—A conspicuous group of defects involving the great brain, eyes, and nose is derived from arrested development of the primary anterior cerebral vesicle. It will be recalled that the latter soon subdivides into forebrain (prosencephalon) and interbrain (thalamencephalon), from which are subsequently developed the cerebral hemispheres, including the lateral and third ventricles and the parts surrounding these spaces. The early outgrowth of the eye sacs from the posterior segment of the primary cerebral vesicle is closely connected with the changes which the latter undergoes. Arrest of development of the primary brain sac, when profound, may prevent the secondary longitudinal subdivision of the forebrain into the two cerebral hemispheres, the latter in extreme cases being represented by a single sac which may occupy a large part of the cranial space and be filled with fluid. When less aggravated and of low degree, the defective development may find expression only in particular parts, as the olfactory region, the anterior convolutions, the corpus callosum, the optic thalamus, etc. Those derived from the middle and posterior primary cerebral vesicles, as the corpora quadrigemina and the parts surrounding the fourth ventricle, are usually little disturbed.

The failure of the cerebral hemispheres to develop, hence apparently to fuse, exerts a profound influence on the relation of the optic vesicles, since instead of being widely separated as in the normal condition, they may become closely approximated or blended and lead to the formation of a single visual organ, this condition constituting *synophthalmus* or *cyclopia*.

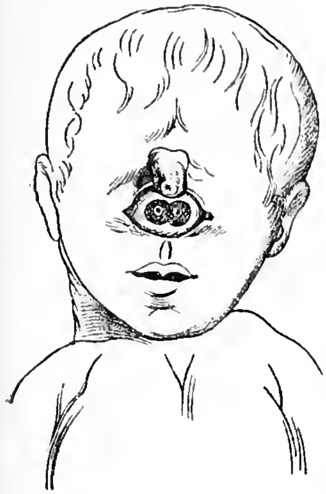

FIG. 4678.—Synophthalmus. (Heyman.)

Since the frontonasal process, which takes an important part in the formation of the external nose, shares in the general defective development of the forebrain, malformations of the nose are usually associated with synophthalmus. The typical cyclopian monster is distinguished by a single eye within a single orbit, occupying the middle of the face. A true nose is wanting, but about the orbit protrudes a fleshy proboscis provided at its end with a single or double opening. Depending upon the extent of developmental arrest, transitional forms of all degrees exist. Beginning with the slightest, in which an unusually narrow face, closely set eyes, and a rudimentary, although normally situated nose are the chief features, the relations of the eyes become progressively more intimate until, in marked instances, they lie within the fused orbits side by side, the rudimentary nose having been replaced by a proboscis above the orbital opening. The two eyes may be represented by a single ball of unusual size, in which double or partially blended corneæ, pupils, lenses, and optic nerves are present. When synophthalmus of high degree exists, the fusion of the two optic organs and nerves may be complete.

Since the normal union of the fronto-labial and maxillary processes (which plays an important rôle in the formation of the face and upper oral boundaries) may be hindered by the same influences that produce cyclencephalus, it is not unusual to find clefts of the lip and palate associated with the characteristic deformities of a well-marked cyclops. Likewise disturbed relations in the position of the visceral arches may result in coincident deformity of the external ear, the fusion of which constitutes *synotus* or *cyclotus*. In extreme cases, in addition to disappearance of the nose (*arhinencephalus*) as well as proboscis, the oral aperture may also become closed (*cyclostomus*) by fusion of the displaced visceral bars. When only feeble development is conjoined with fusion of the optic vesicles, the resulting organ may be so imperfect that a distinct eye is absent (*anophthalmus*), or at best represented by an extremely rudimentary organ occupying a slight central depression.

Coincident with cyclencephalus of high degree, defects involving the parts adjacent to the orbital, nasal, and oral cavities are not infrequent. Such malformations may include imperfections or absence of the ethmoid bone and nasal septum and cleavage of the palate and upper lips; less commonly the inferior boundary of the oral opening may be deficient.

Malformations of the Eye.—In addition to the foregoing conspicuous changes (cyclopia) in the position and development of the visual organs associated with the grave general arrest affecting the development of the anterior brain vesicles, the eye may be the seat of local defects, the more important of which may conveniently be briefly noted in this place.

Retention of fœtal structures and conditions which usually disappear before birth account for some of the slighter anomalies, including persistence of the pupillary membrane in the form of vascular fringes attached to the free edge of the iris; persistence of the remains of the hyaloid artery, as a fibrous cord stretching from the optic papilla toward the posterior surface of the lens; coloboma of the iris and of the choroid, as well as cysts connected with the eyeball and containing portions of its contents, are referable to imperfect closure of the fœtal choroidal fissure.

When the developmental arrest has been more general, the entire organ remains undersized (*microphthalmus*) and retains many features of its fœtal condition, as shown by the unusually large lens, which may occupy the greater part of the eyeball, the persistence of the vascular primary vitreous tissue and remains of the hyaloid artery. The retina is often imperfect and the effects of an unclosed choroidal fissure are seen in coloboma of the iris and choroid. The small eyeball is enclosed by a relatively thick sclerotic coat and diminutive, illy defined and often untransparent cornea. Microphthalmus may be unilateral or bilateral and associated with impaired development of the skull and brain.

Anophthalmus, or total absence of the eyeball, represents the extreme condition of an arrested development which fails to produce even a rudimentary organ within the small and imperfect orbit. This condition may exist on one or both sides.

The eyelids also share in the defective development, and may enclose a palpebral fissure of abnormal narrowness (*ankyloblepharon*), often seen in conjunction with microphthalmus. The fissure may be wanting (*cryptophthalmus*), owing to fusion of the lids, or the latter may be congenitally adherent to the eyeball (*symblepharon*). *Epicanthus* is distinguished by the presence of a cutaneous fold, occupying the inner canthus to a variable extent, attributable to the persistence of the plica semilunaris to a degree corresponding to the nictitating membrane of lower forms.

MALFORMATIONS OF THE FACE AND NECK.—Since these malformations result largely from arrested or defective union of the visceral arches with one another and with the surrounding parts, a brief outline of the normal development will be a useful preface to the description of the defects in question.

The face and neck are primarily formed by the fusion of a paired series of lateral bars, the *visceral arches*, with one another and the unpaired median *frontal process*, the downward prolongation of the region of the forebrain. The visceral arches in man and mammals for a time are separated by *external* and *internal furrows*, the representatives of the slit-like apertures, or *branchial clefts*, of the lower forms (fishes). The median ends of the first pair of visceral arches are subdivided into a short upper or *maxillary*, and a longer lower or *mandibular process*, between which and the frontal process the primary oral cavity is included. With the appearance of the nasal pits the frontal process differentiates into the median *naso-labial* and the *external nasal process*, lying respectively between and outside the olfactory depressions. The lateral angle of the naso-labial process thickens and becomes the *internal nasal* or *globular process*, which on each side

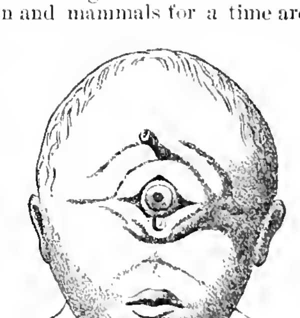

FIG. 4679.—Synophthalmus Cyclopia. (Jourdan.)

bounds the olfactory pit. The further differentiation of the fronto-nasal and inner nasal processes gives rise to the nasal septum and inner boundaries of the nasal apertures and the *nasal groove*, the latter marking the line of fusion between the maxillary and internal nasal processes. The external nasal processes contribute the cartilages and the lateral boundaries of the front of the nasal fossæ. These processes, in conjunction with the adjacent maxillary divisions of the fourth visceral arch, also bound the *lachrymal groove* leading from the eye to the nasal furrow. Fusion of the adjacent portions of the fronto-nasal process with the maxillary bars gives rise to the cheeks and superior oral boundary, the latter differentiating into the upper lip and the superior and intermaxillary alveolar borders. The widely open recess which for a time constitutes the primary oral cavity becomes divided into a respiratory and an alimentary part by the formation of a septum formed by the union of the palatal plates differentiated from the maxillary processes. The palatal shelf thus formed unites with the nasal septum to compensate the closure of the nasal fossæ. The external visceral furrows, with the exception of the first which persists as the external auditory canal, are obliterated by the approximation and fusion of the arches. The internal furrows, or *pharyngeal pouches*, likewise disappear; the first, however, is converted into the Eustachian tube, and secondarily is associated with the tympanic cavity. The entoblastic lining of the third and fourth pouches gives rise to the epithelial anlages of the thymus and thyroid bodies respectively. The inner ends of the second arches contribute a V shaped area, from which the posterior third of the tongue is formed, the anterior two-thirds of the organ being derived from an unpaired elevation, or tuberculum impar, which arises in front of the junction of the second arches.

Facial Clefts.—From the foregoing it is evident that such defects may arise as the result of *primary* arrest of

FIG. 4680. Facial Clefts. (Ross.)

development and union of the embryonal processes, or that they may follow *secondary* disturbances affecting parts already partially formed.

Aprosopus is the most pronounced degree of such primary malformations, and implies an early and complete arrest of development of the parts normally concerned in forming the face. The latter in this condition is practically absent and replaced by a widely open, irregular oral recess.

Clefts of the Lip, Jaw, and Palate.—Usually the primary defective development is less general and limited to faulty union between the processes concerned in forming the upper and lateral parts of the face. The clefts follow the lines of primary union, and may involve (1) the upper lip alone (*cheiloschisis*), (2) the lip and maxilla (*cheilo-gnathoschisis*), (3) the lip, maxilla, and palate (*cheilo-gnatho-uranoschisis*).

Simple cleft lip, or *harelip*, is usually lateral (very rarely median) and on one side only. The fissure follows the line of the nasal groove between the globular and maxillary processes, extending when complete from the inner border of the nasal aperture to the mouth. Subsequent union may reduce the defect to a mere prenatal scar.

The *labio-maxillary clefts* involve the upper jaw as well as the lip, the line of bony separation extending either between the canine and lateral incisor tooth, or, as is most frequently the case, between the lateral and the central incisor. In not a few cases a supernumerary incisor tooth, or sometimes teeth, is present, the cleft then usually passing between the second and third. The defect may be unilateral or double, and the relations to the teeth symmetrical or unlike on the two sides. As emphasized by Marchand, the early stage at which the faulty union is established anticipates the differentiation of the maxilla and the intermaxillary bones, as well as the appearance of the dental buds locating the milk teeth. These facts, together with the possible variations in the relation of the teeth germs to the bony segments later blended to form the upper jaw, detract from the assumed importance of these malformations as evidence in determining the mooted existence of double intermaxillary bones on each side. Symmetrical cleavage involving only the lip and jaw, the intermaxillæ standing out as an isolated process between the lateral fissures, are rare, the labio-maxillary clefts being usually combined with some form of palatal fissure.

Such defects, involving the palate as well as the lip and superior maxillary bone, include two groups, the *median* and the *lateral*. The former, in which a wide median cleft of the lip and jaw is continuous with an extensive central deficiency of the palate, is usually associated with malformation of the fore end of the brain-case, as seen in cyclencephalus, the facial defect being an expression of the same profound developmental arrest that is responsible for the cerebral deformity.

The second and more usual type is distinguished by the lateral fissure, which is very frequently continued into a cleft palate. When one-sided, the imperfect union between the nasal and maxillary processes very often affects that between the corresponding palatal plate, the fellow of the opposite side and the vomer, and results in the cleft palate. With lip jaw clefts of the two sides, the defect of the palate may appear as a conspicuous median hiatus, in consequence of very imperfect formation of the plates, or the attempt at closure may result in leaving a slit on either side of the septum. The latter may be intact and attached to the intermaxillæ, which then sometimes present a snout-like protrusion.

Not rarely only part of the lines of juncture remain permanently ununited, as seen in cases in which slight indentations or linear scars on the lips, partially cleft palate, or split would alone persist as evidences of the imperfect closure. The observations of Friccius, covering 550 cases of harelip, showed the defect to be almost twice as frequent in males (62.5 per cent.) as in females (37.5 per cent.). It occurred on the left side in 52 per cent.; on the right in 21 per cent.; on both in 27 per cent. It was uncomplicated in 35.2 per cent., and complicated by alveolar or palatine cleft in 64.8 per cent. Hereditary influence was indicated in 11.5 per cent.

Occasionally the defective union involves the entire path of junction between the maxillary process and the internal and external nasal processes, the result being a cleft extending from the mouth, through the lip and superior maxillary bone, alongside of the nose, to the inner canthus of the eye. Such defect is known as primary *oblique facial cleft* (*cheilo-gnatho-prosoposchisis*), and is to be distinguished from similar, but less regular, secondary deformities sometimes arising from mechanical influences exerted by abnormal relations of the amnion. These latter defects may vary greatly in position, form, and extent, since they are accidental and do not represent suspension of normal lines of development, as do the primary clefts.

Nasal clefts, median or lateral, occur as rare malformations. The median involve the tip of the nose and depend upon the persistence of the original tubular form of nares separated by a deep groove. The lateral clefts occur in consequence of insufficient fusion of the external nasal with the fronto-labial processes. Lehmann-Nitsche [91] and Lexer [92] report interesting cases.

The mouth may also be the seat of malformations caused by defective union of the embryonal processes constituting its primary boundaries. Where these fail properly to fuse to form the usual lateral limits, the oral opening may remain as a widely open cleft (*macrostomus*), extending laterally almost or quite as far as the ear, on one or both sides. When less marked the defect is sometimes known as *cheek-cleft*. Abnormal fusion, on the contrary, may partially obliterate the oral opening (*microstomus*), this condition being sometimes associated with labio-maxillary clefts. Complete fusion with resulting closure (*astomus* or *atresia oris*) may also occur.

Malformations due to faulty development and union of the mandibular processes of the first visceral arch also occur, but are much less frequent than the foregoing facial clefts, owing to the greater number of processes concerned in the formation of the upper lip, nose, and upper segment of face, and hence the greater opportunity for incomplete fusion.

Defects of the *lower lip*, in the form of median cleft or fistulæ, are rare, since fusion of the mandibular processes takes place unless development be profoundly disturbed.

Micrognathus implies defective formation and growth of the embryonal bars, resulting in a rudimentary and under-sized condition of the lower jaw. Pronounced arrest of these processes may be shown in *agnathus*, in which the mandible may be seemingly totally wanting. According to Winckel and to Kuse,[93] however, rudiments of the inferior maxillary bone are always to be found by critical examination. In consequence of the disappearance of the mandible the external ears are shifted downward and inward until their approximation may become blending (*synotus*). Usually defective development of the ears and, not infrequently, also of the maxillary processes are associated with the malformations of the jaw. The mouth may be imperfectly represented and the lower part of the face appear as if cut off and occupied by a widely open pharyngeal recess.

Partial or complete duplication of the lower jaw (*dignathus*) is an expression of more or less extensive redundant differentiation of the mandibular processes. The doubling may involve only one side, or be limited to the alveolar processes, the accessory segment bearing supernumerary teeth. When partial the additional part projects from the mandible, or, when complete duplication occurs, may be fixed above or below the normal bone.

Cleft *tongue* may also exist as a rare malformation.

The external visceral furrows are the seat of abnormalities due to aberrations in the closure of these depressions between the adjacent arches. Variations in the development of the first furrow and its bordering arches give rise to malformations of the external ear.

Since the auricle is formed by the fusion and differentiation of six tubercles surrounding the outer end of the first furrow, defective development or imperfect union of these parts frequently produces malformations involving the pinna, including the auricular appendages which originate from displaced tubercles. Malformations of the auricle may be associated with closure or absence of the external auditory meatus due to partial or complete abnormal fusion of the first and second arches, with the consequent occlusion or disappearance of the external auditory canal. As already incidentally noted, malformations of the ears are sometimes associated with defective development of the face.

Congenital cervical fistulæ are the results of imperfect closure of the visceral furrows, coupled often with secondary rupture of the ecto-entoblastic epithelial septa, which in mammals separate the external furrows from the internal pharyngeal pouches. The most usual situation of the fistulæ is immediately above the sterno-clavicular articulation; less commonly along the anterior border of the sterno-mastoid muscle. Although it is difficult to determine the exact genetic relations of the fistulæ to the original furrows on account of the changes and displacement which occur during the evolution of the neck, it may be assumed, according to Kostanecki and Mielecki,[94] that the majority of these fistulæ are derived from the second furrow, between the second and third arches. Originally the fistula is only a short pocket separated from the corresponding pharyngeal pouch by the delicate occluding membrane formed by the opposed ectoblast and entoblast lining the outer and inner diverticula. This independence being retained, the fistula is only a short and narrow passage, directed upward and inward, soon ending blindly and without communication with the pharynx. When, as is not infrequently seen, fluids escape from the fistula on swallowing, we must assume that secondary rupture of the delicate epithelial septum has taken place, thereby establishing communication between the pharynx and the exterior.

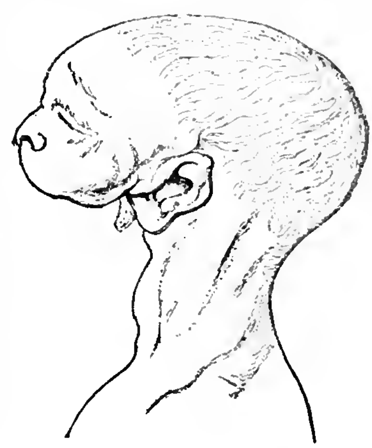

FIG. 4681.—Agnathus. (Guardan.)

Median cervical fistulæ constitute a group modified by the position of their external opening, which is central instead of lateral. As pointed out by Kostanecki, the outer opening of the fistulous passage corresponds to the remains of the precervical sinus of His; the latter is a median depression, resulting from the drawing inward of the blended lower visceral arches, which later becomes closed in by the union of the second arches with the thoracic wall. When complete, the fistulæ in question usually pass upward and inward, but end on the lateral wall of the pharynx in the same positions as do the lateral fistulæ. The median location of their outer end, therefore, must be regarded as secondary and supplementary in consequence of the primary visceral furrow being carried away from the surface and into the sinus, the remains of the latter persisting as the outlet of the original cleft. At times the remains of the precervical sinus alone appears as a median fistula, in which case a short passage is traceable downward instead of up.

Branchial Cysts.—The exceptional opportunities offered by the series of visceral arches and clefts for partial closure and the persistence of an isolated portion of the various furrows and pouches results in frequent production of various forms of cysts and tumors. The most common of these are simple cysts, which differ in character with their origin. If from the external furrows, they are lined with modified integument and are dermoid in type; if from the pharyngeal pouches, their lining approaches the columnar type and their contents are serous. As emphasized when considering true dermoids, the distinction between the productions of transplanted integumentary constituents and true fœtal inclusions, although often difficult, depends upon the presence of derivatives of all three germ layers. Since consideration of the various forms of branchial cysts and tumors does not fall within the province of this article, the reader is referred to the article on *Branchial Cysts* in Vol. II.

Defective or aberrant development of the pharyngeal pouches and the bordering arches may give rise to malformations of their derivatives.

The *tongue* may suffer from impaired development involving the region of the second arches, since its posterior third originates from the vicinity of their fused median ends, while its anterior two-thirds arises from the unpaired anlage, the tuberculum impar, which grows forward from the basal area. Faulty development of the anterior anlage results in deficiency or absence of the front part of the organ, although the base may be present. Glossal defects are often associated with micrognathus. Various degrees of attachment of the tongue to the floor of the mouth depend upon imperfect differentiation of its anterior anlage. Cleavage and partial doubling of the tongue is observed as a rarer malformation.

Persistence of the median anlage of the thyroid body as the thyro-glossal duct, the upper end of which is normally indicated by the foramen cæcum on the tongue, may give rise to a fistulous canal which descends to terminate in the vicinity of the hyoid bone, or in some cases to open as a median fistula in the neck. Isolated portions of the retained duct may become the seats of cysts.

Pharyngeal diverticula are occasionally observed, being due to local persistence of the inner visceral furrows.

Variations in the development of the *thyroid body* are also connected with the visceral arches, since the lateral anlages of this organ are derived as epithelial outgrowths from the fourth pharyngeal pouch and the median anlage as a similar outgrowth from the ventral wall of the pharynx in the vicinity of the second arches. Accessory thyroids occur in connection with both the lateral and the median lobe, those arising from the persisting remains of the embryonal condition of the latter appear at various levels, including a sublingual and a hyoid group. Disturbed development involving the thymus anlage of the third visceral cleft may lead to the formation of dermoid cysts which are subsequently carried into the anterior mediastinum.

When the closure of the precervical sinus remains very imperfect, the deficiency may lead to the rare malformation known as *cervical fissure*. Coupled with thinning and distention of the floor of the depression, the heart may project through the opening, thereby producing the rare suprathoracic type of *ectopia cordis*. The lungs and thymus have been observed to accompany the displaced heart.

Malformations of the Thorax and Abdomen Depending upon Imperfect Closure of the Ventral Body Wall.—The underlying process in the differentiation of the thoraco-abdominal cavity and the contained alimentary canal from the flat and widely extended germ layers is the ventral folding of the splanchnopleura and the somatopleura. By the approximation and union of the first folds is formed the digestive tube; by those of the second the ventral or anterior body wall, the intervening space being the primary pleuro-peritoneal cavity. In each case closure proceeds from all directions, cephalic, caudal, and lateral, the point of latest closure being the umbilicus, through which for a time the gut-tube communicates with the yolk-sac by means of the vitelline duct. Defective union of these ventral somatopleuric folds, the *membrana reuniens anterior*, results in a more or less extensive median cleft, which may be limited to a small portion of the thorax or abdomen, or involve the entire anterior body wall, reaching from the neck to the pelvis.

The most frequent seat of imperfect closure is at the umbilicus, this region in consequence of closure being here longest delayed, being inherently vulnerable. The simplest expression of such imperfection is *congenital umbilical hernia*, portions of the intestines and sometimes omentum protruding through a ring of unusual size. When the defective closure is more extensive and the abdominal contents are confined by a membranous wall composed of the peritoneum and the amnion covering the umbilical cord, the viscera may push before them the occluding membrane, which becomes converted into the hernial sac, lined by peritoneum and occupied by the displaced organs. This condition constitutes *omphalocele* or *funicular hernia*. The umbilical cord, being invaded by the hernial sac and contents, apparently springs from the sac near its apex or toward the side, the entire length of the cord frequently being greatly reduced. A large part of the abdominal organs may find its way into the hernial sac, which may contain, in addition to a variable length of intestine, a portion of the liver, the stomach, and the spleen.

When the defective union is still more extensive, the resulting fissure may involve the larger part or the whole of the ventral body wall. When limited to the abdomen, the condition is known as *gastroschisis completa;* when including also the chest wall, as *thoraco-gastroschisis*. In the former case the abdominal fissure is bounded by the ununited somatopleuric folds, which are directly continuous into the amnion. The latter, in conjunction with the peritoneum or alone, may constitute a considerable or even a huge sac, containing the greater part of the abdominal organs (*ectopia viscerum*). The ununited umbilical vessels may course in the wall of the sac without being collected into a distinct cord, the placenta in such cases being often fused with the sac. Spinal curvature, skoliosis, or lordosis is frequently associated with eventration. The thoracic involvement depends upon the extent of the sac; in exaggerated cases almost complete axial rotation with approximation of the upper and lower segments of the trunk may be present. The pelvis and the lower extremities may also share in the defective development, at times the limbs suffering complete backward luxation and extreme atrophy.

At times the defective closure of the abdominal wall is associated with fissure of the intestinal tube, usually in the vicinity of the beginning of the large intestine (cæcum or adjacent colon). The cleft gut is attached to the belly wall behind the opening through which the wall of the intestine may protrude (*ecstrophia intestini*.)

Fissure of the chest wall (*thoracoschisis*) may be coextensive with the anterior wall of the thorax, or it may be limited to the partial cleavage of the sternum alone. Since the latter is primarily formed by the blending of two curved vertical cartilaginous bars, arrest of union results in complete or partial fissure of the sternum. In the former case the isolated halves bear the costal cartilages and ribs; in the latter, the defective union may be limited and indicated by an opening in the gladiolus, or, more frequently, by fissure of the ensiform process. Rarely the defective development affects only one of the primary bars, this condition resulting in total absence of one-half of the sternum and the associated costal cartilages. When the defective union is extensive, owing to early arrest of development, the pericardium is uncovered or even wanting, and the heart displaced (*ectopia cordis*). According to the position of the protrusion, suprathoracic, thoracic, and subthoracic varieties of the ectopia are recognized, the second form, in which the heart escapes through the cleft sternum, being the most usual. The displacement of the heart into the abdominal cavity seen in the subthoracic ectopia is sometimes due to a defective diaphragm. When entirely exposed, as sometimes happens, life is prolonged only for a few hours after birth. Usually, however, the organ is more protected, and if the defect be small and the protrusion slight the malformation may be masked by the integumentary covering. Malformations of the heart itself, or of the great vessels, are not uncommon in marked ectopia. Concerning the cause of the arrested development involving the general thoracic wall, little is known, although it is certain that amniotic and other abnormal adhesions play an important part in bringing about displacement of the heart and in preventing union.

Subumbilical clefts result from faulty union of the anterior body wall invading the region below the navel, which may be the seat of fissures of varying extent, not only of the immediate abdominal parietes, but also of the associated organs, as the bladder and the external genitals. When the bladder is only slightly involved, the defect may be limited to a small *vesical fissure*, or, when the arrest of development is more extensive, the anterior wall of the organ may be entirely wanting and the exposed mucous membrane covering the postero-inferior wall of the bladder, with the openings of the ureters, be seen lying within the opening, constituting the condition known as *vesical ecstrophy* or *ectopia vesicæ*. At times displacement and complete turning inside out (*inversio vesicæ*) may accompany the cleavage as a secondary consequence of traction induced by unusual relations of the allantois and amnion. The pelvis, urethra, and penis are also seats of clefts associated with faulty union of the lower body wall.

Of the various *causes* to which extensive cleavage of the abdominal wall has been attributed, the most potent primary factor, as emphasized by Marchand, is to be sought in the early abnormal attachment between the ventrally placed vitelline sac and the chorion. This union interferes with the normal differentiation of the somatopleuric folds, which form the ventral body wall, from the amnion, the latter in a measure replacing the usual anterior parietes. In conjunction with these abnormalities a possible unusual dorsal union between the chorion and the amnion may hinder the expansion of the latter, with the result of inducing an early over-extension (lordosis) of the embryo, which further favors non-approximation of the component halves of the ventral body-wall and eventration. Early amniotic adhesions undoubtedly play an important rôle in subjecting the anterior parietes to abnormal tension and pull, in consequence of which arrest of development, delayed union, and displacement of organs may follow.

Malformations of the Diaphragm.—Since the partition subdividing the primitive body cavity into the pleuro-pericardial and peritoneal compartments is completed by fusion of segments which for a time are separate, arrested development or delayed union results in abnormal clefts. The formation of an antero-lateral fold —the *septum transversum*—early effects an incomplete isolation of the pleuro-pericardial cavities from the peritoneal space, and foreshadows the appearance of the primitive diaphragm. The latter is differentiated from the cephalic part of the septum, the caudal portion being intimately concerned with the development of the liver. The completion of the diaphragm is delayed for some time, an opening on either side of the primitive gut tube maintaining communication between the peritoneal and the pleural cavity. Finally, when the developing lungs have reached the young liver, the partition is completed by the forward growth of dorso-lateral folds, which fuse with the previously existing anterior segment. From the foregoing sketch it is evident that varying degrees of developmental arrest and delayed union may produce corresponding grades of imperfection in the septum. These include total absence or rudimentary condition of the diaphragm due to failure or insufficiency of development of the component primary folds. More frequently the defects result from the imperfect union of the anterior and posterior segments, and are therefore less extensive. The communications, larger or smaller in size, between the peritoneal and pleural cavities preserve the primary continuity of the serous membrane lining the abdominal and pulmonary spaces, the peritoneum passing directly into the pleura. In general, these defects occupy the posterior half of the diaphragm and are often in the vicinity of the œsophagus, the congenital orifices being much more frequent on the left than on the right. Other defects lie in the anterior part and correspond to the area of weakness between the sternal and adjoining costal portions.

The most conspicuous result of these imperfections is the displacement of organs as *diaphragmatic herniæ*. These may include a portion of the right lobe of the liver on the right, and the stomach, left liver lobe, spleen, and a variable part of the intestine on the left (E. Schwalbe [95]). Usually the dislocated viscera lie entirely free within the pleural cavity; exceptionally they are

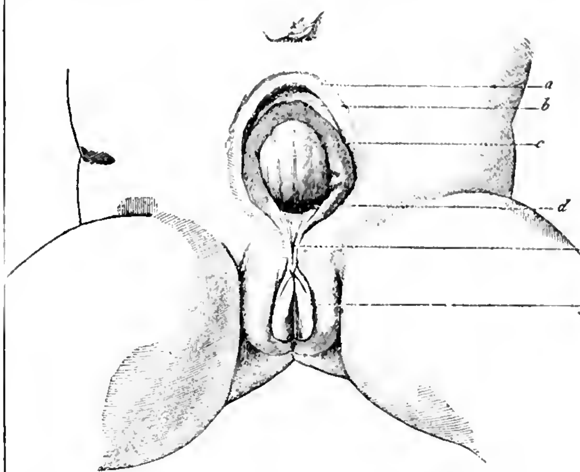

Fig. 4682.—Abdominal Fissure with Open Bladder. *a*, Skin; *b*, peritoneum; *c*, bladder; *d*, cavity of bladder; *e*, urethral groove; *f*, nymphæ. (Ziegler.)

enclosed within a hernial sac derived from the serous membrane. The influence of the intruding viscera upon the lungs and heart may be unfavorable, and these thoracic organs, particularly the lungs, in consequence often exhibit the effects of impeded development. The defective development of the diaphragm is frequently associated with other malformations, such as cleft sternum anteriorly, or imperfectly closed spinal canal dorsally. In certain cases of subthoracic *ectopia cordis* the heart escapes from the chest through the imperfections in the diaphragm, which are often associated with defective closure of the belly wall.

Malformations of the Digestive Tract.—*Mouth.* —Malformations of the boundaries of the oral cavity— the lips, cheeks, and palate—together with those of the jaws, usually depend upon arrested development and defective union of the embryonal processes which surround the primitive oral recess. These defects have been already considered under Facial Clefts (page 700).

The *tongue* likewise has been already considered in connection with imperfect development of the visceral arches (page 702), with the formation of which its origin is related.

The *pharynx* is the seat of fistulæ, cysts, and diverticula resulting from aberrant development of the primary pharyngeal pouches, in connection with which they have been noted (page 702). The slight dorsal recess which usually marks the transition of the pharynx into the œsophagus may be the starting-point of a considerable pouch extending between the spine and the gullet.

The *œsophagus* very rarely is entirely wanting or replaced by a fibrous cord; more usually the gullet is defective only in certain segments. Thus it may end blindly a short distance below the pharynx, or, on the other hand, its lumen may terminate above the stomach, the œsophagus being continued by a cord of fibrous tissue attached to the pharynx above. The atresia may be accompanied with more or less extensive dilatation, not infrequently associated with an abnormal opening into the lower part of the trachea (Hoffmann [96]). A divided condition of a portion of the œsophagus has also been observed.

The *stomach* is only rarely the seat of congenital mal-

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formations. Its development may be imperfect, resulting in retention of the fœtal tubular form and under-size, the stomach at times being little larger than the succeeding gut. The organ may present constrictions, subdivisions, and dilatations. Sometimes the pyloric orifice may be partially or entirely closed, the stenosis being occasionally seen in infants. In company with other abdominal viscera, the stomach may suffer displacement in large congenital umbilical herniæ, as well as transposition in situs inversus. Total absence of the stomach may occur in acephalus.

The Intestines.—Partial persistence of the vitelline or omphalo-enteric duct in the form of *Meckel's diverticulum* is the most frequent congenital deformity of the intestinal tract. The duct for a time normally is pervious, but before birth it loses its lumen and is represented by an atrophic fibrous cord passing from the umbilicus to the ileum. When retained, the resulting diverticulum opens into the ileum, usually a little over a metre from the ileocolic valve. Its length varies from a mere shallow recess to the entire distance from the gut to the umbilicus; usually, however, it is some 10-13 cm. Its width at the intestine is commonly that of the gut, the blind extremity being somewhat less. The latter may exhibit a pouched condition, or a rounded end similar to the finger of a glove. The diverticulum usually springs from the convex side of the intestine, but may join the latter obliquely, or on the side of the attachment of the mesentery. In the latter case the diverticulum is provided with a process of mesentery. In exceptional cases the duct retains its lumen throughout, and on the disappearance of the stump of the cord after birth opens at the umbilicus, thus establishing a congenital umbilical *fistula*. Sometimes a small portion of the pervious duct remains attached to the umbilicus and becomes the basis of a tumor-like mass, which may yield a scanty secretion derived from the modified mucous membrane of the vitelline duct. The diverticulum may become constricted and its communication with the gut entirely lost, it remaining attached to the intestine as a cyst-like appendage. The latter may mark the seat of active growth resulting in the production of an intestinal cyst of huge size.

Total absence or extensive defects of the intestinal tube are always associated with grave general malformation, as in acardiac monsters.

Contraction and *closure* of the lumen of the intestinal tube may occur at different points, or a portion of the

FIG. 4683.—Atresia Ani with Rectum opening into Urethra. (Witt.)

gut may suffer obliteration. The upper part of the duodenum, in the vicinity of the entrance of the bile and pancreatic ducts, is a favorite position for interruption, the atresia of the gut being at times followed by extensive dilatation of the beginning of the duodenum in which the stomach may also be involved. The observation of Tandler,[97] that temporary constriction, or even occlusion, of the gut occurs near the entrance of the common bile duct during normal development of the duodenum, is suggestive in connection with atresia of this portion of the intestine. Ratz[98] reports an interesting case in which the small gut ended blindly, followed by the closed beginning of the large intestine. No evidences of inflammatory processes were present. The cæcum and appendix were wanting.

FIG. 4684.—Atresia of Rectum. *A*, Rectum connected with anal canal (*E*) by means of fibromuscular cord (*D*). (Guinard.)

Malformations of the *lowest segment* of the gut include an interesting group of defects sometimes dependent upon the faulty development of the parts concerned in forming the outlets of the intestinal and genito-urinary tracts. Reference to the early relation of these parts recalls that for a time a common space, the cloaca, receives the gut dorsally and the urogenital sinus ventrally. Separation of these tracts is effected by the extension of the urethro-rectal septum, which grows downward until it meets and fuses with the cloacal membrane closing the cloaca. This structure, the remains of the primary anal membrane, consists of the opposed entoblast and ectoblast and forms a temporary wall between the cloaca and the exterior of the body. Independent openings for the urogenital and intestinal canals are secured by the breaking down of the epithelial layers constituting the occluding membrane.

A conspicuous defect directly referable to arrested development is *persistence of the cloaca*, in which the rectum and urogenital sinus retain their primary relation, in consequence of the failure of the septum to appear, and open into a common space. The latter, closed by the still existing cloacal membrane, becomes distended by the accumulation of the excreta from the intestinal and urinary tracts. More usually the separation of the urogenital sinus and the gut is partially accomplished, the imperfection in the septum being represented by a permanent communication between the two canals; hence in the male the rectum opens into the urethra (usually the membranous but sometimes penile portion), or, rarely, into the bladder (*atresia ani vesicalis*). Occasionally the rectum empties into the vagina, very exceptionally into the uterus.

Imperforate anus (*atresia ani*) is relatively frequent and depends upon more or less extensive arrest of development of the gut, coupled with secondary attachments, which lead to the formation of a fibrous septum, closing the anus. The rectum may be well formed, or so defective (*atresia recti*) as to end blindly at some distance above the position of the anus, lying free and distended within the pelvic cavity. The atrophied gut may be attached by a fibrous cord without lumen. On the other hand, a well-developed anus may exist with closure of the rectum. In exceptional cases of imperforate ani, the rectal opening or fistula may lie farther forward and be found on the perineum, scrotum, or along the penis. The fistula may, on the other hand, be found over the sacral region, the unusual situation being probably associated with the primary dorsal position of the earliest trace of the anal depression, which under usual conditions acquires a more ventral location.

Variations in the form and situation of the *large intestine*, especially the colon and the cæcum, are very common, since the position and relations of this part of the intestine are greatly influenced by the torsion and secondary growth of the early gut tube. With the exception of stenosis, atresia, and possibly dilatation, the congenital defects are variations rather than malformations. Associated with these variations, modifications are also encountered in the arrangement of the peritoneum. The most striking of these is the retention of the fœtal simplicity of the mesentery (*mesenterum commune*), in which the duplicature enclosing the small intestine is directly continuous with the mesocolon and uncomplicated, the usual overhanging and anterior position of the large gut being absent, owing to the upward displacement of the latter having never occurred.

The *liver* is only seldom the seat of malformations, unless associated with general defects involving the intestinal canal, as in acephalic monsters, in which the organ is wanting. Very rarely absence of the liver may be unaccompanied by other malformations. The more usual, but still infrequent, defects include abnormalities in the size and number of the lobes; accessory or dislocated lobes may occur within the falciform ligament. Absence of the gall-bladder has been observed by Marchand in a child otherwise normal. Congenital stenosis of the bile passages, or enormous distention of the common duct due to obstruction near its termination in the duodenum, as well as unusual situations for the latter, are also occasionally encountered. Displacement and modified form are commonly seen in connection with umbilical and diaphragmatic herniæ or abdominal clefts.

The *pancreas* shares with the intestinal tube the effect of profound general malformation involving the alimentary canal. Supernumerary or accessory glands occasionally lie embedded within the intestinal, or at times gastric, wall. They may remain of small size and hidden, or they may become later in life the seat of cysts of large size. Unusual arrangement and abnormally situated openings of the pancreatic duct are dependent upon variations and connections in the development of the original anlages. The pancreas may suffer displacement in consequence of abnormal relations of the duodenum and stomach, or it may share the general inversion accompanying transposition of the viscera.

As a matter of convenience, the congenital defects of the spleen and of the suprarenal body may be here introduced, these organs having, of course, no connection with the digestive apparatus.

THE SPLEEN.—Very rarely the spleen is entirely wanting. Variations in the size of the normal organ include such a wide range that it is difficult to establish the limit of pathological defect. The most common malformation is the presence of one or more accessory spleens, which are usually found in the immediate vicinity of the chief organ, although they may lie at some distance or within the pancreas. H. Albrecht[99] has described a remarkable case of multiple spleens, in which a principal organ in the usual position was wanting and instead segments or supernumerary bodies to the number of almost four hundred were scattered throughout the abdomen. They occurred in groups which occupied the parietal peritoneum, the right half of the diaphragm, the upper surface and the falciform and coronary ligaments of the liver, the root of the mesentery, the splenic flexure of the colon, and the anterior surface of the rectum within the pouch of Douglas. Histological examination confirmed the macroscopic diagnosis of multiple accessory spleens. It is highly probable, however, that in many cases the supposed numerous minute accessory spleens are really hæmolymph glands of the splenic type (Warthin).

THE SUPRARENAL BODY.—The adrenals may rarely be wanting, or abnormally small, such defect being usually associated with deficient brain development (anencephalus). This relation, although recognized by the older writers, has been emphasized by Zander,[100] according to whom the development of the suprarenal suffers when the anterior half of the cerebrum is rudimentary; neither deficiency of the posterior part of the cerebral hemispheres and brain stem nor cerebral atrophy after the suprarenal has developed produces diminution of the latter.

The most frequent abnormality is the occurrence of accessory suprarenal bodies. The structures formerly described under this name included not only those connected with the adrenal or located in its more immediate neighborhood, as in the kidney or the liver, but also those found at a distance in the vicinity of the sexual glands, as in the broad ligaments or between the testicle and epididymis. The careful studies of Aichel[101] have shown that the last group represents constant organs of normal occurrence (*suprarenals*), which develop in relation with the atrophic tubules of the Wolffian body, and that the designation "accessory" is properly restricted to the supernumerary bodies which probably arise from constriction and isolation of a portion of the suprarenal anlage.

MALFORMATIONS OF THE RESPIRATORY TRACT.—The *nose*, in addition to the defects associated with facial clefts, may present congenital malformations involving defective development of the septum, ethmoid, nasal, and turbinated bones. Narrowing and closure of the posterior nares also occur.

The *larynx*, in common with other parts of the respiratory tract, may be entirely wanting, such conditions, however, being associated with grave malformations (acephalus) profoundly affecting the alimentary canal from which the pulmonary apparatus is the direct outgrowth. The congenital defects of the larynx consist usually of abnormalities affecting the cartilages, which may be increased in number, as a doubled epiglottis, or of the ventricle, which may be of unusual size with exaggeration of the lateral laryngeal pouch, the latter at times extending as far as the level of the hyoid bone and suggesting the laryngeal sacs seen in anthropoid apes. Abnormalities of the larynx as to size, excessive or deficient, as well as marked asymmetry, are occasionally observed. Complete closure of the larynx has also been recorded.

The *trachea* at times is absent, the respiratory tube undergoing bifurcation into the bronchi immediately below the larynx, or it may be only abnormally short. Contraction and occlusion also occur. Communication with the œsophagus has already been noted in relation to the defects of the gullet. The remains of such fistula may become a cyst connected with the posterior wall of the wind pipe. The cartilaginous rings are subject to variations in number and size in consequence of division or of fusion. Abnormal branching of the trachea into three bronchi is occasionally seen, the additional bronchus usually passes to the right upper lobe and is regarded by some (Chiari) as a supernumerary eparterial twig springing from the trachea instead of from the right bronchus. Herxheimer inclines to the view that the variation indicates the formation of an accessory lung. This author[102] has recorded an instance in which the first division of the trachea occurred 2.5 cm. below the cricoid cartilage, the right tube passing to a small nodule that presented all the histological characteristics of functionating pulmonary tissue. Rarely an additional eparterial or apical bronchus occurs on the left side in connection with a left lung possessing a third lobe (Chiari). Rudiments of supernumerary bronchi sometimes give rise to congenital diverticula.

The *lungs* are relatively infrequently the seat of primary congenital malformations, although the entire organ on one side may permanently remain uninflated and rudimentary. Such condition may be induced by the intrusion of abdominal viscera which have migrated into the thorax through a diaphragmatic hernia. More usually the defective development of the pulmonary tissue is limited to one part of the organ, the affected area consisting of branches of the bronchial tree surrounded by a relatively dense mass composed chiefly of highly vascular tissue without alveoli, the conversion of the primary epithelial bud-like divisions of the forming organ having never taken place. The bronchial tubes within the rudimentary area may appear normal, but they sometimes exhibit great dilatation and may be converted into congenital bronchial cysts, which may occupy a large part of the entire undeveloped area.

Variations in the number and size of the lobes are frequent, especially in the left lung, in which three lobes are not rarely seen. The division, according to Fürst, is commonly due to the presence of an unusual pleural fold, which effects cleavage of the developing lung. In certain instances the additional lobes may possess morphological interest, as pointed out by Schaffner, in connection with the right inferior accessory lobe, which he regards as the homologue of the constant cardiac lobe seen in other animals.

Rarely a rudimentary supernumerary or accessory lung, lying between the normal organ and the diaphragm, is formed in consequence either of an early division of the original anlage and isolation of the separated portion, or of the outgrowth of an additional independent anlage from the primitive gut tube. An interesting example probably involving such latter condition was recorded by Wechsberg.[10] The rudimentary lung was represented by an ovoid tumor, 5 cm. in its longest diameter, that projected into the left pleural sac, and was attached to the œsophagus by a thin stalk, about 2 mm. above the diaphragm. An aberrant course of the arching vena azygos major and the production of an unusual fold of parietal pleura have been held accountable for the presence of an isolated apical lobe in the right lung (Gruber).

MALFORMATIONS OF THE CIRCULATORY ORGANS.—Under this heading will be considered only the congenital defects of the heart and of the closely associated large blood-vessels, the discussion of the variations affecting the smaller vessels belonging less to the domain of teratology than to that of anatomy.

MALFORMATIONS OF THE HEART.—Since congenital defects of the heart largely result from arrested or perverted progress of development, a brief review of the salient features in the formation of this organ will aid in appreciating the significance of the malformations described.

After the fusion of the two, at first widely separated, anlages to form the single straight heart tube, the flexion and torsion of the latter results in the production of a flattened S like tube, of which the antero-inferior portion is the arterial and the postero-superior are the venous segments. These two divisions soon become partially separated by an external groove, which indicates the position of the auricular canal, the primitive auriculo-ventricular opening by which they communicate. The superior continuation of the arterial segment constitutes the truncus arteriosus. The subsequent conversion of the primary two-chambered heart into one, possessing right and left compartments, and of the truncus arteriosus into the aorta and the pulmonary artery is accomplished by the formation of a longitudinal partition consisting of three parts. 1. An interauricular septum, which, beginning in the fourth week on the upper and hind wall of the primitive auricle, grows downward toward the orifice into the ventricle and separates the original venous chamber into a right and a left half. This septum, however, is for a time incomplete, since until after birth it contains the foramen ovale, which permits the blood stream to pass directly from the right into the left auricle. 2. An interventricular septum, which, starting below, gradually effects the division of the common ventricular cavity into a right and a left ventricle. The primary auriculo-ventricular orifice likewise becomes differentiated into a right and a left division by the formation of the septum intermedium, produced by the downward growth of the interauricular partition, and its fusion with the thickened margins of the auricular canal. The separation of the two ventricles is completed last in the upper part of the interventricular septum, where for a time communication between the two sides persists. 3. An arterial septum, which starting some distance above, extends downward toward the heart to meet the interventricular partition and divide the truncus arteriosus into the pulmonary artery and the aorta, which then communicate with the right and left ventricles respectively. The primary disposition of these vessels is such that the aorta lies directly in front of the pulmonary artery; their later relations to each other and to the heart chambers are acquired secondarily in consequence of the rotation and torsion to which they are subjected during development.

Malformations of the septum constitute the most frequent congenital defects of the heart; of these the imperfections of the *interauricular* partition are most common. That such should be the case is to be expected, since the existence of the foramen ovale predisposes to defects of the septum. The *persistence of the foramen ovale* may be complete, with correspondingly large opening; more usually partial closure has taken place, leaving sometimes only a mere cleft between the anterior margin of the foramen and its valve. Fawcett and Blackford[104] conclude that faulty closure of the foramen ovale exists in 28.3 per cent., the opening (most common in female subjects) varying from 1 to 15 mm. A much rarer defect at times occurs at the lower part of the interauricular partition due to faulty union between the latter and the lips of the primitive aural canal. *Total deficiency* of the interauricular septum, a three-chambered heart resulting, occurs very rarely and then in conjunction with other grave defects.

The *interventricular septum* is the seat of defects much less frequently than is the wall separating the auricles. When present, these malformations usually occupy the upper and anterior part of the septum, known as the pars membranacea. This corresponds to the position in which closure is last effected by union of the upward growing crescentic inferior fold, the septum intermedium and the partition dividing the truncus arteriosus into aorta and pulmonary artery. Since the last-named partition is concerned in completing the interventricular wall, imperfections in the latter are not infrequently associated with malposition of the former. This condition may result in disproportionate division of the lower end of the truncus arteriosus, the aortic orifice being enlarged at the expense of that of the pulmonary artery. Complete absence of the interventricular septum may occur, or even failure of both the auricular and ventricular parts of the general longitudinal partition, the heart under such conditions containing but two chambers.

Malformations of the great vessels are connected with the imperfect or perverted development of the septum, which is formed within the truncus arteriosus by the union of two elevations from opposite sides of the vessel. Normally the equal subdivision of the latter vessel is insured by the median position of the partition. Deviations from this by the ridges forming nearer one wall than the other evidently must lead to disproportion in the size of the resulting vessels, the aorta and the pulmonary artery. Such defects are frequently associated with imperfections of the interventricular partition, since the septum within the truncus takes part in the division of the ventricular chamber by joining the upward growing fold. Sometimes, however, extensive deficiency of the aortico-pulmonary septum may exist with normal valves, as in the case described by Hektoen.[105]

Abnormalities in the *number of the leaflets* of the aortic and pulmonary semilunar valves include both increase and decrease. Such congenital variations are usually referable to atypical division of the four primary leaflets which guard the lower end of the truncus arteriosus. When separation of the latter into two new vessels occurs, each elongated lateral primary leaflet is subdivided, of the six resulting segments three going to form the aortic and the pulmonary valve each. Fusion and cleavage of the original segments are responsible for diminution and increase of the leaflets guarding these openings, which may be so few as two or so many as five. The variations produced by pathological processes affecting the valves are manifestly beyond the present consideration.

Stenosis of the pulmonary artery, commonly coupled with narrowing or closure of its cardiac orifice with defective semilunar valves and possibly contracted conus arteriosus, is not infrequent. Although this malformation may exist unaccompanied with a defective interventricular septum, it frequently occurs associated with the latter condition. Deflection of the septum of the truncus may result in abnormal origin of the great vessels, both being connected with the right ventricle, or transposition of their usual relations occurring, the aorta springing from the right ventricle and the pulmonary artery from the left.

Stenosis of the ascending aorta with excessive size of the pulmonary artery sometimes exists, but is far less common than the opposite condition. Such narrowing may likewise occur independently or in conjunction with septal and other defects. Local constriction, or even complete closure and obliteration, at times takes place, as at the "isthmus" between the left subclavian artery and the ductus arteriosus, in consequence of which the circulation is maintained by the enlarged collateral vessels.

Persistence of the ductus arteriosus may occur without other defect, or it may be a compensatory retention, as when the narrowing of the pulmonary orifice exists to a degree that renders necessary the persistence of the vessel as the means of maintaining an adequate pulmonic circulation, the lungs being supplied by the blood that passes into the pulmonary arteries from the aorta by way of the ductus arteriosus. Stenosis of the aortic valve when of high degree is usually associated with feeble development of the left side of the heart and persistence of both the ductus arteriosus and the foramen ovale. By these channels the blood forced into the pulmonary artery partly passes by the ductus into the aorta and general circulation, while the foramen ovale provides the means by which the blood returned from the lungs may escape into the right auricle to mingle with that eventually propelled from the right ventricle.

The *auriculo-ventricular valves* may also present variations involving the number of the segments and the size of the opening. Such defects depend upon abnormal position, fusion or cleavage of the pad-like thickenings, and elevations of the margins of the orifices from which the leaflets are formed. Congenital narrowing, closure or obliteration of the auriculo-ventricular apertures may occur in consequence of fusion of the early segments, or of deflection and union of the septum intermedium with one side of the opening. When closure of the latter is complete, the maintenance of the circulation is possible only when a defective septum exists.

Abnormalities in the number and arrangement of the papillary muscles, the presence of unusual bands, the excessive prominence of the columnæ carneæ, the honeycombed myocardium, etc., depend upon faulty development and consolidation of the muscular heart, which at first consists of a network of contractile trabeculæ.

Variations in the openings of the venous trunks emptying into the right auricle also occur and are dependent upon arrested or disturbed development of the sinus venosus. The latter vessel, the common chamber for the reception of the venous trunks returning the blood to the heart, communicates with the primitive auricle by a single large opening guarded by two valves, a right and left. With the growth and expansion of the heart, the sinus venosus loses its independence and is drawn into the auricle, of which it constitutes the posterior portion. In consequence of this change, the tributaries of the sinus now open by separate apertures directly into the right auricle as the two cavæ and the coronary sinus. Should arrested development prevent the absorption of the sinus, the venous trunks may communicate with the auricle by a common orifice. Stenosis and atresia of these apertures sometimes are observed. The thread-like trabeculæ, at times forming networks, which are occasionally attached to the Eustachian and Thebesian valves, represent, according to Chiari, the remains of the septum spurium and the right valve, which originally guarded the entrance of the sinus venosus.

Variations in the manner in which the *pulmonary veins* terminate in the left auricle are explained by the early relation of these vessels to the heart. The four pulmonary veins at first join to form a single trunk, which empties into the left side of the original auricular division of the young heart before the organ is separated into a right and left half. With the growth and expansion of the auricle, the short single vessel disappears in the heart wall and the separate pulmonary veins open into the auricle by independent openings. Where the extra-cardiac union is more extensive than usual, or the absorption of the primary single trunk is imperfect, the early relations persist, resulting in a simple, double, or triple venous opening.

The *large arterial trunks* arising from the arch of the aorta frequently present variations in their origin and course, which are referable to abnormal metamorphosis of the five pairs of aortic arches given off from the ventral continuation of the truncus arteriosus. The detailed consideration of these anomalies, which especially involve the innominate, common carotid, and subclavian arteries, belong to descriptive anatomy rather than to teratology. The rare occurrence of double aortæ is to be referred to the persistence of the two trunks of early embryonic life.

The *great venous trunks* entering the heart are subject to abnormalities which depend upon either defective development of vessels formed secondarily, or persistence of primary vessels that usually disappear, or at most are of small size. Results of the first cause are seen in the absence of the inferior vena cava above the renal veins, of the left innominate and of the left common iliac vein.

Examples of abnormal persistence are encountered in the presence of the left cardinal veins and of a left duct of Cuvier in the form of exaggerated hemiazygos veins and a left superior cava respectively. Very usually the retention and excessive size of primary veins which ordinarily atrophy are compensatory and due to the defective development or absence of important secondary trunks.

Malposition or transposition of the heart (dextro-cardia), in which the relations of the organ and its great blood-vessels are accurately preserved in reversed order, is usually associated with general situs inversus involving all the viscera within the body cavities. This condition has been already considered. Very rarely the transposition affects the heart and great vessels alone, the remaining thoracic and abdominal organs retaining their normal positions. Reference has been previously made to the partial transposition which may involve the aorta and pulmonary artery and the ventricles in consequence of faulty division and torsion of the truncus arteriosus. Durante[106] describes a striking example of this malposition. The displacement which the heart suffers in conjunction with extensive clefts of the ventral body wall may result in an extra-thoracic position of that organ (*ectopia cordis*). Doubling of the heart has been described as a very rare malformation. Its possible occurrence is ascribed to imperfect fusion and continued independence of the two primary heart tubes, which ordinarily blend to form a single organ.

MALFORMATIONS OF THE URO-GENITAL ORGANS.—*The Kidney*.—In rare cases and often coupled with other grave defects, both kidneys may be totally wanting, or so rudimentary as to be practically absent, being represented by only meagre suggestions of renal tissue. Dykerhoff[107] has called attention to the fact, and described an illustrative case, that living and otherwise well developed children are sometimes born with aplasia of high degree of both kidneys and obliteration of the ureters. Such defects evidently lead to death within a short time after birth. Since the epithelial elements of the organ are derived as expansions of the primitive ureter, which in turn is an outgrowth from the Wolffian duct, the rudimentary condition of the kidney is usually associated with imperfect development of its excretory duct. More frequently only one kidney, most often the left, is rudimentary, in which case congenital compensatory hypertrophy of the one present exists. Deficiency of both organs is manifestly incompatible with life.

The commoner malformations of the kidneys include various degrees of *fusion* and *displacement*. Union of the two organs at their lower ends produces the *horseshoe kidney* often observed. The connection varies in position, size, and intimacy, in some cases the union being little more than apposition; in others a fibrous band forms the junction, while at times actual fusion of the renal tissue takes place. Much less commonly the intervening bridge may occupy the upper or middle portion of the adjacent surface, or the entire opposed borders of the two organs may be united. Two separate pelves and ureters are usually present, the latter sometimes crossing the anterior surface.

When intimately united *displacement* of one of the kidneys often occurs so that both lie on the same side of the spine, the one over the other. Complete fusion of the kidneys sometimes results in a median, flattened renal mass which usually lies in the vicinity of the pelvic brim, sometimes below the promontory of the sacrum, within the pelvis. The common sinus contains a single or double pelvis, from which proceed one or more ureters. Rarely the fused kidneys occupy a lateral instead of a median position. Displacement of the kidneys is usually associated with abnormal arrangement of the renal arteries and veins, the former springing from the adjacent portion of the aorta or common iliac arteries, the veins ending in corresponding localities into the inferior cava or common iliac veins.

Lobulation of the kidney depends upon the persistence of a condition which, while normally seen during fœtal life, ordinarily disappears in the human fœtus before birth. The superficial areas correspond to the bases of the pyramidal lobules of which the immature human kidney is composed.

The Ureter.—Doubling of the excretory canal of the kidney, on one or both sides, is occasionally observed. It may involve the renal pelvis alone, or extend to the ureter, either to the upper part or throughout its entire length. In the latter case the ureters open by independent orifices into the bladder. Gallusser[108] reported the presence of four ureters, two for each kidney, three of which opened into the bladder, while one ended blindly. The ureters may be abnormally short owing to pelvic displacement of the kidney. They are also the seat of irregular constrictions leading to congenital cyst formations.

Abnormal situations at which the ureters may terminate include the seminal vesicles, prostatic urethra and rectum in the male, and the urethra, the vagina, and uterus in the female. The explanation of these aberrant endings is found in the early embryological relations of the Wolffian duct, the cloaca, and the Müllerian duct. Since both ureter and seminal vesicle are the outgrowths from the Wolffian duct, unusual proximity of their embryonal relations may result in later union. Failure in the normal migration of the lower end of the ureter, whereby its point of termination in the urogenital sinus (later the prostatic urethra) is changed to the bladder, results in persistence of the primary close relations to the vas deferens, the representative of the Wolffian duct. Early displacements may bring the primitive ureter into abnormal relations with the hind gut, resulting in the subsequent ending of the ureter in the rectum. The early close association between the primitive renal, Wolffian, and Müllerian ducts accounts for the exceptional ending of the ureter in the vagina or uterus. Occlusions of the urinary duct in consequence of congenital narrowing and closure of the renal pelvis or ureters may take place, resulting in obstruction to the escape of the urine and distention of the tube.

The Bladder.—The urinary bladder is the seat of profound malformations resulting from arrested and imperfect development affecting the cloaca and the allantoic duct. The latter, an outgrowth from the gut tube, extends from the antero-ventral end of the cloaca for a limited distance within the belly-stalk, its intra-embryonic segment contributing the urachus and the upper part of the bladder.

While usually losing its lumen and persisting as a fibrous cord, the median vesical ligament, the urachus not infrequently remains partially pervious in its lower portion, forming either a narrow tube, lined with epithelium, or a small cyst. Exceptionally the pervious portion may communicate with the bladder and become distended. Occasionally, particularly when obstruction of the urethra takes place at an early period, the urachus may retain its lumen throughout and exist after birth as a tube which connects the bladder with the exterior of the body at the umbilicus, constituting a *uracho-vesical fistula*, through which urine may escape. In rare instances persistence of the urachus may lead to the formation of a fissure at the umbilicus of sufficient size to permit the escape of the bladder (*ectopia vesicæ*).

Vesical fissure, the most important malformation of the bladder, is associated with cleft ventral body wall, of greater or less extent, through which the posterior vesical wall appears as a red mucous surface, usually somewhat modified. The orifices of the ureters are often visible. The edges of the cleft bladder are attached to those of the external fissure, the integument and the lining of the bladder being continuous. This condition of *vesical exstrophy* may give place to complete prolapse or *inversio vesicæ*. When the cleavage is extensive it may reach from the umbilicus as far as the anus, involving the pelvis, abdominal walls, and external genital organs (*fissura abdomino-vesico-genitalis*). Vesical fissures, much more common in the male, are frequently associated with rudimentary development of the penis and dorsal cleavage of the urethra (*epispadias*). When the vesico-abdominal cleft is extensive, the posterior bladder wall is sometimes subdivided more or less completely, projecting prolapsed portions of the gut tube intervening. Pubic fissure when present may be accompanied by prolapse of the bladder and gut, causing wide separation of the halves of the cleft external genital organs, including penis or clitoris, scrotum or labia majora, as well as displacement and prevented fusion of the Müllerian ducts, resulting in double vagina and uteri.

Complete absence of the bladder, uncomplicated by other malformations, in consequence of failure of differentiation, occurs very rarely; in such cases the ureters open into the urethra, since the latter then represents the part of the cloaca which normally contributes the lower part of the bladder. Abnormal smallness of the latter is not infrequent. Subdivision of the bladder into two compartments, a larger upper and a smaller lower, sometimes occurs, the constriction in a general way indicating the extent of the allantoic and cloacal portions of the organ. Longitudinal division of the bladder, varying in completeness, has been rarely noted and probably depends upon doubling of the allantoic duct.

The attempt to explain satisfactorily the production of vesical fissure has occasioned much discussion, authorities even at present being by no means in accord. The older theories attributing the cleavage of the vesical and body wall to mechanical influences, such as overdistention of the bladder or rectum by excretions, or unusual traction of the umbilical cord, may be dismissed as entirely inadequate. Zander[109] regards persistence of the dorsal concavity, which normally for a time distinguishes the contour of the early human embryo, as an important factor in the production of these malformations. Failure to assume the normal ventral curve has been attributed to unusual constriction or attachment of the amnion. Although still uncertain as to details, it may be assumed that these clefts are the result of a very early arrest of development involving the primary structures concerned in forming and in differentiating the cloaca, urogenital sinus, and rectum. The studies of Retterer [110] and of Keibel [111] have thrown much light upon the close relations of the cloaca to the normal development of the bladder. The last-mentioned investigator regards the fissures in question as the result of primary imperfection in the development of the ventral walls and bladder referable to faulty closure of the primitive streak. However that may prove to be, it is certain that the defects under consideration are due to a very early developmental arrest.

The Urethra.—The urinary canal, in both sexes, may be wanting, partly occluded or narrowed, due to imperfect development and more or less marked closure of the urogenital sinus. The urethra in the male consists of two embryologically distinct portions. The one, corresponding to the prostatic and membranous segments, is derived directly from the urogenital sinus; the other is formed by the prolongation and fusion of the primary genital folds along the under surface of the developing corpora cavernosa and includes the penile portion of the urethra. Faulty development and coalescence of these folds result in the production of a cleft and imperfect urethra, the abnormal termination of which may be at any point along the under surface of the more or less rudimentary penis. This condition, known as *hypospadias* and relatively common, depends upon faulty development and imperfect fusion of parts which normally exist in duplicate and unite. In the lowest grades of the defect the cleft is limited to the glans; in extreme cases the fissure may extend not only to the root of the penis, but also involve the scrotum, the component halves of which remain separate and unfused, the urethra being open as far as the prostatic segment.

Epispadias, in which the urethral cleft is associated with dorsal fissure of the penis or clitoris, is not only comparatively rare, but much less evident in its mode of production. Since the genital eminence, giving rise to the chief part of the penis or clitoris, exists as an unpaired anlage, the cleavage implies a profound defect and impression at an early period. This malformation is usually associated with vesico-abdominal fissure, very rarely existing alone, hence its genesis is usually regarded as closely identified with the influences producing the more general clefts. In many cases the dorsal groove exposing the urethra, when coincident with vesico-abdominal fissure, extends as far as the bladder, into which it opens in the vicinity of the trigonum. Doubling of the urethra sometimes occurs in consequence of faulty union of the two component halves. In a case described by Löw [112] the two canals opened by independent orifices in the navicular fossa, the smaller and upper tube extending as far back as the prostatic segment.

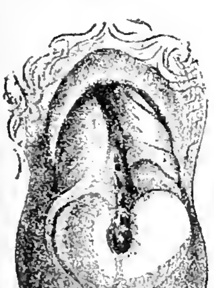

FIG. 4685.—Epispadias. (Hahn.)

MALFORMATIONS OF THE SEXUAL GLANDS AND THEIR DUCTS.—*The Testicle.*—Congenital absence of one or both male sexual glands has been rarely observed. More frequently the defect is only partial, affecting either the testicle itself or its excretory duct. In addition to the imperfections manifested in the epididymis and vas deferens in sympathy with defects of the testicle, these structures may be the seat of independent faulty development.

The most common defect of the testicle is its malposition, occasioned usually by incomplete descent into the scrotum, a migration normally accomplished shortly before birth. The undescended testicle may be retained within the abdomen (*cryptorchism*), either in its primary lumbar position or lodged at the inner end of the inguinal canal. Displacements within the abdominal wall, in front of the external abdominal ring, or within the perineum constitute respectively the inguinal, pubic, or perineal forms of ectopia. One or both testicles may be affected, and, as a great rarity, both organs have been seen to occupy the same peritoneal sac. Frequently the retained organ suffers atrophy, or at least fails to undergo perfect development at puberty.

Malposition or even complete inversion of the descended testicle within the scrotum sometimes takes place in consequence of abnormal attachment and traction of the ligamentum scrotale.

Doubling of the testicle has been observed (Lossen [113]) as a very rare malformation which depends upon subdivision of the primary anlage of the sexual gland. The presence of a single common excretory duct in such cases is explained by the independent origin of the latter from the Wolffian body.

The Ovary.—The absence of both ovaries rarely observed, as well as the more common deficiency of one, is usually associated with other malformations of the generative organs. Sometimes, however, such defects exist along with well-formed oviducts and uterus. In most cases it is probable that absence of the ovary is due to abnormal relations and attachments of adjacent structures, in consequence of which the development of the ovarian anlage is arrested and atrophy follows.

Not infrequently the ovary remains rudimentary, its function as an egg-producing organ being never, or at best only imperfectly, assumed. The ovary may be doubled (Civatte [114]), the supernumerary organ originating from constriction and isolation of a part of the primary anlage, or of the young organ at very early stage.

Malposition of the ovary may occur in consequence of the gland becoming engaged in the inguinal canal and descending into the labium majus. At other times it escapes through the femoral or the obturator canal, or suffers displacement within the pelvis due to abnormalities of the uterus and its attachments.

The Oviducts.—Entire absence of the Fallopian tubes is usually associated with grave malformations of other portions of the generative tract; on the other hand, normal oviducts may exist when the uterus and vagina are defective. Local arrest of the development of the tubes is exhibited in the stenosis and atresia, which may affect either the uterine or abdominal orifices or the intervening portions of the duct, which are at times reduced to a solid cord. Supernumerary abdominal orifices are also encountered (Nagel [115]).

The *uterus* and the *vagina* are subject to malformations arising largely in consequence of imperfect development and faulty fusion of the two Müllerian ducts of the major part, of which these organs are the direct representatives. Normally during the third month of fœtal life the portions of the Müllerian tubes included within the genital cord unite to form a single canal, the upper part of which becomes the uterus, the lower the vagina. The fundus of the uterus for a time is divided into two horns, which are directly continuous with the oviducts, the ununited portions of the Müllerian ducts. Later the uterine horns become incorporated with the fundus.

Imperfect fusion of the Müllerian ducts throughout areas in which union normally takes place results in more or less complete doubling of the uterus and vagina. The duplicity may be effected by a septum within an externally apparently single organ, thereby producing a *bilocular* uterus or vagina. The partition is often limited to one part of the uterus, as the fundus or the cervical segment, or it may imperfectly divide the vagina.

The results of imperfect external fusion of the Müllerian ducts are seen most markedly in the uterus, which then retains the early *bicornate* condition in varying degrees. When the duplicity is restricted to a slight indentation of the fundus (*uterus arcuatus*) the lack of fusion is merely suggested. From this condition all gradations are seen to the complete separation of the tubes (*uterus bipartitus*), at times involving the entire utero-vaginal tract (*uterus didelphys*).

The Müllerian duct of one side may undergo partial obliteration, occasioning the closure and disappearance of the corresponding portion of the doubled uterus, in which one horn may be represented by a solid cord (*uterus unicornis*). Unilateral arrest of development may also affect the Müllerian ducts as shown, when of slight degree, by the asymmetry and obliquity of the uterine fundus. Very rarely the fused ducts may remain so rudimentary that later they are represented by only a solid muscular nodule or cord.

Not infrequently the uterus retains the *infantile form* in consequence of failure of the body segment fully to develop, the cervical portion being unusually prominent as in early life.

The *vagina*, having similar relations to the Müllerian ducts, is subject to the same congenital duplicity as the uterus, although the septum is frequently partial and incomplete. One of the two canals may be partly obliterated by unilateral arrested development of the embryonal tubes. The vagina is very rarely entirely absent. The more usual malformations, however, include narrowing or closure, especially of the upper portion. Congenital vaginal stenosis is often associated with a similar condition, or obliteration, of the uterine cervical canal. Persistence of the infantile type of uterus is usually accompanied by stenosis of the vagina, although the vaginal defects may exist independently of abnormalities of the upper segments of the genital tract. The vagina may be partially represented by a solid cord. The *hymen* is seldom absent; the imperforate, annular, and cribriform types are some of the variations which this duplicature presents.

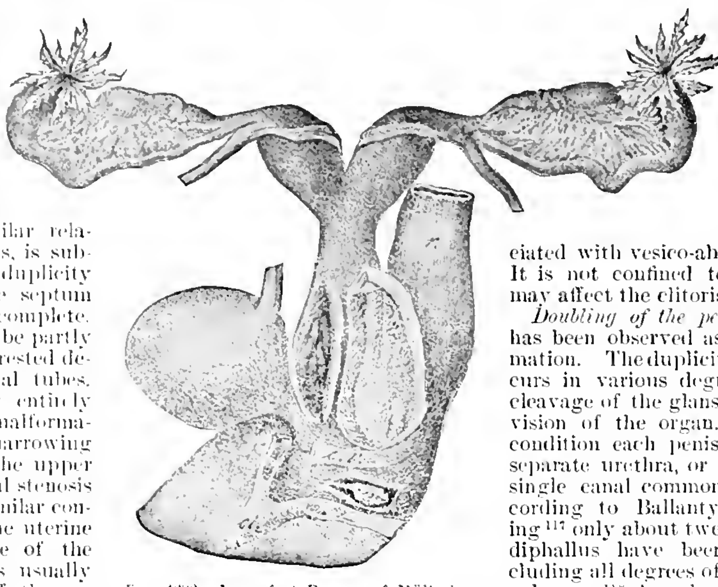

FIG. 4686.—Imperfect Fusion of Müllerian Ducts Resulting in Double Uterus and Vagina. (Schröder.)

MALFORMATIONS OF THE EXTERNAL SEXUAL ORGANS.—The external generative organs of both sexes are derived from three sets of structures—the *genital eminence*, the *genital ridges*, and the *genital folds*—which until the close of the third fœtal month are sexually undifferentiated. Elongation and fusion of these embryonal parts characterize the development of the male organs, while those of the female retain the original separated condition of their constituents.

The Male Organs.—The penis is evolved by the growth and extension of the unpaired genital eminence (from which are derived the corpora cavernosa), in conjunction with the elongation and fusion of the urethral ridges contributed by the walls of the urogenital sinus and the genital folds (from which are formed the corpus spongiosum and the urethra).

The penis may be entirely wanting, although this rare defect is usually associated with other malformations of the external genital organs. More frequently its development is rudimentary in consequence of which the organ remains small and clitoris-like. Arrested or faulty union of the folds, derived from the walls of the urogenital sinus, results in the production of a cleft along the under side of the penis (*hypospadias*) by which the urethra is opened, its termination lying at any point between the glands and the scrotum. When the arrest of development occurs at an early period, the cleft may be extensive and the urogenital sinus may remain entirely open. In such extreme cases the genital ridges, which normally unite to form the scrotum, may persist as separate folds embracing the hypospadial fissure. *Occlusion* and partial *obliteration of the urethra*, on the other hand, may occur in consequence of secondary excessive fusion of the uniting folds, or, when located at the glans, due to persistence if the epithelial urethral septum. Excessive size of the urethral crest surrounding the sinus pocularis has also been found responsible for closure of the urethra (Fuchs[116]). Enormous distention of the bladder and dilatation of the ureters are natural consequences of the obstruction of the urinary passageway. The urethra frequently communicates with the rectum in cases of atresia ani and, in the female, with the vagina when imperfect differentiation in the urogenital sinus exists.

The much rarer dorsal cleft (*epispadias*) is, as already pointed out above, usually associated with vesico-abdominal fissure. It is not confined to the male, but may affect the clitoris as well.

Doubling of the penis (or *clitoris*) has been observed as a rare malformation. The duplicity (*diphallus*) occurs in various degrees, from mere cleavage of the glans to complete division of the organ. In the latter condition each penis may enclose a separate urethra, or there may be a single canal common to both. According to Ballantyne and Skirving[117] only about twenty instances of diphallus have been recorded, including all degrees of duplicity.

Lange[118] has described an additional interesting case in which the two penises lay side by side, each connected with a scrotal sac containing a single testicle. There were two urethræ and two entirely distinct bladders, each with one ureter. The rectum was without anal opening and communicated with both urethræ. This condition, since the primary genital eminence is unpaired, probably depends upon profound early defects involving the cloaca and the urogenital sinus similar to those responsible for the production of epispadias and exstrophy of the bladder.

In rare instances the termination of the Wolffian ducts, later the seminal ducts, is continued during the development of the penis as an independent canal, the urethra being coincidently formed as a second one. In such cases the penis may contain two canals, the one for the products of the sexual glands, the other for the urine. Absence of the prepuce rarely occurs; oftener an abnormal shortening. On the other hand, not infrequently an unusual congenital redundancy exists.

The Female Organs.—In rare instances the external genital organs may be wanting, or so rudimentary that little differentiation into distinct parts takes place. On the other hand, congenital hypertrophy of the clitoris or labia is occasionally seen. Neugebauer[119] has reported the case of a young woman of twenty-two years who possessed a second clitoris, about one inch long, attached to the perineum. it presented the appearance of a diminutive penis, having perfect glans, corpora cavernosa, and partial prepuce, but was imperforate. There where no signs of testicles or other abnormal conditions. Chiarleoni[120] described a remarkable case, that of a child of about three years, in which there were two sets of external genitals, each possessing labia minora and vestibule; on the left side a clitoris was present, below which opened a minute orifice for urine and fæces. A similar aperture opened into the right vestibule. An anus was wanting. The most conspicuous malformations are those arising from an attempt to follow the male type of development. In consequence of such deviation union of the genital folds and ridges takes place, resulting in closure of the vestibule and vagina. Since these malformations play an important part in the production of certain hermaphroditic forms, their consideration is appropriately included under the discussion of that subject.

Hermaphroditic Malformations.

Since the generative organs of the two sexes are differentiated from embryonal structures which are for a time common and neutral, it is not surprising that at times their development is irregular and results in the production of aberrant forms, in which certain characteristics of one sex are combined with those of the other. This applies especially to the generative ducts and the external organs, the sexual glands being very rarely of more than one type in the same individual.

In comparing the various types of sex duplicity it is necessary to bear in mind the salient features of the development of the sexual organs. The latter are produced by three independent but coincident processes: (*a*) the formation of the sexual glands; (*b*) the formation of the excretory ducts; (*c*) the formation of the external genitals.

The sexual gland develops from an anlage in the immediate vicinity of the Wolffian body; for a time indifferent, it later differentiates into testicle or ovary.

The Wolffian body consists essentially of the transverse tubules and their common canal, the Wolffian duct. An additional tube, the Müllerian duct, lies parallel to the former. The four tubes—the two Wolffian and two Müllerian ducts—are associated as the genital cord and open on the posterior wall of the urogenital sinus.

In the development of the male excretory passages, the Wolffian tubules and duct take the most important part, forming the vasa efferentia and coni vasculosa, and the tube of the epididymis and the vas deferens respectively. The Müllerian duct in the male is largely atrophic, remains of its upper extremity persisting as the unstalked hydatid connected with the globus major of the epididymis, while the fused lower ends of the two ducts are represented by the sinus pocularis, or uterus masculinus, on the posterior wall of the prostatic urethra. The sinus pocularis is, therefore, the homologue of the vagina and possibly the uterus. When the intermediate part of the Müllerian duct persists, it constitutes the duct of Rathke.

In the female type the active factors are the Müllerian ducts, the upper segments of which remain separate to become the oviducts, while the remaining parts unite and fuse into a common tube, which becomes the uterus and the vagina. The upper part of the Wolffian duct and some of the associated tubules persist as the epioöphoron, or the organ of Rosenmüller, the homologue of the globus major of the epididymis. The remaining parts of the Wolffian ducts ordinarily disappear, or at best remain to a limited extent as the tubules of Skene, which lie on either side of the vagina. Exceptionally the Wolffian duct persists and is then known as Gärtner's duct.

The external generative organs arise from the genital eminence, genital folds and genital ridges, in conjunction with the urogenital sinus. In the male the genital eminence enlarges to form the corpora cavernosa, the spongy body being formed by the extension of the walls of the urogenital sinus and the genital folds. The scrotum represents the fused and enlarged genital ridges, the raphe indicating the line of union. In the female the original separated relation of the genital ridges and folds persists, the former becoming the labia majora, the latter the nymphæ, while the genital eminence forms the clitoris. The urogenital sinus contributes the urethra and the vestibule.

The duplicity of sex in the same individual implied in the condition termed "hermaphroditism" is almost always only apparent and not real, since response to the crucial test, to be applied to every case by microscopical examination, as to the presence of both forms of sexual glands is rarely affirmative. Hermaphroditism is therefore divided into *true* and *false*.

True Hermaphroditism.—True sexual duplicity (*H. verus*) implies the existence of both the testicle and the ovary in the same subject, the condition of the external generative organs being of far less moment. In view of the manner in which the sexual glands arise, it is assumable that the indifferent anlage of the glands may undergo subdivision, one portion developing into the male, the other into the female organ, or the same may be accepted for the glands of the opposite sides. Theoretically true sexual duplicity may exist in three forms, bilateral, unilateral, and lateral (Klebs).

A. Bilateral hermaphroditism is the condition in which on both sides a testicle and an ovary exist, separate or partly fused into a composite organ. Almost the only instance of this malformation in man worthy of consideration has been the well-known case described by Heppner. In a two-months' child the external organs were of the masculine type, the penis being imperforate. The internal organs included a uterus, with tubes and ovaries on either side; likewise on each side an apparent testicle. While microscopical examination demonstrated the nature of the ovaries, it failed definitely to establish that the neighboring organs were testicles.

Very recently Garré[121] has reported a case which seems to merit the distinction of being regarded as a trustworthy bilateral true hermaphrodite. The individual, who sought the surgical clinic at Königsberg in Prussia, in addition to malformations of the external sexual organs, presented a hernia-like swelling in the left inguinal region. On opening this, various bodies and cords were found which proved to be testicle, epididymis, vas deferens, ovary, oviduct, and parovarium. The diagnosis was positively confirmed by microscopical investigation, the ovary containing numerous well-formed primary follicles and the testicle characteristic, although somewhat atrophic tissue, but without evidences of spermatogenesis. Digital examination through the rectum discovered on the left side two movable bodies, about the size of a pigeon's egg, together with a cord leading laterally to the urethra. These structures were assumed to be the left ovary and testicle with its duct.

B. Unilateral hermaphroditism is the condition in which on one side is a single sexual gland, on the other two—one testicle and one ovary. Two authentic cases presenting these peculiarities have been observed in the human subject, accepting the one described by Gast[122] as such. The latter was a still-born infant with exstrophy of the bladder. A rudimentary but well-developed penis was perforated by a urethra and lay between cutaneous folds. The internal organs were of the female type. The uterus was bifid and on the right was solid with a sheath-like fibrous extension, from which ran an oviduct with abdominal orifice. The left uterine division was also solid and bore an oviduct with fimbriated extremity. Attached to this was an ovary, showing follicles on microscopical examination; on the same side was a testicle, the size of a pea, from which a gubernaculum extended to the base of the left scrotal sac. Microscopical examination showed this organ to correspond to a testicle in its structure. On the right side no sexual gland could be discovered. The most convincing case, reported by Blanker and Lawrence,[123] occurred in a man. Microscopical examination proved the existence of an ovary and testicle upon one side, with the male gland upon the other.

C. Lateral hermaphroditism, in which one gland, testicle or ovary, exists on each side, is the most frequent variety of true double sex and the group within which the majority of reputed cases of true hermaphroditic malformations fall. Very few such cases, however, are substantiated by trustworthy microscopical examinations, and, therefore, are not beyond challenge. Among the most accurately investigated and convincing cases are those reported by Rudolph,[124] Cramer, Meyer, Klebs,[125] Schmorl,[126] Obolonsky,[127] and Zimmermann.[128]

The case reported by Schmorl was that of an art student, aged twenty-two years, who applied to the surgical clinic in Leipsic for operation to correct hypospadias. The scrotum was rudimentary; on the right side was a small testicle, on the left none. The penis was small and drawn bow-like downward, with uncovered, well-formed but imperforate glans. The groove on the under surface of the penis was 3.2 cm. long, running into a small slit 0.5 cm. in length. An operation to correct the hypospadias and to free the penis was performed, but the patient shortly afterward died. The findings at the autopsy were as follows: Face bearded with hairs about 2 cm. long. Breasts undeveloped, but pubes had hairy growth resembling female. The penis, freed from its adhesions by the operation, measured 5.5 cm. in length with a circumference of 8 cm. To the sides of the penis were genital folds which projected above and grasped the penis between them. Opening into the urethra, 3.5 cm. behind the external orifice, was an aperture into which a probe could be passed for 15 cm. Further examination showed this canal to be a vagina and uterus, the latter consisting of a cervix and body. On the right side were a round ligament, tube and ligament analogous to that of the ovary, all of which extended down to the sexual gland in the right scrotal sac. This gland was shown by microscopical examination to be a testicle, although neither spermatozoa nor vas deferens were found. On the left side a tube ran into the inguinal gland and was continuous with an ovoid body, 5 cm. long and 2 cm. thick, which proved to be chiefly a distended and distorted fimbriated extremity. Histological examination revealed within this body a sexual gland having the characteristics of an ovary, but without ova.

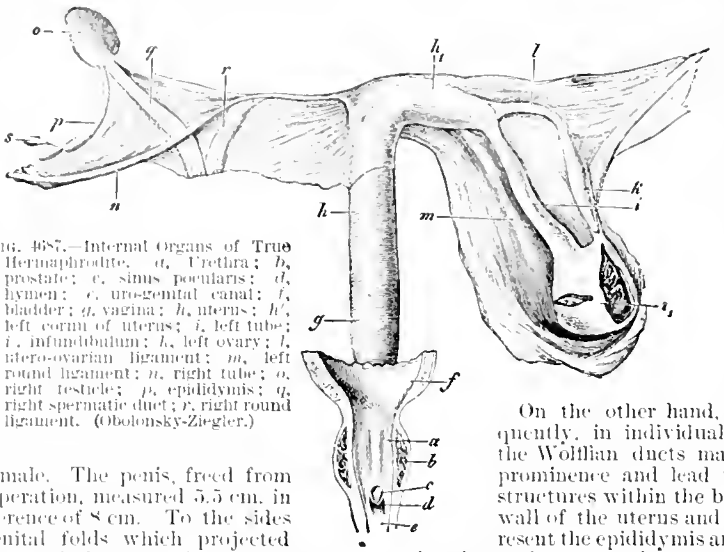

FIG. 4687.—Internal Organs of True Hermaphrodite. *a*, Urethra; *b*, prostate; *c*, sinus pocularis; *d*, hymen; *e*, uro-genital canal; *f*, bladder; *g*, vagina; *h*, uterus; *h′*, left cornu of uterus; *i*, left tube; *i′*, infundibulum; *k*, left ovary; *l*, utero-ovarian ligament; *m*, left round ligament; *n*, right tube; *o*, right testicle; *p*, epididymis; *q*, right spermatic duct; *r*, right round ligament. (Obolonsky-Ziegler.)

The case of Obolonsky was that of a twelve-year-old individual with external organs resembling a female with exceptionally developed clitoris. A well-developed vagina opened into the urethra at the sinus pocularis, guarded by a rudimentary hymen, and led to a unicornate uterus. A prostate was also present. The right broad ligament contained a testicle, an epididymis, and a vas deferens, as well as a rudimentary oviduct and round ligament. The left broad ligament contained an ovary with an ovarian ligament and a well-developed oviduct. Histological examination definitely established the nature of the sexual glands as testicle and ovary.

FALSE HERMAPHRODITISM.—As above pointed out, the crucial test in determining the existence of true double sex is the coexistence of both types of sexual glands; where the presence of these is not established by microscopical examination, the condition is to be regarded as one of pseudohermaphroditism, and the result of aberrant development of the excretory ducts and the external genital organs, which partially represent the characters of both sexes. The most frequent and striking of such malformations are those occurring in individuals of the male sex, in which, in addition to the usual structures, the Müllerian ducts, instead of being rudimentary and atrophic, have undergone unusually extensive development, resulting in the production of an enlarged uterus masculinus, or, in extreme cases, of a more or less well-formed vagina, uterus, and tubes.

In male subjects the external organs may be the seat of aberrant development, in consequence of which the parts assume female characteristics. Thus, the penis may remain rudimentary and resemble a clitoris. Following faulty union of the genital folds hypospadias results, and when extensive the urogenital sinus may open by an orifice resembling a vulva bounded by apparent labia—the ununited scrotal folds, the similarity being sometimes heightened by the absence of testicles in consequence of imperfect descent. Such malformations need not necessarily imply an hermaphroditic condition, although often a part of the defects observed in that connection.

On the other hand, but much less frequently, in individuals of the female sex the Wolffian ducts may assume an undue prominence and lead to the formation of structures within the broad ligament or the wall of the uterus and vagina, which represent the epididymis and vas deferens. Approximation and more or less extensive union of the genital folds, in conjunction with an abnormally large clitoris, may result in closure and obliteration of the vulva to such extent that the urogenital sinus opens beneath the apparent penis by a small aperture resembling a urethra.

Depending upon the predominating sex of the individual, as determined by the character of the sexual gland, pseudohermaphroditism is divided into the *male* and *female* type, in each of which group three varieties are recognized.

Masculine False Hermaphroditism.—I. *Internal*—in which associated with the normal, or nearly so, external male organs are a rudimentary vagina, uterus and, perhaps, tubes. The vagina pierces the prostate and opens into the urethra at the usual position of the sinus pocularis, or uterus masculinus.

II. *External*—in which the outer male organs exhibit faulty development resulting in imperfect fusion of the genital folds and ridges and the consequent resemblance to the female type. The disguise is favored by the general physical characteristics which are often distinctly feminine.

III. *Complete*—in which both internally and externally organs resembling those of the female are present. A more or less well-developed vagina and uterus, possibly also tubes, exist; the vagina opening into a rudimentary urogenital sinus, or short vestibule, into which may lead a groove from the under side of the penis. Less frequently the urethra and vagina open into the urogenital sinus by separate orifices. Very rarely these may be prolonged as canals in an otherwise normal penis, so that this organ possesses apparently double urethræ, the upper tube being the urinary channel, the lower one receiving the sexual ducts.

Of the large number of cases of masculine spurious sex duplicity in the literature the following case, reported by Stroebe,[129] is an interesting example of *pseudohermaphrodismus masculinus internus:* Autopsy on a male subject of sixty-three years showed normal external organs with the exception that the testes were undescended. Within the pelvis an elongated uterus, with well-developed body and fundus (6 cm. broad) lay behind the bladder. On the right side were found an oviduct, a round ligament, and a sexual gland embedded within a broad ligament; on the left the tube was represented by a rudimentary cystic structure that probably was the remains of the Müllerian duct. A sexual gland was also discovered on this side. Microscopical examination showed the sexual glands to be atrophied testicles. The prostate was poorly developed. The uterus opened into the urethra at the sinus pocularis. The course of the vasa deferentia was interesting, since these canals in their lower part lay embedded on either side within the wall of the uterus. The seminal vesicles were abnormal, but the ejaculatory ducts were well developed. These findings point to the simultaneous development of the Wolffian and Müllerian ducts, leading to the production of excretory tubes of both sexes. Failure of the Müllerian ducts to undergo the usual regressive changes was manifestly the immediate cause of the abnormality; the reason for such failure, however, is less evident, although, as pointed out by Stroebe, the disturbing influences must be active at an early period.

Feminine False Hermaphroditism.—This condition is much rarer than in the male. Theoretically it may be subdivided into the three varieties—internal, external, and complete—described in connection with the masculine type.

I. *Internal,* in which, associated with normally formed external organs, the inner are augmented by derivatives of the persistent Wolffian ducts, the homologues of the epididymis and vas deferens, which lie within the broad ligament and the utero-vaginal wall.

II. *External,* in which the external organs assume the appearance of those of the male in consequence of more or less pronounced fusion of the genital folds. The modified parts often resemble a hypospadiac penis with cleft scrotum, the likeness to the latter organ being more striking when, as sometimes happens, the ovary descends through the canal of Nuck into the labium majus. In exceptional instances the urethra may be closed as far forward as the glans clitoridis, in which case the vestibule is no longer open and the external organs resemble those of the male.

III. *Complete,* in which both the internal and external organs present male characteristics. This condition is comparatively very rare. A well-developed prostate and even the homologues of the ejaculatory duct and seminal vesicle have been observed associated with persistent derivatives of the Wolffian ducts.

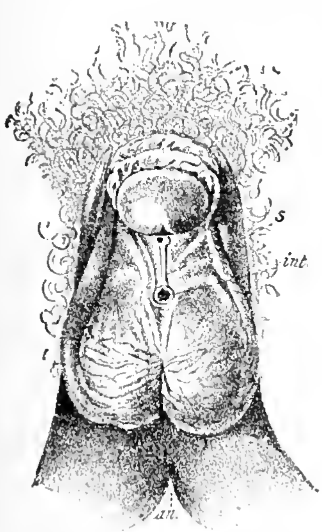

FIG. 4688.—External Organs of Male Pseudohermaphrodite. *s*, Groove; *int*, entrance of uro-genital sinus; *an*, anus. (Günther.)

The determination of the true sex in spurious hermaphroditism by observation upon the living subject is frequently uncertain, especially in view of the possible close resemblances of the external organs to the type opposite the real sex of the individual, as determined by histological examination of the sexual glands. In doubtful cases it is wise to assume that the patient is of the male sex. It should be remembered that spurious menstruation has been observed in masculine false hermaphroditism.

As an example of feminine pseudohermaphroditism established clinically, the case reported by Fitch[130] is of interest. A house servant, aged twenty-eight years, was subjected to examination, when apparently both male and female organs were discovered. The labia majora were of normal size; the labia minora were absent. In place

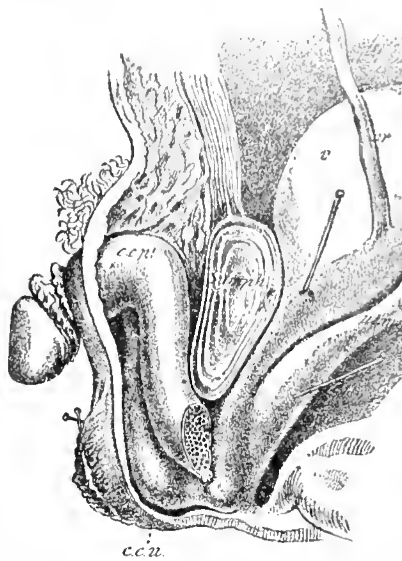

FIG. 4689.—Internal Organs of the Preceding Case. *Symph.*, Symphysis; *v*, bladder; *utm*, uterus masculinus, greatly enlarged; *ur*, ureter; *ccp*, corpus cavernosum; *ccu*, corpus spongiosum. (Günther.)

of the clitoris of usual size was an apparent penis, which, when in erection, measured five and a quarter inches in length and three and three-eighths inches in circumference. The glans was perfect and provided with a urethra. The scrotum was about two inches long and seemingly contained two testicles (?). It was claimed that semen (?) was ejaculated from the urethra. The vagina was spacious and had an os uteri projecting into it. Seven years before the subject had given birth to a normal female infant. Scanty menstruation occurred every three weeks and lasted two days. Sexual gratification was said to be equally distributed between the two sets of organs.

Marchand[131] has described a case of feminine pseudohermaphroditism of exceptional interest as illustrating possible sources of error unless careful histological examination is made of supposed sexual glands. The clitoris was large and but slightly hypospadiac. The vagina opened into the urethra, which was surrounded by a small prostate. Both oviducts were closed at their distal end. Very small ovaries were present in their normal position; that these organs were of this nature was determined by microscopical examination. On the right side the outer border of the broad ligament contained a second body of the size of a well-developed testicle, which proved, however, to be not a sexual gland, but an enlarged accessory suprarenal. Since the presence of these bodies, of very small size, is to be regarded as constant, it is probable that when enlarged they have been mistaken for sexual glands, hence their possible hypertrophy must be borne in mind. Those interested in the literature of the various types of hermaphroditism will find in Taruffi's monograph[132] an exhaustive and systematic review, arranged chronologically.

MALFORMATIONS OF THE EXTREMITIES.—Congenital defects involving the limbs include two chief groups: (1) Those following arrested development, and (2) those occurring in consequence of excessive development, the former resulting in deficiencies, the latter in redundant parts of limbs, especially the digits.

The first appearance of the limb buds in man occurs during the third week of embryonic life, as flattened rounded elevations which project laterally from the body

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wall. During the fifth week these growing processes exhibit differentiation into proximal and distal segments, the latter becoming the hands and the feet. By the close of this week the distal segment shows beginning division into digital areas, the upper limbs anticipating in their differentiation the lower by some days. The proximal segment soon becomes subdivided, so that by the sixth week the three chief segments of each limb are evident. The seventh week brings greater distinctness in the separation of the digits and indication of the carpal region of the hand and the corresponding parts of the foot. With the eighth week appear the elbow- and knee joints. The digits, although advanced in development, are still webbed, being connected by a membranous fold of integument. By the ninth week the several divisions of the limbs are present, but not in their definitive proportions. Thus the length of the entire hand is excessive in relation to that of the arm and forearm; likewise, the fingers are too long in proportion to the remaining parts of the hand, and the thumb too long for the other fingers. As already noted, the upper extremity at first leads the lower in its differentiation, but by the ninth week both are of equal length. From this time, however, the lower limb begins to outstrip the arm in its length growth.

The primary shovel-like form of the limb-bud projects at right angle to the body wall; later, with the differentiation into segments, the limbs become folded ventrally and parallel to the sides, stretching obliquely from head tailward. At this stage the future flexor surface of the limb is presented ventrally, the extensor surface dorsally. The preaxial borders of the limbs (radial and tibial, marked by the thumb and great toe) are directed toward the head; conversely the postaxial borders (ulnar and fibular) look tailward. During subsequent growth the upper and lower limbs undergo partial rotation, the arm turning outward and backward, the leg inward and forward. In consequence of these opposite rotations the preaxial border of the upper extremity (thumb and radius) is carried laterally and dorsally, while the corresponding border of the lower limb (great toe and tibia) is turned medianly and anteriorly, these parts of the two extremities being homologous notwithstanding their apparent dissimilarity in the completely developed condition. In their differentiation from the mesodermic tissue composing the early limb, the skeletal segments follow the order of their relations to the trunk, the proximal segments being first defined, the distal ones last.

FIG. 4690.—Amelus. (Ziegler).

Congenital Deficiencies of the Extremities.—These malformations are attributable to causes of several kinds, some of which lead to primary defects, others to secondary. Among the first are primary deficiency in the primitive limb anlage, perhaps inadequate differentiation of the segments and deficient bone formation. The most important causes producing secondary malformations—those modifying limbs which under favorable conditions would develop into normal members—are inadequate intra-uterine space, thereby inducing pressure, and amniotic adhesions and constrictions. Defective development of the extremities is sometimes associated with profound congenital malformations of the nervous system, as spina bifida, involving the nerve trunks supplying the limbs.

The classification of malformations of the extremities suggested by Kümmel,[133] also followed by Kalussner,[134] is the most consistent grouping based upon anatomical data, and to those especially interested in these defects the monographs by the above authors are of particular value. For the purposes of the general reader, however, the clinical classification is more convenient and, while less exact, presents the defects in a useful sequence; it has, therefore, been followed in these pages.

FIG. 4691.—Phocomelus with Double Harelip. (Hirst and Piersol.)

I. *One or more limbs entirely wanting.*

1. *Amelus.* Both upper and lower extremities are absent, while the trunk is usually well developed. The position of the limbs is often indicated by button-like elevations within a funnel-shaped depression.

2. *Abrachius and Apus.* This condition implies the suppression of either the upper or lower limbs, the remaining pair being often well developed.

3. *Monobrachius* and *monopus* result from absence of a single arm or leg, the other limbs, including the mate to the missing member, may be normal.

II. *One or more limbs defective.*

1. *Peromelus.* All the limbs are imperfect, although the causes have not been so radical in their action as to result in complete absence of the extremities. The degree to which the upper and lower limbs are affected often varies, thereby producing the conspicuous malformation known as *phocomelus.* This is distinguished by the rudimentary condition, or complete suppression, of the proximal segment with relatively well-formed hands and feet. According to Kümmel, the most frequent combinations are (*a*) defective development of thigh with relatively well-developed leg and foot; (*b*) defective development of arm or forearm with comparatively well-formed hand. A defect of the upper extremity corresponding to (*a*), that is, defective arm with well-developed forearm and hand, probably does not occur; likewise suppression of the thigh and leg with well-formed foot is very rarely observed.

2. *Perobrachius* and *peropus* are represented by defective development affecting the upper and lower extremity respectively.

III. *One or more limbs abnormally small, although well formed.*

1. *Micromelus,* in which all of the extremities are deficient in size, the diminution, however, being unattended by malformation.

2. *Microbrachius* and *micropus* include such cases in which the abnormality is limited to one or both arms or legs respectively.

IV. *Limb-bones defective or absent.*

Congenital imperfection or absence of the bones of the arm or thigh, forearm or leg, produces a series of ray defects in which malposition and faulty development of the succeeding segments are usually conspicuous, this being particularly so in the hands and feet in conjunction with the absence of the radius and tibia. Defective fibulæ are generally associated with more or less marked shortening of the limb.

V. *Lower limbs fused.*

Sympus, symmelus, or *siren,* as such malformations are variously termed, is distinguished by more or less complete fusion of the lower extremities. The lower end of the trunk is also defective, as evidenced by the malformations of the pelvis and of the external genital organs and excretory passages which are commonly imperfect. The united limbs usually have undergone rotation outward and backward, so that the primary external surfaces become fused. In consequence of such union the lower half of the body forms a conical mass, which may terminate below in a rudimentary single foot (*Sympus monopus*), or two imperfect feet may be present (*S. dipus*). At other times only one or more stunted toes are seen, or all traces of feet are wanting (*S. apus*), the fused extremities ending in a rounded, somewhat elongated apex.

VI. *Hands or feet defective.*

Malformations of the distal limb segments due to defective or arrested development, or *perodactylism,* occur in great variety as to form and detail. In general these abnormalities result from the deficient formation, or entire suppression, of one or more phalanges, combined frequently with fusion of certain digits (*syndactylism*). The variations in these defects are so great that they include all degrees of imperfection, from the scarcely perceptible shortening of a single finger to the presence of mere stunted knob-like digits. One form of malformation, *cleft hand or foot,* is conspicuous on account of the forked appearance due to separation of the marginal digits by a cleft resulting from the imperfect development, or entire absence, of the intervening metacarpal bone or bones and the directly related carpals. The phalanges of the third finger, with the associated metacarpal and carpals, or the corresponding bones of the foot are most frequently wanting, the remaining digits on either side being fused into a marginal ray. In some cases heredity is apparently an important factor in the production of these malformations, as shown in the striking instance of hereditary brachydactyly recorded by Webb,[135] six generations of a family being "short-fingered."

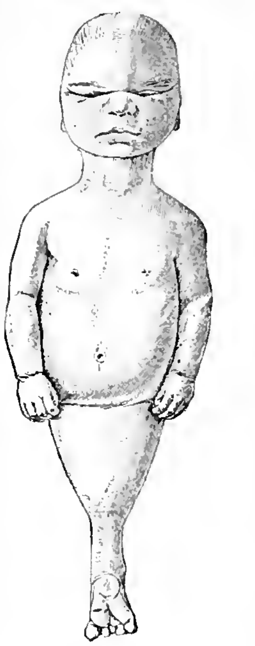

FIG. 4692.—Sympus Dipus. (Ziegler.)

Syndactylism, the congenital union of two or more digits, may be primary or secondary. In the former case the fingers or toes are joined in consequence of imperfect primary differentiation and separation, the digits remaining connected by robust intervening bridges, at times appearing merely as ridges projecting from the fin-like terminal segment. Such malformations are manifestly the result of developmental arrest in consequence either of defective primary formation or of unfavorable influences subjecting the developing digits to unusual pressure. In extreme cases, when all the fingers or toes are blended, the union is usually very intimate, the hand or foot constituting a terminal knob-like mass presenting little resemblance to the normal form. Secondary syndactylism results from more or less extensive union of the digits subsequent to their development. In such cases the connection usually consists of integumentary folds extending for a variable distance from the bases of the digits toward their tips. Exceptionally the union is limited to the latter, the bases remaining free, thereby producing the fenestrated variety of syndactylism.

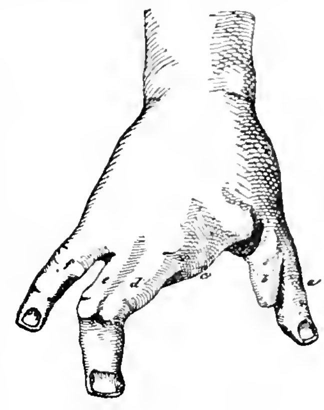

FIG. 4693.—Malformed Hand (Perochirus) with Fusion of Fingers. (Otto.)

Spontaneous or *congenital amputation* of the extremities, effected by constricting cords or bands of amniotic tissue, is responsible for numerous defective limbs. When the ligatures have been insufficient to produce necrosis and complete division of a member, their position is often indicated by marked constrictions and their baneful influence is manifested by the stunted but still attached distal portion of the limb. The latter being compressed within the encircling folds of amnion is unable normally to develop, remains in the fœtal condition, and fails to keep pace with the growth of the more favored parts of the extremity. Spontaneous amputations may involve any part of the extremity, from a part of a single digit to loss of an entire limb. The latter usually ends in a smooth conical stump, while the amputated portion, when separation has occurred at an early period, is commonly not to be found, having undergone complete maceration and disappeared.

Congenital Luxations and Malpositions.—Although the anatomical peculiarities exhibited by osseous and ligamentous structures involved in congenital luxations are usually secondary results and not primary causes of these malformations, the latter call for brief notice in connection with defects of the extremities.

Congenital luxations of the femur are the most important as well as frequent of the prenatal dislocations. They are always secondary and probably due to the effects of malposition of the limbs at a period before the joint was capable of resisting the unusual strain, in consequence of which the femur is forced from its normal socket. Loss of apposition and function result in atrophy and malformation of the femoral head and the acetabulum, the latter being often small and shallow and at times almost wanting. The capsule is stretched and abnormally large. The luxation may be on one or both sides. Similar deformities may affect the knee-, shoulder-, or elbow-joint, although much less frequently.

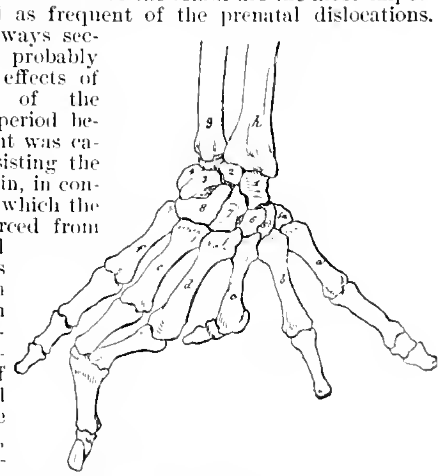

FIG. 4694.—Skeleton of Preceding Deformed Hand. (Otto.)

Congenital malposition of the feet and hands may occur in consequence of faulty position, or undue intra-uterine pressure, without defective development of the skeleton, all types of club-foot or club-hand being observed. In other cases the distortion of the distal segment is associated with defective development of the bones of the forearm or the leg, as of the ulna or radius with talipomanus, or of the tibia with talipes. In the consideration of spina bifida (page 697) attention was called to the frequent occurrence of club-foot with such malformations of the spinal cord. In such cases the talipes results from the loss of balance in the muscular forces acting on the limb in consequence of impairment of the nerve supply to the muscles from the spinal cord.

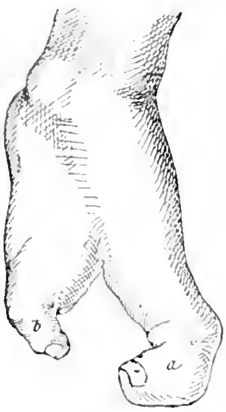

FIG. 4695. Deformed Foot (Peropus). *a, b*, Great and little toes. (Otto.)

The *causes* leading to the various foregoing malformations of all degrees are chiefly those which induce abnormal pressure upon the developing limbs, whether the unfavorable influence be exercised directly by the amnion, or by inadequacy of the space within the uterus. Amniotic attachments or constricting investments are undoubtedly prolific sources of these malformations. Barwell,[136] however, insists that defective limbs are less often the result of constrictions than usually assumed. The histories of many cases, moreover, point strongly to heredity as an additional factor in their production. Ebstein[137] has reported a remarkable example of syndactylism of the fingers and toes through five generations. In other instances it is difficult to account for symmetrical malformations profoundly affecting all the limbs without recognizing an inherent lack of primary development, apart from the dwarfing influences of mechanical forces.

Congenital Redundancies of the Extremities.—These malformations include the frequently observed supernumerary fingers and toes and the rare duplication of the hands or feet. The few instances of reputed doubling of the entire lower limb that have been recorded must be viewed with doubt, since it is highly probable that these cases are to be regarded as double monsters.

FIG. 4696. Skeleton of Preceding Foot. (Otto.)

Polydactylism exhibits all degrees of doubling of the digits, from the scarcely evident partial cleavage of the distal phalanx to the production of a complete two-fold quota of fingers and toes. The presence of ten digits, however, is very exceptional; that of seven or eight is also rare, the most common addition being of only a single supernumerary finger or toe. The position of the latter is usually marginal and about one and one-half times more frequent on the lateral (radial or tibial) than on the median (ulnar or fibular) side. The thumb is oftener doubled than the great toe. The doubling may involve only the phalanges, or the cleavage may begin with the metacarpals or metatarsals. When an entire, comparatively well-formed additional digit is present, it may articulate with the metacarpal or metatarsal of its neighbor, to join directly with the carpal or metacarpal series. More rarely the latter may be also augmented in number to provide special bones and attachments for the extra digit. All possible combinations occur in the relations of the supernumerary parts with the usual digits, especially in conjunction with an associated syndactylism often coincidently present. When very imperfectly developed, the additional finger or toe may be so rudimentary as to be merely a knob-like appendage possessing only integumentary attachment. The extra digits may occur only on a single limb, on both hands or feet, or on all four extremities, although their position is by no means always symmetrical.

The etiology of polydactylism has elicited much discussion, and many theories have been advanced in explanation of these frequent malformations. The assumed causes may be grouped under two headings—external and internal. Foremost among the former are the mechanical impressions due to amniotic cords or folds; among the latter are heredity and excessive differentiation. The presence of opposing amniotic folds is regarded by some authors as the most important factor in producing supernumerary digits which are regarded as arising in consequence of cleavage of the primary anlage, from each portion of which is formed a more or less perfect finger or toe. That in a certain number of cases amniotic folds are probably accountable for the fission resulting in supernumerary digits must be admitted, but the acceptance of such mechanical disturbance as the chief cause of such malformations fails to account for the acknowledged influence of heredity, which is particularly conspicuous in polydactylism. The remarkable case of Muir,[138] in which supernumerary digits were present in five consecutive generations, leaves little doubt as to the importance of these unknown influences in the production of polydactylism.

FIG. 4697.—Polydactylism of Hand. (Ziegler.)

That the presence of amniotic folds is not a necessary condition has been shown by Tornier,[139] who pointed out that polydactylism is particularly frequent in amphibian embryos in which the development of an amnion never takes place. Neither is the assumption convincing that the influence of heredity is not directly exerted upon the limb-anlage, but upon the amnion, in consequence of which a peculiar relation of the amnion to the developing limb is established, resulting in digital fission. It seems scarcely plausible that hereditary influence suffices to arrange amniotic bands with the symmetry necessary to produce supernumerary digits upon all four limbs, as sometimes is the case.

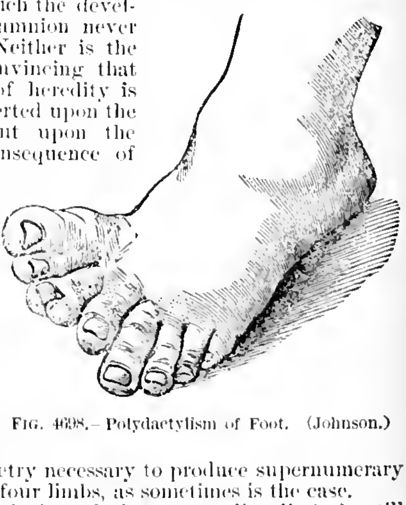

FIG. 4698.—Polydactylism of Foot. (Johnson.)

Since the evolution of the mammalian limb is still shrouded in much uncertainty, we may admit our ignorance concerning the exact rôle played by heredity in producing polydactylism; it is not unreasonable, however, to assume that the impression in some way influences the growth processes which normally result in the differentiation of five digits.

Malformations of the Integument.—The skin is the seat of a variety of congenital abnormalities, some local and others extensive, which depend upon unusual conditions of (1) the epidermis, (2) the cutis and subcutaneous tissue, and (3) the appendages—glands and hair. Since not a few of these congenital abnormalities are caused by pathological lesions more than by errors of development, their consideration falls within the province of dermatology rather than of teratology; such will, therefore, here call for but brief notice.

Abnormalities of the epidermis include more or less general thickening of the epithelial tissue of the integument, which may constitute a horny stratum, several millimetres in thickness, broken only by the furrows caused by the folding and movements of the members of the body. This condition, known as *hyperkeratosis congenita* or diffuse keratosis, is usually characterized by loss of hair and obliteration of sebaceous glands.

Scale-like patches of hypertrophied epidermis distinguish the abnormality termed *ichthyosis congenita*, a condition in which, when extensive, almost the entire body of the fœtus may be covered by irregular areas of greatly thickened epidermis, so that the integument presents a scarred and fissured appearance. When the horny investment of the extremities is very marked, the shell so formed may act as a mechanical restraint to the normal development of the hands and feet, which may, therefore, be defective.

Anomalous pigmentation includes excessive and defective development. The former condition is represented by the smaller or larger colored spots (*nævi pigmentosi*), often very numerous, which may be smooth and unelevated, or raised above the level of the skin and frequently beset with hairs. The color of the pigmented areas varies from a pale to dark brown or black, the epidermis being usually of normal thickness.

Deficient pigmentation or *albinism* of the skin and hair, usually also evident in the iris, choroid, and retina, may be partial or complete. In the latter case the abnormally light-colored skin, white hair, pink irides, and red pupils (due to the vascular reflex through the pigment-free retina and choroid) produce the characteristic appearance of albinos. Partial albinism most frequently affects the hair, genitalia, nipple, and face. The influence of heredity in bringing about the defective development seems questionable, since albinos, although there may be several in one family, are usually the children of ordinarily pigmented individuals, or, indeed, they may be the offspring of negro parents.

Abnormalities of the cutis vera and subcutaneous tissue include the congenital variations affecting the connective tissue of the skin. At times the latter may be of such unnatural density, toughness, and rigidity (*scleroderma congenita*) as to appear tightly drawn, leathery, and unwrinkled. In other cases the same layers may be so loose (*cutis laxa*) that the integument and subcutaneous tissue hang in pendulous folds and admit of unusual extension, recalling the "elastic skin man" of the exhibitions.

In conditions favoring stasis of the venous and lymphatic currents of the subcutaneous tissue, the latter may become the seat of great hypertrophy with enormous distention and infiltration (*elephantiasis congenita*). This condition may affect the integument to such degree that the parts involved lose all resemblance to their normal form. Elephantiasis is frequently observed in acardiac monsters in which the subcutaneous tissue sometimes becomes a misshapen œdematous mass, owing to the infiltration of the areolar tissue.

Dermoid cysts of the skin are not infrequent. These congenital formations are to be distinguished from the true dermoid growths which represent the abortive development of all three germ layers. The ones here under consideration result from abnormal inclusion and isolation of epithelial tissues, which later develop in unusual situations cystic tumors which may attain large size and contain within their walls epidermic deviations, such as hair follicles and sebaceous glands. In accordance with their origin, the favorite seats of such growths are locations in which fusion of the epidermis normally takes place, as along the lines of closure of visceral furrows.

Anomalies of the epidermal derivatives include unusual development of the hair and of the glands.

Congenital *abnormalities of the hair* may be excessive (*hypertrichosis*) or deficient (*hypotrichosis*). The former condition, in which an unnatural profusion occurs in regions ordinarily covered only by fine down, is regarded by Unna and by Brandt[140] as essentially a persistence of the lanugo, or fœtal hair, to the exclusion of the secondary, which commonly later appears. Regarded in this light, hypertrichosis is in fact an arrested development.

The excessive development of hair may be limited (*hypertrichosis localis*), as when confined to some small area, as part of the face in "bearded women," or in individuals possessing hairy nævi or warts; or it may include large tracts or even the entire surface of the body (*hypertrichosis universalis*), as seen in the "wild men" of the museums. In 1883 "Krao," a girl of seven, a native of Indo-China, was exhibited as "Darwin's Missing Link." She was covered with black hair, had prognathic type of face, and possessed extraordinary prehensile powers of lips and feet. Sometimes the hands and feet are uninvolved, as in the case of "Jo-Jo," celebrated as the "Dog-faced Boy." The excessive development of hair commonly takes place after birth, although heredity undoubtedly plays an important rôle in establishing the excessive anlage resulting in this abnormality. Crawford and Yule described a family of Burmah, of which representatives of three generations—father, daughter, and granddaughter—were nearly covered with hair.

Defective development of the hair (*hypotrichosis*) is comparatively infrequent, persistent complete congenital alopecia being decidedly rare. These defects are often associated with deficient formation of the teeth and, sometimes, the nails. A number of instances have been recorded of individuals who have been hairless from birth, even the lanugo having been apparently wanting, although probably partially developed. Heredity here also seems to be an important factor, since in some families congenital alopecia has been noted in successive generations.

Congenital *glandular anomalies* of the skin affect chiefly the sebaceous glands, which may be atrophic or absent, as sometimes seen in keratomous conditions of the epidermis. The cystic growths connected with the sebaceous glands (*atheroma*), formerly regarded as always due to accumulation of secretion, sometimes are probably referable to remains of a congenitally displaced epithelial anlage as a point of origin (Chiari[141]). An excellent presentation of the congenital skin, as well as other diseases affecting the fœtus will be found in Ballantyne's recent work,[142] to which the reader is referred.

Polymastia, the condition of having more than two breasts, is the most important congenital glandular abnormality connected with the integument, since the mammæ in principle are only modified sebaceous glands. Congenital absence of one or both breasts is very rare. Numerical redundancy, on the contrary, is common, supernumerary organs being frequently encountered in both sexes. A distinction, however, must be made between the presence of merely supernumerary nipples (*hyperthelia*) and of additional true milk glands (*hypermastia*), the latter condition being much rarer than the former. The examinations recorded by Bardeleben,[143] including over eleven thousand German soldiers, gave the astonishing results that supernumerary nipples occurred in fourteen per cent., or once in every seven individuals. A percentage so high is probably obtainable only by regarding doubtful cases of pigmented spots as of sufficient significance to be included. Supernumerary nipples seem to be more frequently developed in men than in women; accessory true glands, however, are much more often found in female subjects than in male. The most common situations for the additional nipples are below the position of the normal glands, somewhat nearer the midline; they may occur on one or on both sides, more often, however, on the left side. Other locations of the aberrant nipples generally follow a line passing from the axilla toward the groin; exceptionally they may be upon the back or outer surface of the thigh.

The existence of supernumerary mammary glands is much rarer than of the nipples and is more frequent in women than in men. The positions of such mammæ observed in women include the back, shoulder, axilla, thorax, abdomen, groin, labium majus, and thigh. Trustworthy records show that such organs secreting milk have been located in the axilla, on the chest and the abdomen, in the groin, and on the external surface of the thigh. Hirst [144] refers to a negress of nineteen years who possessed nine mammary glands, five on one side and four on the other. Two of the accessory organs were small and did not secrete; all the others gave milk in large quantities.

The investigations of O. Schultze [145] have shown that the mammary glands are developed along the *milk lines*, ridges of thickened epithelium extending from the dorsal surface, in the vicinity of the fore limbs, ventrally to end in the inguinal region. These observations at once point out the correspondence between the location of the majority of supernumerary nipples and milk glands and the normal formation tracts, the excessive mammæ of the human subject marking unusual development of possible anlages which ordinarily remain quiescent. The influence of heredity seems to be uncertain, although in a number of reported cases both mother and daughter presented polymastia, although the location of the supernumerary mammæ was not identical.

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LITERATURE.

The enormous and ever-increasing volume of the literature relating to malformations forbids any attempt to present systematically in these pages even a synopsis of teratological bibliography. Fortunately this is also unnecessary, since those especially interested will find a practically complete bibliography since 1886 in the Anatomischer Anzeiger and the Centralblatt für allgemeine Pathologie, as well as in Schwalbe's "Jahresberichte der Anatomie u. Entwickelungsgeschichte." The "Reports on Teratological Literature" by Windle, which appear from time to time in the Journal of Anatomy and Physiology, are also useful. A valuable general bibliography, including the most important papers, is appended to Marchand's article "Missbildungen" in Eulenburg's "Real-Encyclopädie." For the older literature the reader can consult with advantage Förster, "Die Missbildungen des Menschen," 1861, and Ahlfeld, "Die Missbildungen des Menschen," 1880. A comprehensive list of journal references and monographs, appearing between 1880 and 1901, will be found in Hirst and Piersol's "Human Monstrosities."

The titles given below are only those of papers to which direct reference has been made in the foregoing article.

1 Ballantyne: Teratogensis. Edinburgh Med. Jour., Nos. 493, 5, 6, 1896.

2 Meckel: Handbuch d. patholog. Anatomie, 1818.

3 Gade: Et Tilfaelde af Anencefali, etc. Norsk Magaz. for Laegevidensk., 1891.

4 His: Anatomie menschlicher Embryonen, 1885.

5 His: Offene Fragen der pathologischen Embryologie. Virchow's Festschrift, 1891.

6 Giacomini: Probleme aus Entwickelungsanomalien d. mensch. Embryo. Merkel u. Bonnet's Ergebnisse, Bd. iv., 1894.

7 Mall: A Contribution to the Study of the Pathology of Early Human Embryos. Johns Hopkins Hospital Reports, vol. ix., 1901.

8 Joachimsthal: Ueber angeborene Verbildungen an extrauterus gelagerten Foeten. Berlin. klin. Wochenschr., 1897.

9 Ridlon: Some Unusual Congenital Deformities. Trans. Amer. Orthop. Assn., 1896.

10 Tesdorpf: Beschreibung einer mit amniotischen Bändern behafteten Missbildung, 1883.

11 Ahlfeld: Neue typische Form durch amniotische Fäden hervorgebrachter Verbildung. Festschrift f. d. Gesellsch. f. Geburtsh. u. Gynäk. zu Berlin, 1894.

12 Ballantyne: Teratogenesis. Edinburgh Med. Jour., 1896.

13 Winckel: Aetiologische Untersuchungen über einige sehr seltene Missbildungen. Münchener med. Wochenschrift, No. 17, 1896.

14 Förster: Die Missbildungen des Menschen, 1865.

15 Marchand: Article "Missbildungen" in Eulenburg's Real-Encyclopädie der gesammten Heilkunde, 1897.

16 Eddowes: A Newborn Infant of Extraordinary Size. London Lancet, vol. ii., 1884.

17 Dickinson: A Child Weighing Twenty Pounds at Birth.—A Child with a Tail. Brooklyn Med. Journal, 1894.

18 Rice: Boston Med. and Surg. Journ., 1876.

19 Baldwin: Presentation of Cases. Brooklyn Med. Jour., 1894.

20 Beach: A Giant Birth; the Child Weighing Twenty-three and Three-quarters Pounds. Medical Record, 1879.

21 Nagel: Princess Paulina. Pediatrics, 1896.

22 Home: Philosoph. Trans. Royal Soc. of London, 1825.

23 Mursick: American Intelligence. Am. Jour. Med. Sc., 1874.

24 Baker: Trans. Med. and Physical Soc. of Calcutta, 1825.

25 Caton: Case of Complete Transposition of Viscera. Jour. Anat. and Physiol., 1897.

26 Lochte: Beiträge zur Kenntniss d. Situs transversus partialis. Ziegler's Beiträge, Bd. xvi., 1894.

27 Koller: Ein Fall von Situs viscerum inversus totalis und seine Deutung. Virchow's Archiv, Bd. clvi., 1899.

28 Born: Ueber Verwachsungsversuche mit Amphibienlarven. Archiv f. Entwick.-Mechanik., Bd. iv., 1897.

29 Gemmill: The Anatomy of Symmetrical Double Monstrosities in the Trout. Proc. Royal Society, 1901. (See Jour. Anat. and Physiol., April, 1902.)

30 Gerlach: Die Entstehungsweise der Doppelmissbildungen, 1882.

31 Gerlach: Ueber die Entstehungsweise der vorderen Verdoppelung. Deutsches Archiv f. klin. Med., Bd. xlii., 1887.

32 Klaussner: Mehrfachbildungen bei Wirbelthieren, 1890.

33 Marchand: Loc. cit., p. 491.

34 Morgan: Half-Embryos and Whole-Embryos from One of the first two Blastomeres of the Frog's Egg. Anatom. Anzeiger, Bd. x., 1895.

35 O. Schultze: Die künstliche Erzeugung von Doppelbildungen u. s. w. Archiv f. Entwickelungsmechanik, 1894.

36 O. Hertwig: Missbildungen und Mehrfachbildungen. Handbuch der Entwickelungslehre der Wirbeltiere, 1903.

37 Féré: Sur l'influence des injections de la solution dite physiologique du sel, etc. C. R. Soc. de Biolog., 1896.

38 Wetzel: Drei abnorm gebildete Eier von Tropidonatus natrix. Anat. Anzeiger, Bd. xviii., 1900.

39 Schumacher und Schwarz: Mehrkernige Eizellen und mehreiige Follikel. Anatom. Anzeiger, Bd. xviii., 1900.

40 Blanc: Exposé d'une classification tératologique. Ann. d. l. Soc. Linnéenne de Lyon, 1895.

41 O. Schultze: Zur Frage von der Entwicklung der Doppelbildungen. Ziegler's Centralblatt f. allg. Pathol. u. path. Anat., Bd. x., 1899.

42 Sobotta: Neuere Anschauungen über die Entstehung der Doppelbildungen. Würzburger Abhand., Bd. i., 1901.

43 Broman: Ueber atypische Spermien und ihre mögliche Bedeutung. Anatom. Anzeiger, Bd. xxi., 1902.

44 Broman: Ueber Bau und Entwickelung von physiologisch vorkommenden atypischen Spermien. Anatom. Hefte, Bd. xviii., 1902.

45 Retzius: Weitere Beiträge zur Kenntniss der Spermien des Menschen und einiger Säugethiere. Biolog. Untersuch., N. F. x., 1902.

46 Ballowitz: Ueber das regelmässige Vorkommen zweischwänziger Spermien im normalen Sperma der Säugetiere. Anat. Anzeiger, Bd. xx., 1902.

47 Windle: On the Origin of Double Monsters. Jour. Anat. and Physiol., vol. xxiii., 1889.

48 Windle: On Some Conditions related to Double Monstrosity. Jour. Anat. and Physiol., vol. xxviii., 1894.

49 Duval: Les monstres par defaut et les monstres par excès de fecondation. Ann. de Gynéc. et d'Obstét., 1895.

50 Laguesse et Bué: Sur un Embryon Humain Derodyme de Dix-neuf Millimètres, et sur l'Origine des Monstres Doubles en Général. Jour. de l'Anatom. et d. l. Physiol., 1898.

51 Sobotta: Die Befruchtung und Furchung des Eies der Maus. Archiv f. mik. Anat., Bd. 45, 1895.

52 Marchand: *Loc. cit.*, p. 503.

53 Schatz: Klinische Beiträge zur Physiologie des Foetus. Berlin, 1900.

54 Gemmill: An Ischiopagus tripus. Jour. of Anat. and Phys., vol. xxxvi., 1902.

55 Barfurth: Ein Zeugniss für eine Geburt von Siebenlingen beim Menschen. Anat. Anzeiger, Bd. x., 1895.

56 Kreutzmann: Ueber einen Fall von Epignathus u. s. w. Inaug. Diss., Marburg, 1895.

57 Ahlfeld: Missbildungen des Menschen, 1880.

58 Broer und Weigert: Teratoma orbitæ congenitum. Virchow's Archiv, Bd. 67, 1876.

59 Beck: Teratom der Hypophysis cerebri. Zeitsch. f. Heilkunde, 1883.

60 Eberth: Intracranielles Teratom mesodermalen Ursprungs. Virchow's Archiv, Bd. 153, 1898.

61 Strassmann und Strecker: Teratom im rechten Seitenventrikel. Virchow's Archiv, Bd. 108, 1887.

62 Gauderer: Teratom der Zirbeldrüse. Inaug. Diss., Giessen, 1892.

63 Aretæos: Parasitus pentadymus encranius. Virchow's Archiv, Bd. 23, 1862.

64 Lovett and Councilman: Jour. of Experimental Med., May, 1898.

65 Brunker: Ungar. med. Presse, Bd. iii., 1900.

66 Christian: Dermoid Cysts and Teratomata of the Anterior Mediastinum. Boston City Hospital Reports, 1901.

67 Pflanz: Ueber Dermoidcysten des Mediastinum anticum. Zeitsch. f. Heilkunde, Bd. xvii., 1896.

68 Wilms: Ueber die Dermoidcysten und Teratome. Deutsches Arch. f. klin. Med., Bd. 55, 1895.

69 Virchow: Teratoma myomatodes mediastini. Virchow's Archiv, Bd. 53, 1871.

70 Marchand: Missbildung. Eulenburg's Encylopädie, 1897, p. 536.

71 Ekehorn: Die Dermoidcysten des Mediastinum anticum. Archiv f. klin. Chir., Bd. 56, 1898.

72 Fletcher: Congenital Cyst of the Mediastinum. Brit. Med. Jour., 1897.

73 Windle: On some Conditions related to Double Monstrosity. Jour. Anat. and Phys., vol. xxviii., 1894.

74 Himly: Geschichte des Fötus in foetu. Hannover, 1831.

[75] Paquy: Rapport par M. Porak sur une note de M. Paquy intitulée "Tératome développé dans l'Epiploon Gastro-hépatique d'un Fœtus du sexe feminin de huit mois environ." Comp.-Ren. d. l. Soc. d'Obstét. de Paris, 1900.
[76] Lexer: Ein Fall von Torsion des Hodens mit Missbildung des Nebenhodens. Langenbeck's Archiv, Bd. 61, 1900.
[77] Klebs: Handbuch der path. Anatomie, 1876.
[78] Highmore: Case of a Fœtus found in the Abdomen of a Young Man. London, 1815.
[79] Ballantyne: Report of Specimen of Fœtus in Fœtu. Brit. Med. Jour., November 17th, 1900.
[80] Wilms: Ueber die Dermoidcysten und Teratome u. s .w. Deut. Arch. f. klin. Med., Bd. lv., 1895.
[81] Wilms: Ueber die soliden Teratome der Ovarien. Ziegler's Beiträge, Bd. xix., 1896.
[82] Wilms: Die teratoiden Geschwülste des Hodens. Ziegler's Beiträge, Bd. xix., 1896.
[83] Répin: Kyste dermoïde de l'ovaire. Annal. de Gyn. et d'Obstét., 1892.
[84] Assheton: Reinvestigation in the Early Stages of the Development of the Rabbit. Quart. Jour. of Mic. Sc., 1895.
[85] Bonnet: Beiträge zur Embryologie des Hundes. Anat. Hefte, Bd. ix., 1897.
[86] Bandler: Die Dermoidcysten des Ovariums, ihre Abkunft von dem Wolffschen Körper. Arch. f. Gynäkol., Bd. lxi., 1900.
[87] Bonnet: Giebt es bei Wirbeltieren Parthenogenesis? Ergebnisse d. Anat. u. Entwick., Bd. ix., 1899.
[88] Beard: The Morphological Continuity of the Germ-Cells in Raja batis. Anatom. Anzeiger, Bd. xviii., 1900.
[89] Roux: Ueber des künstliche Hervorbringen halber Embryonen u. s. w. Virchow's Archiv, Bd. civ., 1888.
[90] Coley and Buxton: Teratoma of the Testis. Annals of Surgery, September, 1901.
[91] Lehmann-Nitsche: Ein seltener Fall von angeborener medianer Spaltung der oberen Gesichtshälfte. Virchow's Archiv, Bd. clxiii., 1901.
[92] Lexer: Angeborene mediane Spaltung der Nase. Archiv f. klin. Chir., Bd. lxii., 1901.
[93] Kuse: Ueber Agnathie und die dabei zu erhebenden Zungenbefunde. München. med. Wochenschr., 1901.
[94] Kostanecki and Mielecki: Kiemenfistein des Menschen. Virchow's Archiv, Bd. cxx., 1890.
[95] E. Schwalbe: Ueber kongenitale Zwerchfellsherulen. Münch. med. Wochenschr., 1899.
[96] Hoffmann: Atresia œsophagi congenita. Dissertation. Greifswald, 1898.
[97] Tandler: Zur Entwicklungsgeschichte des menschlichen Duodenum. Morph. Jahrbuch, Bd. xxix., 1900.
[98] Ratz: Kasuistik der kongenitalen Okklusionen des Dünndarms. Dissertation, Erlangen, 1899.
[99] Albrecht: Ein Fall von sehr zahlreichen, über das ganze Peritoneum versprengten Nebenmilzen. Ziegler's Beiträge, Bd. xx., 1896.
[100] Zander: Beziehungen d. Nebennieren zu anderen Organen, speciell zum Grosshirn. Ziegler's Beiträge, Bd. xxvii., 1900.
[101] Aichel: Vergleichende Entwicklungsgeschichte und Stammesgeschichte der Nebennieren. Archiv f. mik. Anat., Bd. lvi., 1900.
[102] Herxheimer: Ueber einen Fall von echter Nebenlunge. Centralblatt f. allg. Patholog., Bd. xii., 1901.
[103] Wechsberg: Missbildung der Lunge. Centralblatt f. allg. Pathologie, Bd. xi., 1900.
[104] Fawcett and Blachford: The Frequency of an Opening between the Right and Left Auricles, etc. Jour. Anat. and Phys., vol. xxxv., 1901.
[105] Hektoen: Rare Cardiac Anomalies. Amer. Journ. of Med. Sci., vol. cxxi., 1901.
[106] Durante: Cyanose congénitale par anomalie cardiaque, etc. Bull. d. l. soc. anat. d. Paris, An. 74, 1899.
[107] Dykerhoff: Ein Fall von angeborener Aplasia beider Nieren u. s. w. Dissert., Kiel, 1901.
[108] Gallusser: Ein Beitrag zur Kenntniss der Missbildungen des Ureter. Dissertation, Zürich, 1900.
[109] Zander: Ueber Schistosoma reflexum des Menschen. Festschrift v. Max Jaffe, Braunschweig, 1901.
[110] Retterer: Sur l'origine et évolution de la région anogénitale. Arch. d. l'anat. e. d. l. physiol., An. 26, 1890.
[111] Keibel: Zur Entwicklungsgeschichte der Harnblase. Anat. Anzeiger, Bd. vi., 1891.
[112] Löw: Ueber Doppelbildung der Harnröhre. Wiener med. Wochenschr., Bd. l., 1900.
[113] Lossen: Ueberzähliger Hoden. Festschr. d. Stadtkrankenhauses zu Dresden.-Friedrichstadt, 1899.
[114] Civatte: Anomalie des organes génitaux. Bull. Soc. Anat. d. Paris, 1899.
[115] Nagel: Entwickelungsfehler d. weib. Genitalien. Veit's Handb. d. Gynäk., 1897.
[116] Fuchs: Zwei Fälle von kongenitaler Hydronephrose. Dissert., Zürich, 1900.
[117] Ballantyne and Skirving: Diphallic Terata. Teratologia, vol. ii., 1895.
[118] Lange: Verdoppelung des Penis. Ziegler's Beiträge, Bd. xxiv., 1898.
[119] Neugebauer: Angeborene Anomalien der äussern Genitalien beim Weibe. Centralbl. f. Gynäkol., February 4th, 1899.
[120] Chiarleoni: Duplicita genit. estern. e mane. di ano. Ann. di Obstet. e Ginec., 1894.
[121] Garré: Ein Fall von echtem Hermaphroditismus beim Menschen. Anatom. Anzeiger, Bd. xxiii., No. 1., 1903.
[122] Gast: Beitrag zur Lehre von der Bauchblasengenitalspalte und von Hermaphroditismus verus. Dissert., Greifswald, 1884.
[123] Blanker and Lawrence: A Case of True Unilateral Hermaphroditism. Trans. London Obstet. Society, vol. xxxviii., 1897.
[124] Rudolph: Beschreibung einer seltenen menschlichen Zwitterbildung. Berliner Akad., 1825.
[125] Klebs: "andbuch d. Patholog., 1876.
[126] Schmorl: Ein Fall von Hermaphroditismus. Virchow's Archiv, Bd. cxiii., 1888.
[127] Obolonsky: Beiträge zur patholog. Anatomie d. Hermaphroditismus hominis. Prager Zeitschr. f. Heilkunde, 1888.
[128] Zimmermann: Ein Beitrag zur Lehre vom menschlichen Hermaphroditismus. Dissert., Munchen, 1901.
[129] Stroebe: Ein Fall von Pseudohermaphrodismus masc. inter. Ziegler's Beiträge, Bd. xxii., 1897.
[130] Fitch: Hermaphroditism. New York Med. Journ., 1890.
[131] Marchand: Beiträge zur normalen und pathologischen Anatomie der Glandula carotica und der Nebenniere. Internat. Beiträge zur wissenschaftl. Medicin. Bd. i., 1891.
[132] Tarufil: Hermaphrodismus und Zeugungsunfähigkeit. Deutsche Ausgabe von Teuscher, Berlin, 1903.
[133] Kümmel: Die Missbildungen der Extremitäten durch Defekt, Verwachsung und Ueberzahl, Stuttgart, 1895.
[134] Klaussner: Ueber Missbildungen der menschlichen Gliedmassen, Wiesbaden, 1900.
[135] Webb: A Case of Hereditary Brachydactyly. Journ. Anat. and Phys., vol. xxxv., 1901.
[136] Barwell: A Case of Congenital Limb Deficiency and Redundancy. Trans. Path. Soc., London, vol. l., 1899.
[137] Ebstein: Vererbung von Missbildung der Finger und Zehen. Virchow's Archiv, Bd. cxliii., 1898.
[138] Muir: Curious Instance of Abnormal Development of Adventitious Fingers and Toes. Glasgow Med. Journ., June, 1884.
[139] Tornier: Ueber Hyperdactylie, Regeneration und Vererbung mit Experimenten. Archiv f. Entwickelungsmechanik, Bd. iii., 1896.
[140] Brandt: Ueber die sogenannten Hundemenschen, bezw. über Hypertrichosis universalis. Biolog. Centralbl., Bd. xvii., 1897.
[141] Chiari: Ueber die Genese der Atheromcysten. Zeitschr. f. Heilkunde, Bd. xii., 1891.
[142] Ballantyne: Antenatal Pathology and Hygiene. The Fœtus, New York, 1902.
[143] Bardeleben: Weitere Untersuchungen über die Hyperthelie bei Männern. Anatom. Anzeiger, Bd. vii., 1892.
[144] Hirst: Supernumerary Breasts. University Med. Mag., May, 1896.
[145] Schultze: Ueber die erste Anlage des Milchdrüsenapparates. Anatom. Anzeiger, Bd. vii., 1892.

TERATOMA.—A teratoma is a tumor-like growth characterized essentially by the fact that the tissue-formation of which it is composed does not occur normally in the affected region, or at least not during that period of bodily development in which it presents itself. Such a growth may consist of a single tissue, or may be represented by a cyst (*simple teratoid tumor* or *cyst*); but more frequently it is made of several tissues arising from more than one of the germ layers (*mixed tumor*, "*Mischgeschwulst*"). To the more complicated forms the term teratoma is often applied in a more narrow sense, while those highly complex growths which contain tissues derived from all three of the germ layers are known as *embryoid tumors* or *embryomata*. Teratomata composed of tissue-formations which are out of place in the region where found are known as *heterotopous;* those composed of tissue occurring in a given region at a time when it should not normally be found there are known as *heterochronous*. The tissue-formation composing the teratoma takes its origin either from the anlage of the individual affected (*monogerminal*, *endogenous*, or *autochthonous teratoma*), or from the anlage of a second individual (*bigerminal* or *ectogenous teratoma*, *fœtus in fœtu*). Further, either a sarcomatous or a carcinomatous proliferation may develop within a teratoma, and the growth thereby assume the characteristics of a malignant tumor (*malignant teratoma*).

According to their structure, teratomata may be divided into the following varieties:

Teratomata.
1. Simple teratoid tumors. } Ectodermal. { Dermoid. Epidermoid.
2. Simple teratoid cysts. } Mesodermal. Entodermal.
3. Complex teratomata and teratoid cysts (embryoid tumors and embryomata).
4. Malignant teratomata.

I. Simple Teratoid Tumors.—In this class are placed both heterotopous and heterochronous tissue-formations of simple structure, consisting of but a single variety of tissue, or at most of but a few forms of tissue. For the greater part they consist of heterotopous tissue-proliferations which have their origin in misplaced or persistent fœtal anlage. They may occur in any part of the body, but are found most frequently in certain regions. The most common tumors of this class are the hypernephroma (*kidney, kidney region, liver, etc.*), rhabdomyoma or rhabdomyosarcoma (*kidney, testicles, vas deferens, heart, va-*

gina, cervix, bladder, etc.), chondroma (*salivary glands, mamma, skin, testicles*, etc.), chondromyxoma (*salivary and lachrymal glands, mammæ, testicles*), adenomyxoma (*mamma*), adenosarcoma (*kidney*), adenomyoma (*uterus, broad ligament*), leiomyoma (*kidney*), osteoma (*muscles, skin, mamma*, etc.), lipoma (*meninges*), and the tumor-like formations found along the vertebral column (*coccygeal and lumbosacral lipomata, myolipoma, and the tumors of this region which contain nervous elements*).

The occurrence of tissue-formations in regions in which such tissue-elements are not normally found may be explained by the assumption of a misplacement of tissue anlage, or of tissue at a later stage of development, or of the persistence of undifferentiated cells, which possess the power of producing different forms of tissue. In general, it may be said that the simple teratoid tumors correspond in their structure with the tissue-differentiations occurring normally in the region in which they arise. Every part of the body practically has its corresponding mixed tumor, which in its structure harmonizes with the normal differentiation of the tissues and organs of that region. Thus, for example, the mixed tumors of the salivary and lachrymal glands contain cartilage, bone, myxomatous tissue, connective tissue, epidermis, and glandular tissue, corresponding to their origin from ectodermal and mesenchymal anlage of the head or mouth region. In the mixed tumors of the mamma myxomatous tissue, cartilage, epidermis, and gland tissue are found, corresponding to their origin from ectodermal and mesenchymal or mesodermal anlage. The mixed tumors of the kidney and kidney region which contain striped muscle, cartilage, etc., arise from anlage of the myotome and middle plate. Those of the vagina and cervix arise from the anlage derived from the myotome and sclerotome, or from that portion of the mesoderm lying posterior to the kidney. It is probable that the teratoid growths of this region are dependent upon the development of the Wolffian duct, as they are situated for the greater part in the region of the ducts of Gärtner. The fatty tumors containing epithelial and nervous structures, which are found along the spinal column, chiefly in the lumbo-sacral and coccygeal regions, are due to misplacements of anlage or tissue caused by defective development of the vertebral arches, and are to be classed with the various forms of the malformation known as *spina bifida occulta*. Similar tumors are also found in the cranium. In the changes following a hernial protrusion of the spinal cord and meninges in spina bifida both adipose tissue and striped muscle may be misplaced into the spinal canal. Transposition of adipose tissue, muscle, cartilage, ependymal tissue, and neuroglia is not infrequently seen in these malformations. The lipomata of the cerebral meninges are likewise to be explained in part as due to a transposition of adipose tissue following or attendant upon a defective development of the cranium.

Though the great majority of the simple teratoid tumors are to be regarded as heterotopous proliferations of tissue arising from autochthonous fœtal anlage, it is also possible that some may be due to bigerminal inclusions, in which only one or but a few of the tissues of the parasitic twin persist. The parent cells of the simple teratoid growths in either case remain latent or grow slowly until through some exciting factor a more active proliferation is set up. At first the misplaced anlage increases through a proliferation of undifferentiated cells, but with changing conditions of growth a portion of the cells becomes differentiated, and there are formed mature tissues, which may continue to proliferate in their differentiated form. The causes of active proliferation of latent anlage are unknown; inflammation or irritation or atrophy of the affected part may play the rôle of exciting factor. That the early stages of growth consist in the formation of undifferentiated cells is shown by the fact that the younger portions of the tumor are always composed of such cells. These may predominate to such an extent that the growth resembles a sarcoma (adenosarcoma, rhabdomyosarcoma). Further, the fact that the different tissues constituting the growth (cartilage, striped muscle, etc.) occur in all parts of the tumor can be explained only by the assumption of a later differentiation of cells arising through the proliferation of the undifferentiated cells of the misplaced or persistent anlage. Moreover, the fact that the metastases of the mixed tumors may contain all the tissue found in the primary points to the metastasis of undifferentiated cells, which later become differentiated.

The simple teratoid tumors of the salivary glands, mamma, kidney, uterus, etc., though placed in the same tumor class because of their analogous origin from cells of the ectoderm, mesenchym or mesoderm, nevertheless show great differences in their manner of growth, malignancy, etc. The mixed tumors of the parotid are very slow in development, they produce no metastases, and are relatively benign in character; those of the kidney, uterus, and vagina may grow very rapidly, set up metastases, and assume the character of very malignant tumors. The metastases arise from the transportation of undifferentiated cells from the primary tumor; through the differentiation of these the daughter tumor comes to contain the same tissues as the parent tumor. However, a metastasis of more highly differentiated cells may occur, and the tumor arising from these may present a less complicated structure than the primary. The metastases of the mixed tumors, like those of sarcoma, are hæmatogenous, the lymph glands being rarely involved. The differences in malignancy between the mixed tumors of the salivary glands and those of the kidney cannot at present be explained. The latter present the clinical characteristics of sarcoma, occur more frequently in early life, grow rapidly, and are usually fatal; the former develop in later life, grow slowly, and are only rarely fatal. A secondary carcinomatous or sarcomatous proliferation may, however, develop within the benign teratoid growths of the lachrymal and salivary glands, mamma, etc. The hypernephroma is also frequently the seat of a proliferation so active as to assume clinically the characteristics of malignancy.

All the teratoid tumors are to be regarded as congenital tumors, even when developing very late in life. The persistence of undifferentiated anlage in a latent condition for years has physiological analogues in the late development of the beard, pubic hair, wisdom teeth, etc. Nevertheless, many authors do not accept the congenital origin of these growths and assign to them a development from endothelium, or explain their mixed structure as arising from a metaplasia of other tissues, some going so far as to assume a metaplasia of unstriped muscle into striped, or even of connective tissue into smooth muscle. In some of the simple teratoid tumors, particularly those of the salivary and lachrymal glands, the proliferation of the endothelium is often the predominating feature of the growth, and from a purely structural point of view justifies the designation of *endothelioma* or *myxochondroma endotheliale*, as the case may be. In the consideration of these growths it must be borne in mind, however, that the proliferating endothelium arises from the tumor anlage, and not from the endothelium proper of the region concerned.

2. Simple Teratoid Cysts.—The simple teratoid cysts may be divided into three classes: the *ectodermal, mesodermal*, and *entodermal cysts*.

(*a*) *Ectodermal Cysts*.—These arise from the misplacement or transplantation of ectodermal anlage. They may consist of cavities lined only by stratified squamous epithelium, without hairs or other skin structures (*epidermoid cysts, epidermoids*), or of cysts whose walls contain hairs, glands, subcutaneous fat, etc., presenting all the characteristics of skin (*dermoid cysts, dermoids, dermatocysts*). In the case of the former only epidermal anlages are transplanted; in the case of the latter, embryonal dermal tissue must also be transplanted. These growths are of frequent occurrence; they vary in size from that of a pea to that of an orange. Both epidermoids and dermoids occur chiefly in the skin and subcutaneous tissues as cysts filled with a pultaceous material, resembling atheromata or sebaceous cysts caused by retention of the secretion of sebaceous glands. In the epidermoids the cyst contents consist of desquamated horny cells alone; in the dermoids hairs are found in addition to the desquamated cells. The hairs are of a light or reddish color. Fatty degeneration or liquefaction of the cyst contents may occur, and cholesterin plates may be present in large numbers. At other times the contents are firmer, dry, and present a pearly translucency or lustre. The cyst contents may also become calcified.

Epidermoids.—These are found most frequently in the cranium, neck, thoracic cavity, mediastinum, pelvic cellular tissue, coccygeal region, and perineum, and more rarely in the peritoneal cavity. In the cranium they occur in the meninges or in the hypophysis in the form of the tumors known as *cholesteatomata* or *pearl tumors*. These are spherical or nodular tumors, varying in size from that of a pea to that of an orange, and are distinguished by their glistening satiny white surface. Microscopically, they consist chiefly of thin, non-nucleated, scale-like cells arranged in closely packed laminæ, the central portions of which may present a pultaceous disintegration and enclose plates of cholesterin. According to Boström they are invariably situated at some point upon the pia, which at the site of the growth is covered with stratified squamous cells. These become piled up into a tumor-like mass, and in the course of years form the horny laminæ, which constitute the growth. The neighboring brain tissue and the arachnoid are not concerned in the formation of the horny cells. The dura and arachnoid may cover the tumor. Portions of the cholesteatoma may become separated from the main mass and be misplaced into the brain tissue. At the base of the brain cholesteatomata may be found in the neighborhood of the olfactory lobe, tuber cinereum, corpus callosum, pons, medulla oblongata, cerebellum, and choroid plexus. They are seen but rarely in the meninges of the spinal cord. The intracranial epidermoids arise most probably from epidermal germs which have become misplaced into the anlage of the pia at a very early stage of development. According to Boström, this takes place in the time between the closure of the medullary canal and the separation of the secondary vesicle of the fore-brain from the fore-brain or tween-brain, and the separation of the after-brain vesicle from the hind-brain (fourth to fifth week). The mediastinal dermoids probably arise from disturbances of development of the thymus. Those occurring in the neck arise from remains either of the branchial clefts or of the ductus thyreoglossus. The cholesteatomata of the middle ear may in part be explained as due to misplaced epidermal germs. The epidermoids of the pelvic cellular tissue are the result of epithelial inshoots from the perineum.

Dermoids.—The simple dermoid cysts or dermoids possess walls showing all the characteristics of skin—that is, papillæ, hair follicles, hairs, sweat, and sebaceous glands, and often also subcutaneous fat. The cyst contents are similar to those of the epidermoids, but contain in addition hairs. The dermoids are found in the same regions as the epidermoids, and are to be explained as due to transplantations of dermal anlage at the same time as epidermal.

Both the epidermoids and dermoids may be the seat of development of a squamous-celled cancer. This event occurs most frequently in the neck region (branchiogenic and subcutaneous carcinoma).

(*b*) *Mesodermal and Entodermal Cysts.*—Cysts arising from misplaced or persistent entodermal or mesodermal anlage are of relatively frequent occurrence. They are characterized by a lining of columnar cells, which are often ciliated; and they form cysts varying in size from that of a pinhead to that of a man's head. They are found most frequently in the broad ligament and tubes, less often in the peritoneal cavity, intestine, in the neighborhood of the trachea and bronchi, in the lungs, pleura, tongue, neck, liver, kidneys, etc. They owe their origin to the persistence of fœtal glands or ducts, or to misplaced entodermal or mesodermal epithelial anlage. Those found in the uterine wall, broad ligament, and tubes arise from remains of the Wolffian body and the duct of Gärtner; those of the cervix, portio vaginalis, vagina, and hymen arise from remains of the latter. In the peritoneal cavity and abdominal wall they may arise from snared-off and persistent portions of the intestine (*enterocysts*), or from portions of the urachus (*urachus cysts*). In the liver and kidney they may arise from portions of the gland tubules, which become constricted during the period of development (*adenocysts*). In the neck remains of the internal branchial clefts, in the posterior portion of the tongue the remains of the thyreoglossal duct, or of epithelial buds and glands developing from the same, in the œsophagus and respiratory tract snared-off portions of the intestinal canal or air passages, or remains of the communication between the alimentary tract and air passages, may form the anlage for the development of such cysts. Cysts lined with columnar cells may arise in the central nervous system or its immediate neighborhood (*myelocysts*). These are seen most frequently in the lumbosacral and coccygeal regions. In the abdominal wall cysts lined with columnar cells may arise from remains of the omphalomesenteric duct (*umbilical cysts, omphalomesenteric cysts*).

The origin of entodermal and mesodermal cysts can usually be determined from the anatomical relations and their structure. When the misplacement of the tissue is but slight, and when the anatomical structure still shows clearly the character of the mother tissue the genesis of the growth may be easily determined. The size of these cysts varies from that of a pinhead to that of a man's head. Their clinical importance is dependent upon their location, size, and the character of the secondary changes occurring in them. The cyst wall may become inflamed or undergo degeneration, or through an active epithelial proliferation either adenoma or carcinoma may develop. Adenomata, cystadenomata, and adenomyomata develop frequently from remains of the Wolffian body. In rare cases an adenoma may develop from the remains of the omphalomesenteric duct (*umbilical adenoma*). Adenomata and cylindrical-celled carcinomata may develop from snared-off portions of intestine, or of kidney and liver tubules.

3. Complex Teratoid Cysts and Tumors.—The teratoid cysts and tumors of complicated structure are found in the same regions as the simple teratoid growths, but occur most frequently in the sexual glands, and in the region of the coccyx. Their complicated structure is shown by the presence, either in the cyst wall or in the solid growth, of a great variety of tissues: squamous and columnar epithelium, ciliated epithelium, dermal structures, nerve tissues, cartilage, bone, striped and unstriped muscle, fat tissues, gland tissues, etc. They may also contain tissue of a carcinomatous or sarcomatous nature. The different tissue elements are sometimes of embryonal character. At other times they resemble fully matured tissue. They are sometimes found in orderly arrangement, suggesting the arrangement of tissues and organs found in the normal human body. In many cases, however, there is no definite grouping of tissue elements beyond that of the germ layers, ectodermal tissues being grouped together, mesodermal together, etc. The cysts may be lined with squamous, simple columnar, or ciliated epithelium, and in the first case may contain hair. Teeth and bone are of frequent occurrence in these growths.

Complicated tumors belonging to this class occur in the mouth, nose, and throat, as the so called *hairy polypi*, consisting of polypoid growths covered with hairy skin, and a mass of adipose tissue in which cartilage, bone, teeth, muscle, gland tissue, cysts, etc., are found. In the kidney they occur as solid tumors consisting of sarcomatous tissue containing tubular glands, striped and unstriped muscle, cartilage, bone, etc. Similar tumors are found in the vagina and cervix of young children; they consist chiefly of myxomatous and fibrous tissue, striped and unstriped muscle, and more rarely cartilage and gland tissue. Tumors containing cartilage, bone, muscle, glands, nerve tissue, fibrous, myxomatous, and adipose tissues, ectodermal and entodermal cysts, etc., are found in the region of the coccyx, in the cranium, orbit, mediastinum, abdomen, neck, and lumbo-sacral region. The tissue elements forming these growths may be grouped into rudimentary or fully developed body parts, so that it is possible to recognize portions of the respiratory or intestinal tracts, etc. The complex teratomata of the ovary and testis form the most important and interesting tumors of this class. They occur partly as solid tumors containing multiple cysts, and partly as dermoid cysts, the former being found chiefly in the testis, the latter in the ovary.

Ovarian Dermoids.—The complex dermoids of the ovary occur usually in the form of thick-walled cysts, varying in size from that of a pea to that of a man's head, or even much larger, and containing a fatty pultaceous material, and hair of a light or reddish color. Extending into the cavity of the cyst at some point in its wall there will always be found a polypoid, flat, nodular, or septum-like prominence covered with hairs, and often set with teeth. The latter may arise from a bony formation suggesting the jaw bone. The inner lining of the cyst consists of columnar epithelium, while that of the prominence extending into the cyst consists of skin structures, epidermis, dermis with papillæ, hairs, sweat and sebaceous glands, and beneath these subcutaneous fat. The cyst contents consist of desquamated horny cells undergoing disintegration, cholesterin plates, and hairs. Occasionally the contents are serous or mucoid. The columnar cells lining the remainder of the cyst wall may be absent in part; and the surface so denuded may be covered with granulation tissue, containing many giant cells, which in part surround hairs that have been implanted secondarily into the bare surface. The deeper layers of the wall and of the prominence in particular contain a great variety of tissues, brain, muscle, cartilage, bone, teeth, glands, spaces lined with ciliated columnar epithelium, thyroid tissue, etc. Representatives of all three germ layers are present, the derivatives of the ectoderm and mesoderm being developed to the greatest extent; in particular the skin and its appendages, bone, teeth, and brain substance; while entodermal structures, such as mucous glands, cysts lined with columnar epithelium, etc., are usually developed to a much less degree, and are found only in the deeper portions of the growth. While all ovarian dermoid cysts possess in general the same essential characteristics, the deviations in the character, amount, and relations of the tissues forming the growth are so great that each tumor may be said to have an individuality of its own. This is very clearly shown in the descriptions given of the various cases of ovarian dermoids reported in the literature. They are not to be regarded as simple tumors or cysts, but are composed of two distinct portions—a purely cystic growth and a tumor composed of embryonal elements, any one of which may develop in excess of the others.

In the simplest forms the cyst enclosing the dermoid is of the monolocular variety, although remains of the septa of a previously multilocular cyst may usually be found on close examination. The cystadenoma may predominate over the dermoid, the latter playing such an unimportant part in the development of the tumor in many cases as to constitute only an accidental finding. In the case of a multilocular cyst the dermoid may be located upon the wall of the chief cyst, or upon a septum in the midst of the cystadenoma. Usually, however, the dermoid structures stand out from the wall as a hairy prominence, as described above.

The dermoid portions of the growth may be localized to that part of the cyst wall which is occupied by the prominence, or they may be scattered throughout the wall. In addition to the simple tissue elements various rudimentary organs and structures have been described as occurring in these growths. The parts of the body most frequently found are those of the cephalic end; hence the frequent occurrence in these tumors of brain tissue, maxillary bones, teeth, rudimentary eyes, oral structures, etc. Sections through the dermoid area usually show a groundwork of adipose tissue, through which run connective-tissue trabeculæ containing bone or cartilage. The areas composed of brain tissue may often be recognized by the naked eye. Portions of the skeleton, and such structures as the mammary gland, mouth, eye, etc., may also be recognized by the gross appearances.

In a case reported by Regnier an entire skeleton was found, the right extremities showing complete jointing. Axel-Key describes an ovarian dermoid, in which there were found a head with rudimentary jaws, two lower extremities, and an ossified cranium containing brain substance. In a case observed by Wertheim two extremities were attached to the top of a dermoid containing a well-developed jaw. Graves reports a case in which there was found a head-like extremity with orbital sockets and eyelids with lashes. In a dermoid removed by Thornton there was a head-like process with maxillæ containing teeth, and the stump of an extremity tipped with long nails. Klaussner reported a case containing an entire extremity with jointed skeletal attachment, and fingers with rudimentary nails; Wilms, a case containing an upper jaw with well-formed molar and premolar teeth and a petrous bone; Grechen, one with an entire lateral wall of the cranium; Schramm, a case showing an ossified rib; Küster and Smigrodsky have reported the presence of pelvic bones and ribs; Kapeller, several jointed bones; Pfannenstiel two bones joined by a ball-and-socket joint; and a number of observers have reported the presence of fingers. In some cases the upper and lower jaws have been so well formed as closely to resemble normal specimens; but usually they are so irregular that such a differentiation is impossible.

Teeth are found in the majority of these growths. In some cases several hundred are present. They are sometimes situated within a rudimentary oral cavity, and may project from the alveolar border. Not infrequently they are enclosed within the bone. The dental structure is normal, and all the varieties of teeth may be found; incisors, molars, etc., being arranged upon a rudimentary jaw bone. The absorption of milk teeth and the formation of permanent teeth have also been observed. Such a secondary growth may explain the large number of teeth seen in some cases. Besides the teeth, other structures belonging to the mouth region are seen. Simons has described a parotid gland, Flaischlen a submaxillary, and Mortens and Kroemer have found muscle beneath a mucous membrane, the structure suggesting a rudimentary tongue. In those cases in which there is a more or less well-defined oral cavity there is a sharp line of transition between the epidermis and the oral mucosa. A narrow tube running from the oral cavity in one case was regarded as a rudimentary œsophagus. Thyroid tissue has been found in a number of cases.

Brain tissue may be present in very large amounts. In some cases cerebral hemispheres, gyri, cerebral fissures, and pia mater have been seen. All stages from the earliest rudiments to the fully-developed type are seen. The brain is usually enclosed in a fibrous envelope consisting of a single or several layers of connective tissue. The outer layers contain a great deal of elastic tissue, and often cartilaginous and osseous areas. In some cases it is possible to differentiate between the dura and the pia. In the majority of cases the most striking evidence of the presence of rudiments of the brain is afforded by the retinal pigment, which is of very common occurrence in these tumors. In a number of cases more or less completely developed optical vesicles have been found in the shape of bilateral pedunculated appendages. Born has described open spaces and bony structures lying posterior to the optical vesicle, and he considers them to be the rudiments of the ear. The brain tissue is sometimes differentiated into cortical and medullary layers, the former containing typical pyramidal cells. In some cases cranial nerves and ganglia were found which were regarded as corresponding to the optic and trigeminus. Sympathetic ganglia are frequently present. Kroemer observed a sympathetic plexus within the muscular wall of a rudimentary intestine. In a case reported by Kappeler a complete medullary tube with central canal, anterior commissure, longitudinal sinus, and intervertebral ganglia enclosed in a vertebra were found.

The presence of mammary gland tissue has been noted by several observers. Of these cases the most remarkable is the one described by Yamagiva, who regarded the adenocarcinomatous changes found in a teratoma of the ovary as primary in a nipple-like growth of mammary gland tissue which presented itself on the inner surface of a large dermoid cyst.

Of entodermal tissues, there have been found rudimentary œsophagus, trachea, larynx, lungs, nasal and pharyngeal cavities. In all of these an abundance of ciliated epithelium was present. Portions of the gastro-intestinal tract lined with cylindrical epithelium containing goblet cells have also been observed. Typical villi, intestinal glands, a characteristic muscular wall, typical Peyer's patches, and solitary follicles were present. In one case described by Pommer there was a cæcum-like intestine with a vermiform appendix. Liver and pancreatic tissues have not yet been observed.

Of mesodermal tissues, there have been observed the various connective tissues, cartilage, bone, marrow, striped and unstriped muscle, lymph glands, lymph- and blood-vessels. Kroemer found a rudimentary uterus, in which the branching glands of the cervix and the tubular fundal glands were easily differentiated. Katsurada has recently reported the presence of heart muscle. Kidney tissue has not yet been observed.

Solid Teratomata of the Ovary.—The solid mixed tumors of the ovary are somewhat more rare than the dermoid cysts. They contain the same tissues found in the latter, but differ from these in that the tissues show a less orderly arrangement, and, as a rule, a more rudimentary character. They may contain numerous small dermoid cysts. Inasmuch as transition stages may be found between the dermoids and the solid teratomata, the two forms are to be classed together as closely related genetically. In some cases the solid character of the growth may be due to adenomatous, carcinomatous, or sarcomatous proliferation of the tissues of a dermoid. There is, however, no very logical reason for separating the so-called dermoid from the solid form.

The ovary may be completely destroyed by these tumors, but in the majority of cases some remains of its tissues are preserved. The dermoids and solid teratomata of the ovary are observed most frequently in early adult life, but may occur in children. They not infrequently develop at puberty. Several dermoids may in very rare cases be found in the same ovary. They occur on both sides in about fifteen per cent. of the cases. Carcinoma or sarcoma may develop in these growths, and secondary inflammation, degeneration, etc., may also take place.

Since the most characteristic feature of ovarian dermoids and solid teratomata is the fact that they contain tissues derived from all three of the germ layers, their structure gives the impression of a rudimentary embryo, and they have been accordingly classed as *embryomata*. By some writers the term embryoma is applied only to the dermoids, while the solid teratomata, because of their lack of any structural organization approaching that of the human embryo, are designated *embryoid tumors*. The presence of tissues derived from all three of the germ layers can be explained only by the assumption of a development from an ovum. According to Wilms and others, a *parthenogenetic development of an unfertilized ovum* may be assumed. No absolute proof of this hypothesis exists at present, and nothing is known concerning parthenogenesis in mammalian ova. It does not seem probable that the development of these tumors is due to parthenogenesis, since the latter is a normal process in lower animals and plants, having for its aim the propagation of the species, and the development of these tumors can be regarded only as a pathological process, in which the growth and differentiation of tissues and organs are atypical and apparently without a definite law. In favor of the ovulogenous theory of origin is an observation made by Lee in one case in which the minute dermoid maintained the same relationship to the follicular cavity as that of the ovum to the follicle. Steinlin has also described a case in which a small dermoid remained as an intrafollicular growth connected with the follicle wall by a delicate vascularized pedicle. Sutton made a similar observation in the case of a dermoid cyst in the ovary of a horse, and Kroemer was also able to establish a similar relationship between the dermoid and the follicle in two cases in the human being. From these observations it would appear that the epidermal covering of the dermoid is derived from the ectoderm of the ovum. The dermoid is sometimes surrounded by a membrane resembling amnion.

Bonnet, on the other hand, regards it as much more probable that the complex ovarian teratomata arise from *one or more blastomeres which during the early stages of development of a fertilized ovum* are delayed in division, and later give rise to an independent formation containing elements of all three germ layers; or that a *fertilized polar body* finds its way between the blastomeres of a developing ovum, and later develops within the embryo. The fertilization of the polar body has been demonstrated in vertebrates. The first assumption seems more probable, and the ovarian embryomata and embryoid tumors may, therefore, be regarded as *rudimentary unioval twin malformations*, and are to be placed in the same category with the fœtal inclusions found in other organs. The fact that the ovary is the favorite seat of such growths may be dependent upon the fact that the urogenital anlage forms relatively such a large part of the embryonal anlage, or that the blastomeres from which the sexual glands arise take on more easily than others an especial development which leads to the formation of a rudimentary twin. Duplication of the embryonic area, or of the primitive streak or medullary groove, with subsequent inclusion of one twin (parasite) by the autosite might explain the formation of some of the ovarian embryomata. Wilms, Pfannenstiel, and Kroemer are the chief advocates of the ovulogenous origin of these tumors. Bandler, on the other hand, has recently attempted to prove their congenital origin, holding that they arise from derivatives of the ectoderm, which have a mesodermal stroma, viz., the Wolffian bodies and ducts (according to Spee, the epithelium of the Wolffian body and duct comes from the ectoderm). Bandler, therefore, holds that the ovarian dermoids and cystadenomata have a closely related histogenesis. His attempt to refer the embryomata of the sexual glands to ectodermal implantations occurring accidentally during the development of the urogenital system cannot be regarded as successful, since the anlage of many structures found in these tumors (teeth, thyroid, eye, etc.) cannot possibly be located in the urogenital anlage. There is an increasing number of writers who accept the ovulogenous origin, but the majority of these reject the hypothesis of parthenogenesis. The etiology of the anomalous development of the ovum is not yet known.

Complex Teratomata of the Testicle.—Complex tumors of the character of the ovarian dermoids have been found in the testicles, in the case of both children and adults, but are of rare occurrence. Their structure is essentially the same as that of the ovarian tumors. Solid complex teratomata are of much more common occurrence in the testicles. They may be congenital, but are found more frequently in early adult life. In structure they differ from the complex ovarian teratomata in that they do not contain so great a variety of tissues, and that these are not grouped so as to form easily recognized organs or systems. The tissue elements, moreover, are more embryonal in character and attain only a very rudimentary development. Ectodermal tissue is present usually in but scanty amounts, and is represented by pigmented epithelium or by small groups of cells showing cornification. In some tumors it may be entirely absent, or at least cannot be demonstrated. The cysts are lined usually by entodermal epithelium, but the character of the epithelium may vary in one and the same cyst. Simple cubical and cylindrical epithelium, either with or without cilia, stratified cylindrical ciliated epithelium and pigmented epithelium may be found. Mucous glands may also be present. Of the connective-tissue elements, fibrous tissue, myxomatous tissue, cartilage, bone, striped and unstriped muscle, are most frequently present. All these present a more cellular and embryonal character than the tissues found in the ovarian teratomata. As a rule, some one of the tissues predominates, and a carcinomatous or sarcomatous proliferation occurs in the majority; hence the teratomata of the testis have been reported under a great variety of names: *adenochondroma, adenocystoma, chondrosarcoma, malignant chondroma, rhabdomyosarcoma, adenomyosarcoma, cystosarcoma, cystocarcinoma, adenocarcinoma, myxosarcoma*, etc. In some cases an endothelial or perithelial proliferation predominates, and the tumor assumes the character of an *endothelioma* or a *perithelioma*. Syncytial like formations have also been described as occurring in these growths. In some cases the formation of cysts with fluid or mucoid contents is the most striking feature of the tumor; in other cases the growth may be cystic only in part, while in other cases it is solid throughout. They are often of very rapid growth, and those in which carcinomatous or sarcomatous proliferation occurs are of very malignant character, giving rise to numerous metastases throughout the peritoneum, retroperitoneal glands, lungs, etc. The metastasis in the majority of cases is hæmatogenous, like that of sarcoma. To what extent the teratomata of the testicle are to be classed with the embryomata as of ovulogenous origin, or to what extent they are due to tissue-implantations, cannot at present be determined. Those containing tissues derived from all three of the germ layers may be classed with the embryomata or embryoid tumors; those consisting of single tissue-formations may be explained by the assumption of a tissue-transplantation or inclusion.

The complex teratoid cysts and solid teratomata of other regions, as well as those of the sexual glands, are in many instances to be regarded as local disturbances of development, due to a misplacement or separation by constriction of tissue anlage or tissue within a single individual (*monogerminal tissue-implantation, autochthonous teratoma*). The hairy polypi of the throat and mouth cavity, the cystic or solid teratomata at the base of the skull or in the hypophysis may be explained as due to inclusions of ectoderm. The presence of cartilage and mucous glands in the mediastinal teratomata may be explained by the proximity of the trachea. The teratoid mixed tumors of the cervix and vagina are probably due to inclusions of the myotome or sclerotome, and to malformations in the development of the Wolffian duct; those of the kidney are due to proliferation of remains of the Wolffian body, and to inclusions of the myotome; those of the lumbo sacral and coccygeal regions are due to proliferations of remains of the neuro-enteric canal, hind gut, and medullary canal, in association with ectodermal and mesodermal inclusions.

There is, however, another possibility of origin for these tumors—they may arise from a rudimentary twin (bigerminal implantation). Such an explanation receives support when the teratoma in question contains fully developed or rudimentary organs or body parts, or tissue-formations that cannot be explained by the misplacement of tissue of a single fœtus. The complex teratomata at the base of the skull, in the sacral region, in the mediastinum, and in the abdominal region are regarded by the majority of investigators as bigerminal implantations. Such teratoid tumors are then to be interpreted as parasitic twin malformations, and are to be classed with the double monsters (see *Teratology*). All possible transition forms exist between those composed of rudimentary tissue-elements and the double monsters with symmetrically developed twins. In those cases in which partly or fully developed extremities or organs lie within the tumor mass or cyst the diagnosis of bigerminal inclusion is clear, but in the case of a more rudimentary development of tissues which are not arranged in an orderly manner it is not always possible to differentiate between monogerminal and bigerminal inclusions.

Malignant Teratoma (*Teratoma malignum*).—Malignant changes may take place in any form of teratoid tumor or cyst, the simple forms as well as the more complex, but are of more common occurrence in the latter. Of the simple teratomata the epidermoids and dermoids most frequently take on a malignant activity of growth (*branchiogenic* and *subcutaneous carcinoma*), although ectodermal inclusions in any part of the body may be the starting-point for an epitheliomatous growth. The tumors of the kidney, vagina, and cervix that contain striped muscle and myxomatous tissue usually behave as sarcomata. The mixed tumors of the salivary and lachrymal glands become malignant much more rarely. Since the great majority of other forms of teratoid tumors are usually benign, the term malignant teratoma is more appropriately applied to the malignant embryomata and embryoid tumors. The complex dermoids are less frequently malignant, or at least but relatively few cases of carcinomatous or sarcomatous dermoid of the ovary have been reported. Yamagiva has reported a unique case of a dermoid of the ovary, showing adenocarcinomatous changes. The patient was a woman sixty-three years old, dying from the effects of a large ovarian tumor, which was in part composed of solid mixed tissues and cysts, and partly dermoid. The adenocarcinomatous changes present he regarded as primary in a mammary gland which presented itself on the inner surface of the large dermoid cyst. Metastases were present in the retroperitoneal, mesenteric, and right supraclavicular glands. To Bierman belongs the credit of having recorded the first case of epidermal cancer arising from the epidermal lining of the cyst cavity. Similar cases have been reported by Krukenberg, Clark, and others. The majority of the cases have been in women at or near the menopause. The metastases are found chiefly upon the peritoneum. Of much greater frequency is the development of carcinoma or sarcomatous changes in the solid complex teratomata of the ovary, testis, and mediastinum. In the case of the malignant teratomata of the testis the metastases may present the appearances of cystocarcinoma, cystosarcoma, chondrosarcoma, chondrocarcinoma, myosarcoma, myxosarcoma, endothelioma, etc. Occasionally the metastases show differences of structure, or may present a combination of tissue elements. This may be explained by the metastasis of undifferentiated cells. In some cases the tumor presents the appearance of a mixture of sarcomatous and carcinomatous proliferation ("*sarcocarcinoma*"). The distribution of the metastases varies somewhat with the character of the malignant changes. In the case of adeno- or cystocarcinoma of either an ovarian or a testicular teratoma the metastases are found chiefly upon the peritoneum; in other cases the metastases are usually hæmatogenous, and are found chiefly in the lungs.

Treatment.—The fact that a large class of tumors is composed of tissue-formations resembling those of the normal body, and derived from misplaced anlage or tissue, or from fœtal inclusions, throws important light upon the treatment. Since such tumors are manifestly not of parasitic origin, their treatment by toxins, antitoxins, Roentgen rays, etc., is naturally contraindicated. Only those toxins would destroy the mixed tumors which would at the same time destroy the normal tissues. The treatment is purely operative, and even here the knowledge of the mixed nature of the tumor is of great importance in modifying the operation. The mixed tumors of the mamma do not set up metastases in the axillary glands; and since the encapsulated mixed tumors in general usually give rise to hæmatogenous metastases, and not lymphogenous, a more conservative operation may be carried out than in the case of carcinoma. In the case of the tumors of the testis the greater tendency to malignancy with the rapid setting up of metastases in the peritoneum in the case of carcinomatous change, and in the lungs in the case of sarcomatous or endotheliomatous changes, speak for the necessity of early operation. (See also *Teratology*, *Hypernephroma*, etc.) *Aldred Scott Warthin.*

TEREBENE.—Terebene, $C_{10}H_{16}$, is a liquid hydrocarbon, obtainable by the action of strong sulphuric acid on oil of turpentine. It is a colorless, mobile fluid, of a pleasant pine-wood odor and taste, free from the acridity of oil of turpentine. It is insoluble in water, but dissolves in an equal measure of alcohol.

Under the name *Terebenum*, Terebene, the United States Pharmacopœia makes official "a liquid consisting chiefly of pinene, and containing not more than very small proportions of terpinene and dipentene." Terebene should be kept in well-stoppered bottles and in a cool dark place.

Terebene seems to affect the human system like a mild oil of turpentine. It has been taken in so large quantities as a teaspoonful every four hours, continued for a week, without untoward effects; but such quantities are unsafe. Under the influence of the medicine the urine acquires an odor as of violets, and may increase slightly in quantity. Medicinally, terebene has been found of service for the alleviation of cough and dyspnœa from respiratory disease, and of dyspepsia with flatulence and acidity. The drug is commonly given in doses of ten drops, or thereabouts, in emulsion or in capsules. It is not at all unpleasant to take, clear, washed down with a small sip of water. In respiratory affections the vapor of terebene may be inhaled in addition to the internal administration. *Edward Curtis.*

TERPIN HYDRATE.—When a mixture of turpentine oil and water is permitted to stand, crystals of terpin hydrate, $C_{10}H_{18}(OH_2) + OH_2$, often deposit. For artificial preparation of the crystals in quantity, a mixture is made of oil of turpentine, nitric acid, and alcohol, which is set aside in shallow vessels for crystallization to occur. The substance is official in the United States Pharmacopœia under the title *Terpini Hydras*, Terpin Hydrate. Terpin hydrate is in the form of colorless, rhombic crystals, practically devoid of odor and taste. It dissolves in about 250 parts of cold water and in 32 parts of boiling water; in 10 parts of cold alcohol and in 2 parts of boiling alcohol. The drug is claimed to possess the medicinal "expectorant" virtues of the terebinthinates, while free from the deranging influence of the class. It may be administered in doses ranging from 0.20 gm. to 0.65 gm. (from gr. iij. to x.), given a number of times daily, in emulsion or pill. *Edward Curtis.*

TERPINOL is an oily liquid of hyacinthine taste, obtained by distilling terpin hydrate with dilute sulphuric acid. It consists of *terpineol*, $C_{10}H_{17}OH$, mixed with three terpenes, $C_{10}H_{16}$, and is insoluble in water and soluble in alcohol and ether. Lazarus employs it like terpin hydrate as a bronchial stimulant and antiseptic in dose of 0.3 c.c. (♏ v.). Janowsky gives it in hæmoptysis, three drops frequently repeated. It is sometimes added to iodoform as a deodorizer. Under the name of "stomatol," a mixture of terpinol, soap, alcohol, and aromatics, is sold as a mouth wash and general antiseptic and deodorizer. *W. A. Bastedo.*

TESTICLES, DISEASES OF. See *Sexual Organs, Male, Diseases of.*

TETANUS.—(Synonyms: Trismus, Lockjaw.) Tetanus is an acute infectious disease caused by inoculation with the tetanus bacillus, and characterized by tonic spasm of certain muscles, sometimes by clonic spasms as well. The more severe acute cases usually end fatally in from one to seven days. Mild cases, sometimes called chronic, may last for some weeks and end in recovery.

For a full description of the tetanus bacillus the reader is referred to the article on *Bacteria*, p. 698, vol. i., of this Handbook. It must be remembered that this organism is almost everywhere to be found in garden and field soil, in the street dirt of cities, about manure piles, and in the foul mud of marshes and river beds. The reason that more people are not infected by this well-nigh omnipresent germ is because it is anaërobic and quickly killed by sunlight.

Etiology.—For the growth of the tetanus bacillus in or upon the human body it is essential that there be a wound upon which the bacillus shall be received. If the wound be septic or becomes septic, it offers the best soil for the growth of this bacillus, since the ordinary septic organisms absorb all the oxygen present and so produce the anaërobic conditions necessary for the life of the tetanus bacillus. It is doubtful whether any truly aseptic wound was ever the seat of tetanus infection. There need, however, be no gross solution of continuity in order for the development of the tetanus bacillus, since it has been found at the site of a severe blow or bruise.

Pathology.—There are no definite anatomical changes as yet known to belong to this disease. The bacillus is to be found in or near the infected wound, although the local lesion may not be prominent and the wound may have healed. A few observations are on record in which the bacilli were found on the *pia mater* and arachnoid of the spinal cord. In the brain and cord are found perivascular exudation, congestion, and granular degeneration of nerve cells. The local infection with the tetanus bacillus seems to produce a toxin, which, when it reaches the brain and spinal cord, causes symptoms similar to those of strychnine poisoning. A substance called tetanin has been isolated from tetanus cultures; it is said to be four hundred times more poisonous than strychnine.

Symptoms.—The period of incubation varies considerably. In temperate climates it is likely to be two weeks, sometimes three. In tropical climates, or in localities where the disease is especially virulent, there may be as short a period as one day. The onset is gradual, with soreness and stiffness in the muscles of the neck and jaw, until at the end of from one to three days the mouth cannot be opened (trismus or lockjaw). This muscular rigidity or tonic spasm extends to the muscles of the face and trunk, in less degree to those of the legs, while the arms are often exempt. The contraction of the face muscles so draws up the corners of the mouth as to produce a fixed grin, the so-called *risus sardonicus*. The abdominal and chest muscles become board-like in their rigidity, greatly impeding respiration. The body is often arched backward (opisthotonos), or it may be fixed in some other position. An aggravation of the spasms, which may have somewhat relaxed, is produced by any sudden stimulant, such as a loud noise, a draught of cold air, or an attempted movement. These spasms are always tonic or continuous, never intermittent. Some patients complain of great pain connected with the spasms, others of none whatever. The mind usually remains clear throughout. The temperature in mild cases may be but little raised. Usually, however, it reaches 104° or 105° F., sometimes as much as 108° during life, and it often rises a degree or two after death. The body is bathed in sweat, the urine is scanty and often albuminous. Death may occur in twenty-four hours from the outbreak of the disease, or not for four or five days.

Chronic tetanus usually begins a longer time after infection, is milder in form, often without fever, and the spasmodic contractions may be limited to the part of the body near the wound, although they may also be general. This form may last for two or three weeks and is much less fatal. A variety of the chronic form, called by the Germans *Kopftetanus*, follows injuries about the distribution of the cranial nerves, especially those of the supra-orbital margin. It is marked by trismus with facial paralysis, although both tonic and clonic spasms may occur in other parts of the body.

Diagnosis.—The history of a poisoned wound, especially a dirty, punctured wound of the foot or hand, is an important factor in the diagnosis. Mild forms of trismus, with none of the other symptoms of tetanus, sometimes follow dental irritation, as from a carious tooth or an unerupted wisdom tooth. Apparent trismus may also be hysterical. Tetanus may be distinguished from strychnine poisoning by the fact that in the former the onset is comparatively gradual, while in strychnine poisoning it is sudden. In tetanus the muscles are continuously rigid, even during the intervals of spasm, while in strychnine poisoning they are relaxed during the interval. Trismus is always present in tetanus, not so after strychnine. The arms are always involved in strychnine poisoning, very rarely in tetanus. Hydrophobia is to be distinguished from tetanus by the character of the spasms, which are clonic in the former, tonic in the latter. In hydrophobia the muscles of respiration, and especially those of deglutition, are early and prominently involved; not so in tetanus. In hydrophobia there is no trismus nor opisthotonos. The demonstration of the presence of the tetanus bacillus in a suspected wound would be conclusive evidence of the character of the malady.

Prognosis.—This is very unfavorable. From seventy to ninety per cent. of all cases are fatal. This, at least, has been the record of the past. Under more recent methods of treatment (antitoxin and carbolic-acid injections) better results are claimed in some countries. Thus, at a recent congress of surgery Dr. Valles, of Lyons, France, had collected 373 cases with 145 deaths, or 39 per cent. There is no doubt but that the very acute cases are almost uniformly fatal, and that a short period of incubation is proportionately dangerous. In Rose and Carless' "Manual of Surgery" (William Wood & Co., 1901) the statement is made that if the period of incubation is under ten days only 4 per cent. recover; if it lasts from eleven to fifteen days, 27 per cent. recover; while if the outbreak is delayed for fifteen to twenty days, 45 per cent. live.

Treatment.—The preventive treatment consists, first, of thorough antisepsis applied to wounds, and the worse the sanitary conditions under which patients are found the more radical should be this antisepsis. This means the thorough laying open and cauterization of recent wounds, with pure carbolic acid, for instance, or the excision of cicatrices of longer standing, with cauterization of the site. The immediate prophylactic injection of 10 to 20 c.c. of Behring's tetanus antitoxin, in case of the existence of "a suspicious wound," and the repetition of this treatment every day or every other day for a week or ten days have been recently advocated in Germany. It is evident that any amount of good results can be claimed from such treatment, when it is not certain that the wound is infected with tetanus. The best that can be said for it is that it is safe.

After the appearance of the general symptoms of tetanus three methods of treatment are before us, viz.: the old treatment, with absolute quiet and sedatives; second, the antitoxin treatment; and third, the Bacelli treatment, with hypodermic injections of carbolic acid. In view of the dire nature of the disorder and the unsatisfactory results of all treatment, the probabilities are that the wide-awake practitioner will avail himself of all three of these methods at once. The old method of treatment consists in the isolation of the patient, so as to secure absolute quiet, and the free administration of chloral and the bromides or of hypodermic morphine, enough being used to insure quiet rest. Chloroform by inhalation is also used to control spasms, or to permit of feeding by the stomach tube two or three times a day. The *antitoxin treatment*, as ordinarily practised, consists in the subcutaneous injection of some one of the various preparations of tetanus antitoxin serum. The original serum is that of Behring, of which 20 to 30 c.c. should be injected every five or six hours. Of Behring's dried serum 5–10 gm., dissolved in distilled water, is used. Various manufacturing houses in this country prepare these antitoxin serums, and they are also prepared by certain of our state boards of health. It is of the utmost importance that the article should be obtained from a reliable source, and that it should be reasonably fresh.

Much disappointment has followed the use of tetanus antitoxin. Even early prophylactic treatment by this method, vigorously pushed, has often failed. And yet there is no doubt that when the statistics of large numbers of cases are studied a decided lowering of the mortality can be recognized. Large doses, begun early and used thoroughly and persistently, will often accomplish the desired result.

Of late years the opinion has been gaining ground that subcutaneous injections of antitetanus serum are merely preventive of further general infection; that when the first symptoms of tetanus appear the nerve centres are already gravely poisoned, and that the best results must be sought by bringing the antitoxin into immediate contact with those nerve centres. Hence the employment of *intracerebral injections* of antitetanus serum. Rose and Carless (*opus cit.*) thus describe the procedure: "The injection is made through the dura mater into the posterior portion of the second frontal convolution on each side; 2.5 c.c. of the dried serum dissolved in 5 c.c. of sterilized water are injected very slowly, and this may be repeated several times, if an interval of a few days be allowed to elapse between two consecutive injections. The point selected is placed midway between the external angular process of the frontal bone and the centre point of the line between the root of the nose and the external occipital protuberance. A small trephine may be applied here, or simply a hole drilled through the skull sufficient to allow of the introduction of a syringe, which is pushed about two inches deep into the brain. Of course the strictest antisepsis is essential. Probably it will be found wise to restrict this method to the treatment of the worst cases, and it must be augmented by subcutaneous injections and other subsidiary measures."

Some brilliant results from this method have been reported. The greatest number of cases of intracerebral injection which the writer has been able to find tabulated is 233, with 96 recoveries and 137 deaths, giving a mortality of 58.7 per cent.

Spinal subarachnoid injections have also been employed and good results reported, although the total number of cases recorded is still too small to permit of positive conclusions. Five to ten cubic centimetres of cerebro-spinal fluid are withdrawn and 10–20 c.c. of antitoxin injected very slowly under weak pressure.

The *carbolic-acid treatment*, also called the Bacelli treatment, after the name of its distinguished originator, consists in the subcutaneous injection of a two-per-cent. solution of carbolic acid, at intervals of from two to four hours, in such quantity that not less than three grains of the acid is used the first day. As much as six or eight grains per diem may be employed, according to the urgency of the case. No poisonous effects have been noted and excellent results have been claimed, especially in Italy. It is believed by some observers that tetanus is not so virulent in Italy as in some other countries.

As previously stated, there is no reason why the various methods of treatment above given may not all be employed at the same time. The writer recently saw a case of tetanus following the usual punctured wound of the foot from stepping on a nail. Tetanus developed on the fifth day, with trismus, opisthotonos, and violent periodical spasms. Antitetanus serum (Parke, Davis & Co.'s) was injected every six hours, carbolic-acid injections were used to the extent of five grains a day, and the periodical spasms were controlled by the hypodermic use of hyoscine hydrobromate, gr. $\frac{1}{50}$ *pro re nata*. The disease yielded on the fourth day so as to permit of the patient's drinking from a cup. An individual case, such as this, proves nothing, and it is only mentioned as an example of the combined treatment.

As this article goes to press the writer learns of certain experiments on animals made by Prof. A. P. Matthews, of Chicago, which may in the near future give us the means of successfully combating the toxins of tetanus as well as other toxins. It appears that Profs. J. Loeb and A. P. Matthews have for some time been experimenting in the production of a saline infusion which should cause stimulation of the cells as well as produce cell catharsis and diuresis. Having attained this object, so far as the washing out of ordinary metabolic bodies is concerned, and wishing to ascertain whether bacterial toxins could also be thus eliminated, the experiment was made with tetanus toxin. After careful control experiments it was found that the toxin could be washed out of an animal after the symptoms of tetanus had been well established for some time, many times the lethal dose of toxin having been administered. For full particulars of the process we must wait until the investigators themselves publish their results.

Edward W. Schauffler.

TETANY or **TETANILLA.**—The "little tetanus" is a disease characterized by attacks during which there occur bilateral tonic spasms of various groups of muscles, most frequently of those of the upper extremities; also by extreme hyperexcitability of the peripheral motor nerves in response to mechanical and electrical stimulation. We shall see that, although the disease has a very distinct symptomatology, it is often confounded with other diseases, and is so little known that no special mention is made of it in some of our largest treatises, that it is referred to incidentally only in Reynolds' "System of Medicine," as a symptom associated with others of spinal irritation, and that in Pepper's "System" it is merely alluded to in the article on Tetanus.*

History of our Knowledge of Tetany.—In 1830 Steinheim described this disease as a special form of articular rheumatism; in the following year Dance published "Une observation sur une espèce de tétanos intermittent," and in this article expressed the view that the intermittent character of the spasms proved the disease to be of the malarial order. In 1852 the entire subject was reviewed by Lucien Corvisart, and it was he who proposed the name tetany. Previously to Corvisart, the great Trousseau, as early as 1845, had observed this disease in nursing women, and supposed a connection between tetany and the function of lactation; he therefore termed it "contracture rhumatismale des nourrices," but, having observed the same trouble later on in children and adults after intestinal obstruction, he was forced to abandon his "nourrice" theory. It was Trousseau also who first discovered the very important fact that these attacks could be excited by compression of the arteries and nerve trunks of the affected extremity.

Many of these cases were regarded, in Germany particularly, as cases of professional neuroses, professional spasms, until Kussmaul showed conclusively that there was a distinct difference between this affection and the ordinary professional neuroses. Riegel insisted on the causal relation between the disease and the presence of entozoa in the intestines. Erb and Chvostek examined the electrical behavior of the affected muscles, Chvostek directing particular attention to the increased mechanical excitability of the affected muscles and nerves. In 1874 Langhans published the first case of tetany in which a careful post-mortem examination had been made, and in 1881 the late Dr. Nathan Weiss, of Vienna, published an excellent monograph on "Tetany"† (Volkmann's Vorträge, No. 189), in which he described the disease most carefully, reviewed the entire literature of the subject, and showed an interesting connection between tetany and the surgical removal of goitre.

Etiology.—The disease is most apt to occur in young persons; in children between the ages of four and six years; then again at the age of puberty; while the majority of cases of tetany are observed in persons between the ages of sixteen and thirty-five years.‡ Pregnancy, child-bed, and lactation appear to be predisposing causes. It is now well established that it is *not* one of the professional neuroses, although cobblers evince an unusual predisposition to the disease. Persons who have been exposed to cold or wet seem particularly liable to attacks of tetany. Intestinal irritation is another cause; stubborn constipation or protracted diarrhœa has been followed by tetany. Riegel (*Deutsches Arch. f. klin. Med.*, Bd. xii.) instances a case in which attacks of tetany were inhibited by the removal of the ova of tænia mediocanellata and trichocephalus dispar; and Weiss makes mention of a case in which tetany occurred as a complication of typhoid fever. The attacks of tetany disappeared as the typhoid (intestinal) symptoms subsided, and returned with a relapse of the intestinal symptoms. Tetany has also been observed in the wake of smallpox, Bright's disease, malaria, cholera, and in children during the period of dentition. It has also been observed after severe mental shocks. The causal connection between extirpation of goitre and tetany, as proven by the cases of Weiss, has been referred to above. The frequent association of tetany with gastro-intestinal disorders has led to a belief in the auto-intoxication origin of some of the cases. Eulenburg states that non-malignant stenosis of the pylorus, with subsequent dilatation of the stomach, is a condition particularly favorable to the development of tetany. And finally, it is to be noted that tetany occurs frequently as an epidemic,* and that it is of much more frequent occurrence in some countries than in others. The present writer observed a number of cases of tetany in Vienna, while he has seen only very few typical instances, in this country, among a large number of neurological cases of every description.

Symptomatology.—In describing the symptoms of the disease we must mention the symptoms noticed during the *attack* and during the period of *latency*.

The *attack* is preceded by vague tingling pains, by formications in the hands, forearms, and legs; these sensory symptoms are followed by a feeling of stiffness in the hands and legs, and soon afterward the spasms are fully developed. These tonic spasms occur most frequently in the upper extremities, and give rise to such a marked rigidity of the muscles that passive movements are impossible. The position of the hand varies according to the groups of muscles affected by the spasms, whether flexors or extensors. It is a common occurrence for the hand to assume the shape of the accoucheur's hand as it is ready to be introduced into the vagina. Occasionally, also, the thumb is so firmly pressed upon by the flexed fingers that the nails are buried in the skin of the palm of the hand. In some rare cases there is complete extension of all fingers. As a rule, the forearms are flexed, the upper arms in adduction; it is exceptional for the arms to be in abduction and removed from the trunk of the body.

Mild cases of tetany are apt to consist only of a series of such attacks as have just been described; and this is true even of the earlier stages of severe forms of tetany. In a large majority of cases, however, and particularly in the later stages of the disease, spasms are apt to affect other groups of muscles, viz., the muscles of the lower extremities, causing adduction of the thighs, with extension of the hip- and knee-joints, and plantar flexion of the foot, the toes being bent forcibly toward the soles of the feet. The spasms may also affect the muscles of the abdomen, chest, and back. The tonic contractions of the abdominal and thoracic muscles may interfere with the movements of the diaphragm and with respiration, causing severe dyspnœa and universal cyanosis. If the muscles of the neck be involved additionally, the return of venous blood from the brain may be retarded, and Weiss reports one case in which loss of consciousness was the result. Opisthotonos is frequently the result of spasms affecting the muscles of the back. Trismus is occasionally observed, but never in the beginning as in

* An excellent chapter on tetany will be found in Gowers' "Diseases of the Nervous System."

† The present writer is greatly indebted to this monograph for many of the historical and other facts to be found in this article. He has made liberal use of Weiss' monograph, without in each instance acknowledging his indebtedness.

‡ Gowers has tabulated 142 cases, and of these he found that 42 occurred at the ages of from one to four years and 36 at the ages between ten to nineteen years.

* Cases of epidemic tetany have been reported as occurring in schools and prisons of France.

tetanus. In other (severe) cases again, spasms of the ocular muscles, of the œsophagus, of the larynx (spasmus glottidis), and of the muscular apparatus of the bladder (desire to urinate, but micturition impossible) have been observed.

During the attack patients complain of severe pain in the affected muscles; there is, furthermore, marked diminution of tactile sensibility in the extremities, the patients not being able to distinguish the character of objects placed upon the skin, and having the feeling, when standing on the bare floor, as though they were walking on velvet.

In a few cases a rise of temperature to 104° F. has been observed; Weiss observed a rise in only one case out of twelve.

Headache, vertigo, tinnitus aurium, and excessive perspiration are other symptoms which are occasionally observed during an attack of tetany. The attacks may last only a few minutes, but may at times last for hours and even days. Severe attacks of tetany may bear a striking resemblance to genuine tetanus; but it may be noted that there is no initial spasm of the masseters in tetany, and that in this form the spasms spread from the periphery centripetally, and not centrifugally as is the case in tetanus; and, furthermore, it is evident that the reflex excitability is not nearly so great in tetany as in tetanus. There is also this further distinguishing characteristic, that in cases of tetany the patient may be entirely free from attacks for hours, days, weeks, and even months.

A. Westphal (*Berl. klin. Wochenschrift*, 1901, p. 849) has called attention to the occasional association of epilepsy with tetany, and believes that toxic products are important etiological factors in both diseases.

Symptoms of the Latent Period.—In the intervals between the attacks the patient may be entirely well; but some exhibit even at this time weakness, with rigidity of the affected muscles. The calf muscles are particularly apt to be the seat of slight tonic contractions. Weiss observed in one case, during the latent period of the disease, tonic rigidity of the calf muscles, and fibrillary as well as fascicular contractions in the quadriceps cruris and vastus externus; in another case Chvostek observed slight contractions of the orbicularis palpebrarum.

The intervals between the attacks of tetany may vary in duration from several hours to a few days, and even a few months. Of course, we can speak of a latent interval in the course of the disease only in case the disease can be proven still to exist. This can be done by proving the presence of Trousseau's symptom, and of increased electrical and mechanical excitability.

Trousseau's Symptom.—This symptom refers to the fact discovered by Trousseau, that in persons afflicted with tetany a characteristic attack can be elicited by pressure upon the large nerve trunks and arteries of the extremities usually affected during an attack. The attacks cease as soon as the pressure is removed. Kussmaul and Quincke maintain that in some cases pressure on arteries only is necessary, while in other cases the slightest pressure on a nerve trunk is sufficient to produce contractions of all the muscles supplied by this nerve. *Trousseau's symptom is present in no other convulsive disease.*

Increased electrical excitability is another symptom observed during the *latent* period. Erb, Chvostek, and Weiss showed that the motor nerves of the extremities and of the trunk, in cases of tetany, exhibited an increased response to both the faradic and the galvanic currents. They could not only obtain the cathodal closure contraction (CCC) with very small currents, but were able, with moderate currents, to obtain CCT and even an AOT, which had not been observed in any other condition; while Chvostek reports having obtained a COT—a condition unheard of in man. Erb failed to obtain these phenomena in the facial, but Chvostek and Weiss claim that they were as well able to obtain these phenomena with the facial as with any nerve of the extremities. J. Hoffman found an increased excitability upon mechanical and electrical stimulation of the sensory as well as of the motor nerves. Erb found the electrical excitability greatest at a time when the attacks were most frequent, and it was he who first ventured the suggestion that the increased electrical excitability might be used as a diagnostic test during the latent period of the disease.

Increased mechanical excitability is another well-marked symptom; a simple tap with a percussion hammer upon a nerve trunk being sufficient to produce contractions of the muscles supplied by the nerve. Pressure with a lead-pencil upon the focal point of the pes anserinus is followed by contractions similar to those which a strong faradic current applied to this point would have produced. Increased reflex excitability of the nerve must be taken as an explanation of this phenomenon. At all events this should be the first employed diagnostic test during the latent period of the disease, as it certainly is better to try this test than to attempt to excite an attack by pressure upon a large nerve trunk or a large artery.

Pathological Anatomy.—In spite of the post-mortem examinations made by Langhans, Weiss, and others, there is little or nothing known of the pathology of tetany. Langhans claimed to have found a periarteritis and periphlebitis of the blood-vessels of the white commissure, and of the anterior horns in the cervical portion of the spinal cord. Weiss found nothing of the sort in his case. He has built up an ingenious theory of the disease, according to which he believes that the attacks of tetany are due to an irritable condition of the gray matter of the medulla and spinal cord, and that this irritable condition is due to sympathetic disturbances, causing irregularities in the vascular innervation of the blood-vessels of the spinal cord: but this is mere theory. H. Schlesinger is of the opinion that tetany is a disease of the entire nervous system; that some of the symptoms are due to involvement of the peripheral nerves, and that the spasms and Trousseau's symptom are due to an increased excitability (of vaso-motor origin?) of the central nervous system, brain, medulla oblongata, and spinal cord. A satisfactory explanation of the disease or of the attacks cannot be had.*

Differential Diagnosis.—There can be no difficulty as to this. There is the mere possibility of confounding an attack of tetany with genuine tetanus. It is necessary to remember the distinctly centripetal character of the attack of tetany, the fact that the disease never begins with trismus, and, above all, the shortness of the attacks, and the existence of a latent period—all of which differs widely from what is observed in real tetanus. During the latent period Trousseau's symptom, and the increased electrical and mechanical excitability, help to establish the diagnosis.

Prognosis is favorable except in those few cases in which the spasms affecting the respiratory muscles may lead to serious lung trouble.

Treatment.—In the way of treatment, it is necessary above all things to remove the active or predisposing cause, to change the patient's abode, to procure absolute rest for him, and, if there is suspicion of intestinal irritation, to look to this, to purge the bowels, and to remove entozoa that may happen to be present.

During the attack, the physician will have to resort to the hypodermic use of morphine, possibly of hyoscyamine. Applications of ice to the back of the neck helped to inhibit an attack in one of Weiss' cases. As soon as the attack is over, it will be well to administer chloral hydrate in daily dose of ʒ i.–ʒ ij.; or the combined bromides in doses of ʒ iss.–ʒ iiss. pro die. During the intervals careful electrical treatment (stabile currents ascending from peripheral nerve trunks), as well as methodical lukewarm baths, deserves a trial; but it is gratifying to know that the majority of cases will get well without any treatment at all. The use of thyroid gland and of thyreoiodine has been favored by some. There can be no objection to a careful use of these prepara-

* Gowers, relying on cases in which a wasting of the muscles has followed upon tetany, believes that the trouble starts in the motor cells of the spinal cord.

tions in suitable cases. By way of warning, we would suggest to the physician not to employ either counter-irritation or the faradic current. *B. Sachs.*

TETRA-ALLYL-AMMONIUM ALUM and **TETRA-ETHYL-AMMONIUM-HYDROXIDE** are soluble crystalline salts used in dose of 0.06–0.12 gm. (gr. i.–ij.) as uric-acid solvents. *W. A. Bastedo.*

TETRA-IODO-DI-CHLOR-SALICYLIC ACID, (C_6S_2-HCl.OH. COOH)$_2$, is a reddish-yellow antiseptic dusting powder obtained by heating salicylic acid with sulphur chloride. It is soluble in alkaline solutions.

W. A. Bastedo.

TETRA-IODO-PHENOLPHTHALEIN. See *Nosophen.*

TETRONAL, POISONING BY. See *Synthetic Products, Toxicology of.*

TEXAS.—The great extent of this State, its situation on the continent in relation to the surrounding land and water, and the diversity of its surface in mountain, plain, hill, and desert naturally produce a great variety of climatic conditions. The area of the State embraces 237,504 square miles, extending over eleven degrees of latitude and thirteen of longitude. It stretches "from a parallel very nearly coincident with the extreme southern portion of Florida to one touching the southern boundary of Virginia; while east and west it is bounded by the meridians coincident with Sedalia, Mo., and Leadville, Col." [Morse K. Taylor in the previous edition of the Handbook.] In the southern portion, on the gulf coast, we have the zone of tropical cyclones, as witness that of September 7th, 1900, at Galveston, which destroyed over six thousand lives and a considerable portion of the city; while on the northern border the arctic blizzards are experienced.

The eastern and southern portions of the State are at nearly sea-level, and, as one goes northwest, the elevation increases until an altitude of seven thousand feet is reached in the Chinanti Mountains. The intermediate country consists of "high, wide rolling prairies and river bottoms." The vegetation also varies greatly, according to the altitude and topography of the surface. The eastern border, for example, is heavily timbered, while in the west the land is barren of trees, and only the cacti and the stunted mesquite are found. In the extreme south we have a subtropical flora, and in the central portion are fertile agricultural lands where various cereals, fruits, and flowers of temperate latitudes are cultivated. The climate of such an extensive area, so diversified and so situated, cannot well be considered as a whole, except in the most general manner, and it is only by taking various portions of the State, each representing peculiar climatic characteristics, that one can obtain an adequate and intelligent idea of the climate, or rather climates, of the whole State. Taylor's division (*loc. cit.*) appears to be a serviceable one for this purpose. He divides the State into five districts: Eastern Texas, the gulf district, southwestern Texas, northwestern, and central Texas.

Only those districts which offer some claim as health resorts need occupy our attention to any great extent. The eastern district is comparatively level, has no elevations much above five hundred feet, and is heavily timbered throughout. Its climate is a moist, warm one, with a mean relative humidity of seventy-four per cent., and an annual rainfall of about forty-nine inches, with exacerbations in the form of heavy rains and floods. The annual mean temperature is about 66° F. Yellow-fever epidemics occur in this section. It is not a wholesome climate.

The gulf district has a coast line of about three hundred and seventy-five miles, and its surface is comparatively level. Its climate is of a subtropical nature—hot, moist, and windy. For a large portion of the year the winds are from the sea. The annual mean temperature is 73.9° F.; the rainfall, 41 inches; and the relative humidity, 78.6 per cent. Away from the river bottoms it is said to be generally healthy, although malaria is prevalent. During the summer the gulf coast is said to offer a soft, equable temperature and excellent surf bathing, the heat being tempered by a pleasant sea breeze. The beach at Galveston is a fine one, and is a very popular resort; the accommodations are reported to be good.

Southwestern Texas is higher than either of the two previous districts, much of the northern portion being at an elevation of two thousand feet. This district is well drained, and is beyond the yellow-fever line. The climate is moderately dry, particularly so on the Rio Grande line. The annual mean temperature is 68.1° F.; the relative humidity, 67.3 per cent.; and the rainfall, 26.6 inches. "The possibility of outdoor employment," says Taylor, "during the whole year makes this portion better suited for those in delicate health who wish to remain a length of time, and, as they say, 'rough it,' than any other portion of the State. Life on the ranches, though lonely for many, is novel and interesting, and often beneficial." One should, however, bear in mind the wise advice of Hinsdale, that no invalid should go into the country districts unless he is able to endure positive hardships and to subsist on the coarsest food.

While, in general, the summers in Texas are hot (and the invalid from the North is advised not to go there at this season), yet in the southwestern portion "the heat is so tempered by the winds that its intensity is greatly modified . . . and the nights are always cool and dry. From May to October there is rarely any dew, so that persons may sleep in the draughts, on their porches, verandas, housetops, or under the trees with perfect freedom from liability to take cold" [Taylor]. The same authority also avers "that the summer nights of southwestern Texas are more delightful than those of any interior region south of the great lakes." The two health resorts of Boerne and San Antonio are situated in this district, and the reader is referred to Vol. II. and to the first part of the present volume for a consideration of their climate and merits.

Central Texas, which contains the capital, Austin, in the southern portion, ranges from six hundred to two thousand feet above sea-level, and embraces the best agricultural land in the State. It is well settled, and contains several cities. The whole district has an annual mean temperature of 65.4° F., and an annual rainfall varying from 23 to 41 inches, and a relative humidity of from 59 to 67 per cent. The most desirable portions of central Texas for a winter residence are those centering about Dennison on the northern border, Corsicana about 120 miles directly south, and Austin 150 miles south of the latter town. "The general aspect of the country is pleasing," says Taylor; "it is productive and of easy cultivation, and for one seeking a home in a mild and healthful climate it offers advantages scarcely surpassed in the United States." The average maximum temperature at Austin is 99° F., and the average minimum 19°. The annual rainfall is about 33 to 35 inches. The "northers" are experienced throughout this district, especially in the northwestern portions.

The northwestern portion of the State is dry, more or less barren, and sparsely settled, and its climate is characterized by great dryness, small annual rainfall, low humidity, and almost continual sunshine. In the extreme northwestern portion of this district, not far from the boundary line between New and old Mexico, is the health resort of El Paso, a city of 15,000 inhabitants, with an elevation of 3,764 feet. The surrounding country is arid and barren, except as irrigation has been instituted; the city itself, however, is quite attractive. There are several hotels, one or more good boarding-houses, a modern hospital, and a sanatorium. There are various churches, good public schools, and a military fort—Fort Bliss—near by. A large majority of the exports from Mexico enter the United States by way of El Paso. From the middle of September to the middle of May the climate is suitable for tuberculous invalids; after that time it is too hot for comfort, at least in the middle of the day. As Hinsdale* remarks, El Paso is a good place in which to begin the process of acclimatization to regions of greater rarefactions of air. The soil is dry and porous, except near the river (Rio Grande), where it is adobe. Water can be obtained from artesian wells. The peculiar climatic features which render this a desirable resort are the extreme dryness and purity of the air, the almost constant sunshine, and the mild winter temperature. The moderate elevation, moreover, adds a freshness and tonicity to the air. There is no malaria or fog, and in the winter the winds are not high, though there are occasional dust storms. The rainfall is very low, averaging from 9 to 13 inches during the year, falling principally in the summer, and some years there is hardly any rain at all. The mean relative humidity is 37 per cent. for the year, and for the season from September to May 49 per cent., according to Hinsdale. The average monthly mean temperature is: For January, 43.8° F.; February, 47.9°; March, 55.5°; April, 64.5°; July, 81.2°; and for the year, 63.3°. There are evidently not many resources for the diversion of the visitor. El Paso is reached by the Atchison, Topeka and Santa Fé Railroad.

In conclusion, a few words as to the "northers." They are cold, dry winds sweeping down, as their name indicates, from the north or northwest, occurring during the winter at intervals of about seven days, and lasting twenty four to forty-eight hours. They are most prevalent and severe in the northern portion of the State. They come suddenly, and produce a sudden marked lowering of the temperature, not infrequently reducing it from summer heat to ten or fifteen degrees below the freezing point in a few hours. Their effect has been thus described: "Northers are intensely dry, and soon drink up all the moisture on the surface of the earth and of the objects upon it capable of yielding their humidity. Great thirst of man and animals is experienced, with many an itching of the skin, a highly electrical condition of the skin of horses and cats, a wilting and withering of vegetation, even when the temperature would not account for it." Taylor (*loc. cit.*) considers their influence invaluable as a sanitary flushing of the country, and that the air following in their track constitutes one of the chief curative agencies in this climate, acting as a vigorous tonic. *Edward O. Otis.*

TEXAS FEVER. See *Arachnida.*

TEXAS SOUR SPRINGS (known also as Caldwell Springs).—Caldwell County, Texas.

Post-Office.—Luling. Hotel.

Access.—Via Galveston, Harrisburg and San Antonio Railroad to Luling; thence six miles north to the springs. The location may also be reached by way of the Burdett Mineral Wells (*q. v.*), which are not far distant.

This is quite a new resort, although the existence of the springs has been known since the early settlement of the country. Tradition has it that the aborigines employed the waters for medicinal purposes, and that Colonel Davy Crockett bathed his wounds in their cool and limpid flow after his famous single handed fight with the Mexican lions in this vicinity. The springs are located in a rolling country, at an elevation of seven thousand feet above the sea. The air here is dry and balmy, the winters being mild and the summers breezy and pleasant. It is stated that malaria never develops in the neighborhood. The springs are five in number, and afford about sixty gallons of water per hour. They differ but little in their chemical constitution. The following analysis was made by Prof. H. H. Dinwiddie, of the Texas Agricultural and Mechanical College: One United States gallon contains (solids): Aluminum and potassium sulphate, gr. 100.08; ferrous sulphate, gr. 7.58; magnesium sulphate, gr. 16.17; sodium chloride, gr. 42.74; calcium sulphate, gr. 125.01; magnesium chloride, gr. 132.84; lithium chloride, a trace; free sulphuric acid, gr. 7.26; soluble silicates, gr. 12.18; organic matter and loss, gr. 5.12. Total, 448.98 grains.

This analysis shows a rich and potent mineral water. It is a well-marked example of the acid-saline-chalybeate class, and exerts a marked influence when taken internally. It possesses cathartic, alterative, diuretic, and tonic properties. Locally it is astringent, and is beneficial as a lotion in conjunctivitis, a gargle in pharyngitis, a douche in leucorrhœa, etc. The water is used commercially, and an extract prepared from the dried residue is also found in the markets under the name of the "Texas Sour Mass." It is said to possess all the virtues of the water. *James K. Crook.*

THALAMUS OPTICUS. See *Brain.*

THALLINE.—The name *thalline* was given by Skraup, of Vienna, to a body prepared by him synthetically in 1884, of which body the *sulphate* and *tartrate* salts have been used in medicine. Chemically, thalline is *tetrahydroparaquinanisol*, $C_9H_6H_4N(OCH_3)$. Thalline sulphate, the more commonly used salt, is in the form of a cream-colored powder, of a pleasant odor, resembling a perfume of some flower, and of a taste which, though at the outset biting and bitterish, leaves an aromatic flavor upon the palate. The salt dissolves freely enough in water, sparingly only in alcohol, and is insoluble in ether.

Thalline is a fairly efficient antipyretic medicine, operating after the general manner of antipyrin and kairin, and holding rank about midway between those two agents. With efficient dosage, a fall of from 2° to 4° F. can be procured within an hour or so after administration; but very soon after the extreme of reduction the temperature begins to rise again, and quite rapidly, commonly regaining its original elevation in from two to four hours. This after-rise is quite frequently accompanied by a chill, lasting from a few minutes to an hour. Other symptoms commonly observed are a slight diminution in pulse rate and respiration rate, and a very considerable diaphoresis. Vomiting occasionally occurs, but collapse has not been reported, though the subjects may show some depression of strength and present a more or less cyanotic appearance when under the full influence of the drug. Thalline may be detected in the urine within an hour and a half after administration, and its presence may give that secretion a characteristic darkish-green color. Experimentation upon animals has shown that the medicine, in sufficient dosage, is competent to cause arrest of the heart in diastole, to hasten coagulation of the blood, and to exercise a destructive influence on the hæmoglobin of the red blood corpuscles. Some consider that the antipyresis wrought by thalline is due to this action of the drug on hæmoglobin (Brouardel and Loye).

Thalline has been used in medicine as an antipyretic, the dose of the sulphate ranging from 0.25 gm. (gr. iv.), given hourly, up to 1 gm. (gr. xv.), to be repeated in from two to three hours. So large a quantity as 7.33 gm. (gr. cx.) has been given in twenty-four hours without inconvenience (Maragliano). Thalline sulphate may be administered in form of pill, wafer, or in aqueous solution, aromatized to taste. But the thalline salts have practically gone out of use in medicine, having been superseded by more modern antipyretics, which are equally efficient and much more kindly in operation. No preparation of thalline is official in the United States Pharmacopœia. *Edward Curtis.*

THALLIUM.—Thallium is a somewhat rare metal. It was discovered by Crookes in 1861. It has been classed chemically with the metals of the lead group, but its reactions are in many cases different and peculiar to itself. It forms salts which in many respects resemble the corresponding ones formed by potassium and the other alkalies.

Symptoms in Animals.—Its action was investigated by Lamy in 1863, who found that the symptoms in a dog

* "System of Physiological Therapeutics," vol. iv., Book II., "Climatology."

were general weakness, restlessness, tremor, loss of appetite, dyspnœa, salivation, and severe intestinal pains. Convulsions of the posterior limbs occurred, and later these became gradually paralyzed. Paulet, in rabbits, after injection of thallium, found general tremor, loss of co-ordination, slowing of respiration, and death under asphyxia. He found that 1 gm. of the carbonate killed a rabbit in a few hours. Results essentially similar were obtained by Marmé. In small doses, nausea, vomiting, loss of appetite, and salivation were produced with intestinal pain and diarrhœa with bloody dejections; also slowing of both respiration and circulation with dyspnœa. Tremor and inco-ordination, both static and motor, occurred. The autopsies showed swelling and hyperæmia of the mucous membranes of the stomach and intestines with extravasations of blood therein; small hemorrhages and pneumonic infiltration of the lungs; hemorrhages in the epicardium and effusion in the pericardium. The brain and spine showed no constant changes.

The soluble salts are said to be cumulative poisons of slow elimination which may last for three weeks.

Rabuteau, using 5 cgm. of the iodide, found much the same symptoms in dogs (1883). He mentions also albuminuria.

In 1891 Luck used a double salt of thallium and sodium on cats, dogs, and rabbits. The symptoms appeared not immediately, but on the first, the second, or the beginning of the third day. They were weakness, apathy, loss of appetite, vomiting, diarrhœa with blood. Tremor of the extremities and static and motor inco-ordination were present, and twice there were clonic convulsions. The heart action was weak and rapid; the respiration slowed. Clinically there existed the symptoms of a parenchymatous nephritis. Hemorrhages were found in the stomach and intestines.

Richet found in chronic poisoning a generalized muscular atrophy, not simply a wasting of the muscles but their almost total disappearance. This affected especially the masseters, temporals, and muscles of the lumbar spine. He declares that in its great toxicity it resembles lead, while lithium is much less toxic.

Action on Man.—In 1884 Pozzi and Courtade recommended the use of iodide of thallium in doses of 0.010 gm. daily in certain cases of syphilis and obtained favorable results. They found, however, that it produced unpleasant digestive symptoms—pain in the stomach and vomiting; in some cases also they reported that the gums were reddened and there was a blue line at their junction with the teeth. These latter symptoms have not yet been confirmed by other observers. Combemale in 1898 used acetate of thallium for the profuse sweats of pulmonary tuberculosis, and found that even in the last stages of the disease it exerted a strong effect. The ordinary dose was 10 cgm., the maximum 20 cgm. He observed no toxic symptoms during the administration of the drug. Huchard relates two cases in which severe pains occurred in the lower extremities. These patients were in the later stages of phthisis. As the pains disappeared when the administration of the drug was stopped, it was concluded that they were due to the thallium.

Symptoms of poisoning in man are not common. Crookes states that he has swallowed 0.065–0.130 gm. of thallium salt without any effect. Combemale seems to have been the first to notice the peculiar and specific action of the drug in causing alopecia, or falling of the hair. This symptom did not occur while the drug was being taken, but came on later. The loss of hair was said to be total and extraordinarily rapid. This action of thallium was soon confirmed by other observers. Jeanselme reported the case of a woman who, in three days, took nine cachets of acetate of thallium, containing 3 cgm. each. Fifteen days later her hair suddenly began to fall and she lost about one-third of it. Buschke and Bettmann have succeeded in producing alopecia in animals by the administration of thallium acetate.

The writer has lately reported a case of poisoning by sulphate of thallium in a male twenty-seven years old. The symptoms were those of a multiple neuritis coming on with considerable rapidity and continuing for several weeks. There were loss of motion of the lower extremities, diminution of the sensation of a portion of the legs and feet, with pain and extreme tenderness at times in the same regions. The knee jerks were increased. The patient recovered from these symptoms so as to be fairly well in about six weeks, and in three months was able to resume work. About six weeks or two months after the beginning of the illness his hair fell out completely.

The typical or specific symptom of subacute or chronic thallium poisoning in men is the extraordinary falling out of the hair. This has proved an absolute contraindication to its use for therapeutic purposes in many cases, especially in women. The case last reported illustrates the danger of experimenting with this drug. The amount in this case was half a grain to a grain of the sulphate, which was taken every other day for three or four doses. This was done twice at an interval of about two months. There were no symptoms the first time, but within two or three days after the last dose of the second series numbness was noticed in the toes and finger-tips, and after this the neuritis developed rapidly.

William N. Bullard.

THANATOL. See *Guaiacol-ethyl.*

THEOBROMA. See *Cacao, Oil of*

THEOBROMINE-LITHIUM SALICYLATE. See *Uropherin.*

THEOCIN, $CH_2(CH_3)_2N_4O_2$, is a name given to the synthetically prepared theophylline, an alkaloid found in very minute quantity in tea leaves. It is prepared from urea by a complicated process in twelve reactions, and is the first alkaloid to be manufactured synthetically from such a simple substance. Chemically it is di-methyl-xanthin, a member of the purin group, and is isomeric with theobromine. It occurs in colorless needles and is soluble in one hundred and eighty parts of cold water, more soluble in hot water, soluble with difficulty in alcohol, and insoluble in ether. Its ammonium and potassium compounds dissolve readily in water, the sodium salt but slightly.

Minkowski finds that the diuretic action of theocin is greater and more rapid than that of theobromine, and that while it has little if any effect on the circulation, it increases the excretion of both solid and liquid. Given on an empty stomach, however, it produced nausea and vomiting unless in very dilute solution. Ach considers it nearly twice as powerful as diuretin. Meinertz, in Grawitz's clinic, studied the action in twenty-three cases and found it a very valuable diuretic in cardiac and renal affections; in four other cases in which the urinary condition was normal, there was no diuretic effect at all. The dose is 0.3–0.5 gm. (gr. v.–viij.).

W. A. Bastedo.

THERMAL ACID SPRINGS.—Inya County, California. These remarkable springs are found in the Caso Range, twelve miles east of Little Owens Lake, and sixteen miles southeast of Olamoha. The country for miles around the springs is rich in pure crystallized sulphur, having, no doubt, been ejected by the sulphurous steam in the form of sulphurous anhydride (SO_2). On being exposed to the air the sulphur was deposited pure and water liberated. This seems to be a rational explanation of the formation of these large sulphur banks. The water now flows in rather limited quantities through the small crevices and fissures, and is accompanied by sulphurous steam and vapors. The following analysis of the waters has been made by a chemist whose name has been lost: One United States gallon contains: Sodium sulphate, gr. 145.75; potassium sulphate, gr. 880.33; magnesium sulphate, gr. 891.91; calcium sulphate, gr. 69.96; aluminum sulphate (?), gr. 7,407.41; ferric sulphate (?), gr. 1,934.56; sulphuric acid (?), gr. 4,670.72; nitric acid, chlorine, ammonia, lithium, traces. Total solids, 15,997.64 grains. In Anderson's work on the mineral springs of California the above analysis is stated in parts per thousand. Its correctness cannot be vouched for. This acid sulphate water does not seem to have come into much use as yet. Well diluted and properly administered, it ought to be valuable in many conditions requiring tonic and astringent remedies. It will be observed that the water closely resembles that of the Matchless Mineral Wells of Butler County, Alabama, being, however, according to the above analysis, much stronger. *James K. Crook.*

THERMIN, tetra-hydro-beta-naphthylamine hydrochloride, $C_{10}H_{11}.NH_2HCl$, is a crystalline body recommended by Filehne as a powerful mydriatic. *W. A. Bastedo.*

THERMODIN, acetyl-para-ethoxy-phenyl-urethane, $C_6H_4.OC_2H_5.N.CH_3CO.COOC_2H_5$, is an almost odorless and tasteless, insoluble, white powder with mild antipyretic and antineuralgic properties. Dose 0.3–1 gm. (gr. v.–xv.). *W. A. Bastedo.*

THERMOMETERS, CLINICAL (θέρμη, heat; μέτρον, a measure).

Definition.—Instruments for determining the temperature of the body in disease.

History.—The ancients had no better means of estimating the temperature of bodies than that of observing the sensation of heat or of cold which they imparted to the hand. Hippocrates applied this method to the clinical investigation of diseases, and was fully sensible of the value of the information thus obtained.

The first successful attempt to represent differences of temperature to the more accurate sense of sight has been attributed both to Drebbel, of Holland, and to Sanctorius, of Italy, living in the early part of the seventeenth century. The first instruments for this purpose, called weather glasses, depended upon the expansion of air, and were both rude and inaccurate. Atmospheric thermometers of a much better pattern were afterward devised by Boyle and the academicians of Florence. The liquid was colored spirits of wine. After the spirits had been boiled to expel the air, the tube was hermetically sealed. A system of markings, or a scale, had next to be devised. The fixed points at first selected were the cold of snow or ice, and the greatest warmth known at Florence. A great deal of discussion arose, however, throughout Europe in regard to the most suitable fixed points upon which to base the scale, as well as upon the most suitable substance for use in the instrument. Newton discovered that snow and ice melt at invariably the same temperature, and that the heat of boiling water is almost as constant. These points were then selected, and are still maintained, except that the temperature of the vapor arising from boiling water is taken as being more constant than that of the water itself. Deluc and Römer demonstrated the even expansibility of mercury under the influence of heat, and adopted it in the construction of their thermometers; but to Fahrenheit is generally given the credit of having brought the mercurial thermometer into favor.

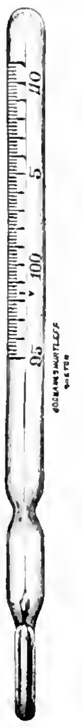

Fig. 4699.—Self-registering Clinical Thermometer.

Sanctorius is said to have adapted the thermometer to the investigation of human temperature, but fully a century elapsed before any systematic use of the instrument for that purpose was recorded. Boerhaave, Van Swieten, and De Haen are the three names which appear most prominently in the literature of thermometry in the eighteenth century. But it required another hundred years to bring thermometry into favorable clinical use.

Description.—The mercurial thermometer has been almost exclusively used for clinical purposes. It consists of an exhausted capillary glass tube, one end of which is expanded into a globular or cylindrical bulb containing mercury (Fig. 4699). Its action depends upon the great difference in the extent to which glass and mercury expand when exposed to the same degree of heat.

The scale of the thermometer is generally engraved on the stem and illuminated by a white or black stripe incorporated in the glass behind the mercurial column. A range of 10° C. (18° or 20° F.) is quite sufficient for the scale of a clinical thermometer. This should embrace from 35° to 45° C. (95° to 113° F.), limits which include the range of probable physiological and pathological temperatures. The thermometer must be long enough to bear a legible scale (not less than three inches); for the sake of portability, however, it should not exceed five inches. The bulb or reservoir should be formed of as thin glass as is compatible with strength. Thermometers having rather long but narrow reservoirs (*e.g.*, the "minute thermometer," Fig. 4700) register more promptly than those whose bulbs are short and thick.

Thermometers having a double, "twin," bulb, or a branched, "crescent" bulb are also meeting with favor, although their superiority to the simpler patterns is questionable.

Fig. 4700.—The Minute Thermometer. The column of mercury appears magnified by means of the so-called lens front.

Thermometers are now made self-registering. This was first attained in the instruments used by Currie, in the early part of the nineteenth century, by means of a small piece of iron resting upon the surface of the mercury. The register now used is known as the "indestructible" index, secured by a constriction of the tube near the bulb so narrow as to prevent the passage of an unbroken column of mercury through it. The expansion of the fluid causes it to pass the constriction in little "jumps" which render the reading slightly inaccurate, but not to the extent of one-tenth of a degree in a properly constructed instrument. The index must be "shaken down." This is best accomplished by grasping the upper end of the instrument between the thumb and fingers and giving it a short, sharp swing from the wrist or elbow.

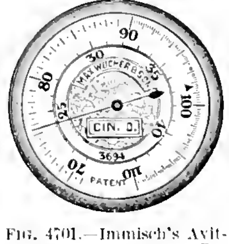

Fig. 4701.—Immisch's Avitreous Thermometer. (Exact size.)

The reading of the register is greatly facilitated by the so-called "lens-front," a conical form given to the face of the instrument, through which the column of mercury appears greatly magnified.

The avitreous (Immisch's) thermometer (Fig. 4701) depends upon the same principle as the mercurial, but its construction is different. In appearance it resembles a miniature watch. Its mechanism consists of a small metallic tube bent into a circular form, having one end fixed to a support, the other free to move, but connected by a fine spring to a shaft which carries a needle or dial indicator. The tube is filled with a highly expansive fluid. In consequence of its expansion the tube uncoils, producing a corresponding vibration of the indicator. Upon cooling the tube curls and the indicator returns to its point of repose. The dial over which the indicator moves is graduated according to both the centigrade and the Fahrenheit scales. A device for "registering" the temperatures has been added, in the form of a stop-catch passing through the stem. In action this thermometer is slower than the mercurial. It is now used chiefly as a surface thermometer.

The surface thermometer is designed chiefly for determining differences in temperature of the surface of various regions. The reservoir is usually given a flattened extremity (Fig. 4702), or is made into a coil, the object in either case being to expose as great an amount of the expansive medium as possible to the temperature of the surface to be investigated. In using the instrument the bulb must be carefully covered, in order that the result may not be altered by the temperature of the atmosphere.

The differential or metastatic thermometer was devised by Walferdin for the purpose of determining with great accuracy the fluctuations of temperature within certain narrow limits. It consists of a capillary tube of very small calibre, at either extremity of which is a small reservoir. At the junction of the upper of these reservoirs with the tube there is a slight constriction. The quantity of mercury contained in the reservoir and tube must bear such relation to the capacity of both that an elevation of temperature amounting to three or four degrees Celsius (from five to seven degrees Fahrenheit), will cause the entire lumen of the tube and reservoirs to be filled. In order to prepare the instrument for use, it must be warmed to about the highest temperature that is anticipated in the investigation to be made. The column of mercury is then broken at the point of constriction by a quick tap. The mercury in the tube rapidly falls, but is not followed by that in the upper reservoir. The lower bulb is now inserted into one of the thermometric cavities, and permitted to remain, while the fluctuations of temperature are carefully observed and recorded. The only advantage possessed by the instrument is its great delicacy, depending upon the wide space allotted to each degree. Walferdin was able with it to detect variations of temperature amounting to but one two-hundredth of a degree Celsius.

FIG. 4702.—The Surface Thermometer of Seguin.

The thermo-electric apparatus has been used in clinical investigations. It was introduced into physiological experimentation by Becquerel, especially for determining the differences of temperature which exist in different regions of the body. The apparatus was perfected by Dutrochet. Its action depends upon the physical law that when, in any metallic circuit composed of two or more different metals, the points of contact are exposed to a temperature different from that of the other parts of the circuit, an electric current is produced which is readily recognized by the magnetic needle, and may be measured by a galvanometer. The thermo-electric pile constructed in conformity to this principle has been applied to the measurement of temperatures in physiological experiments on animals by Gavarret, Heidenhain, and others, and to the determination of human temperature by Lombard and Hankel. Its action is both delicate and prompt. It can be applied to the investigation of internal temperatures by means of a properly constructed needle, composed of two or more elements brought into contact at its point. The instrument is not suitable to general clinical use, on account of its size.

The Thermograph.—Instruments have been devised by Marey and W. D. Bowkett for the purpose of automatically registering changes of temperature, by which continuous observations can be made over a considerable period of time. To these the name thermograph has been applied. They have not, however, been much used for other than experimental purposes.

GRADUATION OF THERMOMETERS.—Thermometers are graduated according to the scales of Celsius, Fahrenheit, and Réaumur. The Celsius, or centigrade, scale is used exclusively on the continent of Europe; the Fahrenheit, almost as exclusively in the United States and Great Britain; whereas that of Réaumur, at one time preferred in France and in some parts of Germany, is now retained only in Russia and Sweden. The relative position of fixed points in these scales is shown in the following table from Wunderlich:

Celsius	..	0	25	50	100
Fahrenheit	0	32	77	122	212
Réaumur	..	0	20	40	80

The subdivision of the scale between the fixed points is arbitrary; hence we find that Celsius divided it into 100 parts, or degrees, Réaumur into 80, and Fahrenheit into 212. The zero, centigrade, corresponds to the thirty-second degree of Fahrenheit; 100° C. = 212° F., and 1° C. = 1.8° F., or $\frac{9}{5}$° F. If, therefore, it is required to convert a given temperature expressed in terms of the C. scale (*e.g.*, 40° C.), the number is first multiplied by 1.8. The product in the example is 72. To this 32 is added, in order that the degrees may be counted from the same fixed point. This gives us 104. Therefore, 104° F. = 40° C.

If, therefore, C represent a given temperature expressed in the centigrade scale, the unknown equivalent of which in the Fahrenheit scale is F, the formula for finding the latter term is:

$$C \times 1.8 + 32 = F;\ \text{or},\ \frac{9}{5}\,C + 32 = F.$$

Conversely, a temperature expressed in the scale of Fahrenheit may be converted into that of Celsius by means of the formula:

$$\frac{F - 32}{1.8} = C;\ \text{or},\ \frac{5}{9}\,(F - 32) = C.$$

In the same manner the terms of the Réaumur scale may be converted into those of Fahrenheit by the formula:

$$R \times 2.25 + 32 = F;\ \text{or},\ \frac{9}{4}\,R + 32 = F.$$

Consequently, to convert Fahrenheit into Réaumur:

$$\frac{F - 32}{2.25} = R;\ \text{or},\ \frac{4}{9}\,(F - 32) = R.$$

To convert degrees of the Réaumur scale into their equivalent in the centigrade scale, it is only necessary to multiply them by 1.25.

The following table gives the thermometric equivalents within the range of physiological and pathological temperatures:

Cent.		Fahr.	Cent.		Fahr.
35	=	95	40	=	104
35.55	=	96	40.5	=	104.9
36	=	96.8	40.55	=	105
36.11	=	97	41	=	105.8
36.66	=	98	41.11	=	106
37	=	98.6	41.66	=	107
37.22	=	99	42	=	107.6
37.77	=	100	42.22	=	108
38	=	100.4	42.77	=	109
38.33	=	101	43	=	109.4
38.61	=	101.5	43.33	=	110
38.88	=	102	43.88	=	111
39	=	102.2	44	=	111.2
39.44	=	103	44.5		112.1
39.5	=	103.1	45		113

The centigrade scale, based upon the decimal system of numeration, is now almost universally used in scientific observations, and its adoption by the medical profession is recommended on the highest authority. The Fahrenheit scale, based as it is upon an error, has nothing to recommend it but usage.

More important to the clinician than the kind of scale which is adopted is the use of a thermometer of known accuracy. It is not essential that the thermometer shall be precisely correct in its readings throughout the entire scale so long as the exact amount of error and its location are known, for the correction may then be made in reading the register. To insure this, a certificate may be obtained through the manufacturer, guaranteeing the accuracy of the instrument, or stating to what extent it is inaccurate.

Unfortunately, mercurial thermometers do not retain their accuracy. Owing to the liability of glass to undergo molecular contraction, the bulb not infrequently becomes reduced in size and thus causes the instrument to register erroneously high temperatures. This is generally avoided by thoroughly "seasoning" the tubes before engraving the scale.

Application of the Thermometer.—The object to be attained in the use of the clinical thermometer is usually to determine as nearly as possible the temperature of the interior of the body, the blood heat. Several localities are available for this purpose, on account of the nearly constant character of their temperature, but the axilla, the mouth, and the rectum are most employed. At times the conditions of disease render necessary the selection of other localities, as the groin, the urethra (female), the vagina, or the closed hand, and it has been proposed to take the temperature of freshly voided urine. The mouth is the most easily accessible. The bulb should be placed under the tongue, and the lips closed on the stem. The mouth must remain closed during the observation. If oral respiration has been carried on previous to the introduction of the instrument, a minute or more should be allowed for the rise of the mercury beyond the time that would otherwise be required.

In many cases the axilla will best answer the purposes of thermometric investigation. The arm-pit must be thoroughly dried, if moist, before the introduction of the thermometer. The instrument should then be inserted into the middle of the axilla in such a manner as to insure contact with the skin only. The cavity is then closed by pressing the arm firmly against the chest, the forearm being drawn slightly forward. It is advisable, when practicable, to use the thermometer in the axilla of the side upon which the patient has been lying. From three to five minutes are usually required for a correct register of the axillary temperature.

Taking the temperature in the rectum yields the most trustworthy results, particularly in children. The use of the urethra or vagina is resorted to only in such conditions as Asiatic cholera, when the temperature of the axilla has been found as much as 7° C. (12.6° F.) below that of the vagina; and the temperatures of the mouth and rectum are also unreliable. Whatever locality is selected in an individual case, the same should be used for all subsequent observations.

Thermometric observations should be made at stated intervals, the frequency of which must depend upon the character of the case and the object of the examination. In the commencement of a febrile disease it is often necessary, in order to arrive at a correct diagnosis, to take the temperature at frequent intervals, every half hour, every hour, or every two hours; but regular morning and evening observations are, as a rule, sufficient for the requirements of treatment. These are best taken between 7 and 9 A.M., and between 5 and 7 P.M. If, however, the points of maximum and minimum temperature are found not to occur in these intervals, the times must be made to conform to the peculiarities of the case.

In addition to the periodical observations, the thermometer should be used upon the occurrence of any phenomenal event during the progress of the disease, as after a rigor, a sweat, or psychical disturbances.

The systematic observation of temperature changes is essential to the intelligent treatment of almost every febrile disease. The attendant should be provided with a reliable self-registering thermometer, with instruction how and when to use it in the absence of the physician.

It is not enough that the temperature be regularly measured; it must be regularly recorded on a chart prepared for that purpose. Every chart should bear the name of the patient, the diagnosis of his disease, the region in which the temperature is taken, the date and time of day. Its value is enhanced if it have recorded upon it the rate of the pulse and respiration at each thermometric observation, the occurrence of critical evacuations, the alvine dejections and urine, the explanation of any anomaly of temperature or other feature of the disease.

The Temperature in Health.—In speaking of the body temperature, whether physiological or pathological, reference is usually had to the temperature of but a single thermometric region, which region, accuracy of statement requires, should always be indicated in clinical reports.

The temperature of the axilla in health averages about 36.89° C. (98.4° F.), as stated by Liebermeister, or 37° C. (98.6° F.), according to Wunderlich. It varies, however, between 36.40° C. and 37.77° C. (97.5° and 100° F.). Landois states, as the average of five hundred observations, 36.49° C. (97.68° F.). The temperature of the mouth is from a fifth of a degree to a degree higher than that of the axilla. The last-named authority gives as the average 37.19° C. (98.94° F.). The rectal and vaginal temperatures vary from 37° C. to 38° C. (98.6° F. to 100.4° F.). Thermometric observations in the closed hand are too variable for clinical purposes, as they are liable to be altered by external conditions of heat and cold. Römer places the variation which is liable to occur in this region at 6° C. (10.8° F.).

The factors which are generally recognized as influencing the results of thermometric observations may be summarized thus: 1. The region in which the observation is made; the closed cavities are warmer than exposed parts, the trunk is warmer than the limbs. 2. The temperature is higher in the extremes of life than in middle age. 3. The taking of a full meal causes a slight temporary depression of the temperature; digestion elevates it. Fasting lowers it. Alcohol produces a prompt but transitory depression, after which the temperature again rises to about the normal. 4. Physical exercise short of fatigue causes a slight rise of temperature, whereas mental exertion is said to depress it. 5. The body is coolest in the morning, gradually becoming warmer until evening, reaching the maximum, as a rule, between five and seven o'clock. A gradual decline to the morning minimum occurs during the night. This daily fluctuation ordinarily amounts to a little more than 0.5° C. (1° F.). 6. Prolonged exposure to heat causes a slight elevation of temperature, exposure to cold a slight depression. A marked effect is produced by agencies which promote or retard the radiation and convection of heat from the body. 7. The nervous system exerts a considerable influence over the bodily temperature, as has been shown by the experiments of H. C. Wood and others.

The Temperature in Disease.—A large proportion of diseases are accompanied by an elevation of temperature. In a comparatively few, there is at some period a decline below the normal. In order to denote a morbid process, in the absence of other positive signs of disease, the temperature must remain for several hours outside the bounds of health. The temperature in febrile affections undergoes a fluctuation from morning to evening and from day to day, which is typical of the underlying morbid process. By the use of the thermometer we are able to recognize this fluctuation and estimate from it the severity of the disease, and any variation which may occur in the course of the affection as a result of complications, accidents, or treatment.

The thermometer is therefore a valuable aid in diagnosis, in prognosis, and in treatment.

In Diagnosis.—The early diagnosis of infectious diseases is of the utmost importance. By the use of the thermometer we are often able, more than by any other means, to corroborate our suspicions of their existence, or, on the other hand, to disprove the evidence of fictitious symptoms. Complications arising in the course of a fever and relapses from convalescence are usually indicated by a more or less pronounced alteration of the temperature range, or by a return of high temperature.

Thermometry is no less valuable in the diagnosis of certain chronic affections, but more particularly for determining their activity or latency at the time of the observation. This is particularly true of tuberculosis. The thermometer has led to the discovery of this affection in individuals who had exhibited no subjective manifestations of the disease.

An inequality of temperature between corresponding surfaces of the body, in the absence of local inflammation, often points to the existence of paralysis of the cooler part, or of other nervous disorder, a fact which is especially of value in the presence of coma.

A diagnosis cannot be based upon a single thermometric observation. A series of observations must be made before we can learn enough of the temperature range to render a differential diagnosis possible. The absence of abnormal temperature conveys more positive information than does its presence.

Notwithstanding the value of thermometry, its results are not infallible. A sudden rise of the temperature may be due to a specific infection, but it may arise solely from an acute attack of indigestion. The taking of food, exercise, and excitement are liable to elevate the temperature in disease, as does also the retention of urine or of fæces. Due caution is always to be exercised in estimating the diagnostic as well as the prognostic importance of an elevated temperature in women, when accompanied by hysterical manifestations, when the pyrexia often appears to be due solely to the peculiar condition of the nervous system. Children are subject to sudden elevations of temperature as a consequence of the most trivial disorders, such as a simple angina or a disturbance of digestion.

In Prognosis.—The thermometer is an aid to prognosis in the extent to which it enables us to detect an approach of the temperature to the danger line. But the points at which the temperature crosses the lines of danger are not fixed points, and depend in most instances upon a combination of circumstances peculiar to the individual case. A few more or less positive rules may, however, be stated.

When the temperature reaches a height of 40° C. (104° F.), it is considered a factor of considerable gravity in prognosis. When 40.5° C. (105° F.) is passed the febrile state is termed "hyperpyrexia," and the gravity of the prognosis rapidly increases until 42.5° C. (108.5° F.) is reached, when death is usually imminent. A few cases of recovery from a temperature of 43.3° C. (110° F.) have occurred. In a few instances recovery has been reported after hyperpyrexia ranging from 44.5° C. to 50° C. (112° to 122° F.). Anomalies of such rarity, even if real, have little or no scientific value.

It is not when considered by itself that the temperature is of most value in prognosis, but when taken in connection with the other features of the disease in which it occurs; for in some diseases hyperpyrexia is frequent, whereas in others it is exceptional. A temperature which in one malady would be looked upon as of the gravest import, would in another be considered of less significance. Acute articular rheumatism, scarlatina, relapsing fever, and tetanus, for example, are often attended with hyperpyrexia, 41° to 42° C. (105.8° to 107.6° F.), which is not necessarily serious. Yet persistently high temperature is an evil omen in these diseases. A high evening temperature is less to be feared if the morning remission be considerable than if it be slight. An evening hyperpyrexia followed by an equal or still higher morning temperature is very apt to foreshadow death by a short interval, the temperature, as a rule, continuing to ascend until the fatal issue. It follows, as a corollary to this, that a high morning temperature is more to be feared than a high evening elevation.

A sudden pronounced rise of temperature after it has, in the ordinary course of the disease, declined to near the normal, is generally of evil import, because it often denotes the development of a complication, except in such diseases as malaria, smallpox, and relapsing fever.

A persistence of pyrexia, even of low degree, after the other symptoms have subsided, very often indicates a delayed convalescence, generally from the presence of a complicating affection, as when a catarrhal pneumonia or tuberculosis follows measles or smallpox; or when sepsis follows typhoid fever.

Many febrile diseases undergo a more or less rapid defervescence, involving a fall of temperature to or below normal; but under other circumstances a sudden marked decline is often as much to be feared as a sudden rise, particularly if the fall be accompanied by acute prostration. The designation "collapse temperature" has been applied to a fall below 35.5° C. (96° F.); falling below 34° C. (about 93° F.), it has been called algid collapse. A rapid fall of temperature may augur evil to the patient, without, however, reaching a subnormal degree.

In some conditions the temperature falls from the norm without previous elevation, as in certain forms of insanity, in emphysema, asthma, cardiac lesions, and in the coma of alcohol and narcotic poisons. In these the prognosis is not always so grave as the temperature would, under other circumstances, indicate. Several well-authenticated recoveries have occurred after a temperature as low as 37.7° C. (90° F.), the result of alcoholism.

In Treatment.—Here a thorough knowledge of symptomatology, including the usual temperature range of the affection in which the observation is made, is imperative. It is generally recognized that a high temperature demands prompt recourse to the application of cold or other remedies to reduce it. *Per contra*, a subnormal temperature calls for the application of heat and the use of such measures as promote heat production or retard its radiation. The cause of the pyrexia must in all cases be taken into account. *James M. French.*

THIGH, THE.—The term thigh is used to mean the part comprised between the hip and the knee. In this sense it is limited above by the line of the groin (Poupart's ligament) in front, and the gluteo-femoral crease behind. The patella and knee-joint mark its boundaries below.* In its restricted sense, as the regio femoralis of regional anatomy, the thigh has more artificial, but more definite, boundaries. It is limited above and posteriorly by the gluteo-femoral crease and anteriorly by a line drawn 12 to 15 cm. under Poupart's ligament (Lig. inguinale) and below by a line drawn around the limb from 3 to 8 cm. above the superior boundary of the patella.†

In this restricted sense the inguinal region (regio subinguinalis) lies between its superior boundary and Poupart's ligament. However, the separation into two regions at this point is entirely artificial.

Various bony prominences aid us in determining the relations of the structures of the thigh. The most important are the anterior superior spine of the ilium, the crest of the pubis, the tuber ischium, and the great trochanter above. Below, the patella, the internal and external condylar processes serve as guides. The most important muscular landmark of the thigh is formed by the sartorius. This is best seen when the limb is raised, and it helps to form the boundaries of Scarpa's triangle, Hunter's canal, and the popliteal space.

The general shape of the thigh is that of a truncated cone with its base above. Its contour varies with the amount of muscular development, the condition of contraction of these muscles, and the thickness of the subcutaneous fascia. Its median surface is marked by a furrow running from the inguinal fossa (fossa subinguinalis) to the inner side of the knee. This groove marks the boundary between the adductor muscles and the vastus internus muscle (M. vastus medialis). The sartorius lies

* The term thigh is defined in this manner in the Century Dictionary and is used in this sense by Cunningham, Quain, Morris, etc.

† Joessel: "Lehrbuch der topographischen Anatomie;" article on the *Thigh* by Huntington, in the first edition of this work; etc.

directly external to this, and the larger nerves and blood-vessels of the thigh are just median to this upon the adductor muscles. On the external surface (regio femoris lateralis) it is possible to see a furrow, unless the amount

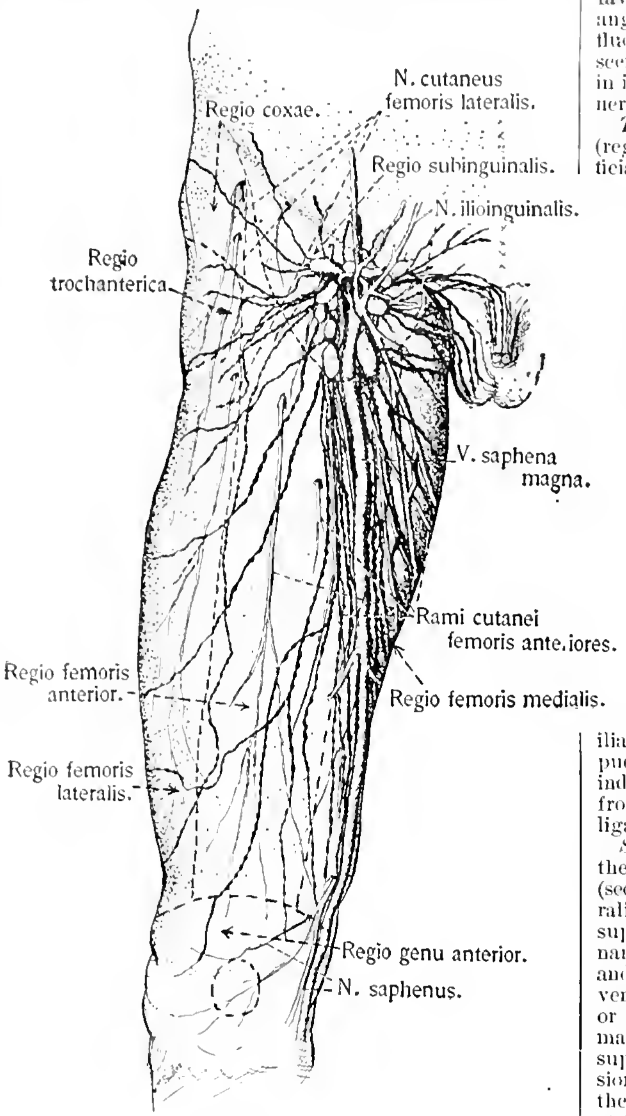

FIG. 4703.—Superficial Veins, Nerves, and Lymphatics on the Front of the Thigh. Only part of the lymphatic vessels is shown, in order not to make the figure too complicated. Drawn from the dissection and from photographs. The dissection was made by A. J. Price, Cornell University Medical College, Ithaca, N. Y. The regions are taken from Spalteholz's "Atlas of Human Anatomy."

of fat is so thick that it is hidden. It is caused by the intermuscular septum (lig. intermusculare externum) between the vastus externus (M. vastus lateralis) and the biceps (M. biceps).

On the median surface (regio femoris medialis) the gracilis muscle is assumed as a dividing line, although it does not form an easily recognized boundary.

The skin covering the thigh is very retractile, due to the loose subcutaneous fascia. It is relatively thick and covered sparsely with hair. Over the inguinal region it is thinner, and in new-born children and very stout people the secretion of the glands may cause irritation. It is attached rather firmly at Poupart's ligament (lig. inguinale).

The superficial fascia (fascia subcutanea) is usually quite thick and better developed in women than in men. It may be from 2 to 3 cm. thick over the femoral artery (A. femoralis) in stout persons, and it is also apt to be the favorite seat of fatty tumor, especially over Scarpa's triangle. It is nowhere very dense, and has little or no influence upon the progress of a superficial abscess, as is seen in the readiness with which pus reaches the surface in inguinal buboes. This fascia contains the superficial nerves, veins, lymphatic vessels, and glands.

The Superficial Lymph Glands.—In the inguinal region (regio subinguinalis) there are from nine to twelve superficial lymph glands that can usually be felt with the finger. From three to five are arranged in a row parallel to Poupart's ligament (glandulæ inguinales) and the others at right angles to it (glandulæ crurales) (see Fig. 4703). The glandulæ inguinales receive the vessels returning from the abdominal wall, perineum, and external genitalia. They are often the site of inflammatory processes in infections of the genital organs, and when they are enlarged from such a cause, they are known as buboes. The glandulæ crurales receive the vessels of the lower extremity. Swelling of the different sets of glands serves to indicate the region of infection and thus are an aid in diagnosis. In operating upon these glands for suppuration their intimate relations with the large veins, arteries, and nerves should be borne in mind. The deep lymph glands (usually two in number) lie under the femoral vein (V. femoralis) and receive vessels from the limb. Most of the large lymphatic vessels which supply the thigh and leg accompany the long saphenous vein (V. saphena magna) as shown in Fig. 4703.

Superficial Arteries.—The superficial arteries of the thigh that have been given definite names are all found in the inguinal region (regio subinguinalis). They are the superficial epigastric (A. epigastrica superficialis), the superficial circumflex iliac (A. circumflexa iliaca superficialis), and the external pudic (A. pudenda externa subcutanea). Their names indicate sufficiently well their position, and hemorrhage from them is usually easily controlled by compression or ligature.

Superficial Veins.—The principal superficial veins are the long saphenous (V. saphena magna) and its branches (see Fig. 4703). It empties into the femoral vein (V. femoralis) after passing through the fossa ovalis. The three superficial veins corresponding to the arteries already named (V. pudenda externa, V. epigastrica superficialis, and V. circumflexa iliaca superficialis) empty into the vena femoralis as it passes under the fossa ovalis, or one or more of these may empty into the vena saphena magna by separate openings. These veins are all well supplied with valves. The vena saphena magna is occasionally double, and is often the seat of varix, and is then very much enlarged and tortuous. It is also ligated at times in the inguinal region as a curative measure for varix at a lower level.

Superficial Nerves.—The principal superficial nerves of the regio subinguinalis and the regio femoris are the ileo-inguinal (N. ileoinguinalis), genito-crural (N. lumbo-inguinalis and N. spermaticus externa), the external cutaneous (N. cutaneus externus), the middle cutaneous (N. cutaneus medius), the internal cutaneous (N. cutaneus internus), and the cutaneous branches of the obturator (N. obturatorius).

The ilio-inguinal nerve receives most of its fibres from the first lumbar nerve. It emerges from the external abdominal ring and divides into terminal branches, which supply the skin over the adductor longus, and that of the scrotum in the male or of the labia majora in the female.

The crural branch of the genito-crural nerve (N. lumboinguinalis) is formed principally by fibres from the second lumbar. It is distributed to the skin as far as the middle of the thigh.

The external cutaneous nerve (N. cutaneus externus) arises also from the second lumbar. It ordinarily penetrates the fascia lata 2 to 3 cm. under the superior anterior spine of the ilium (spina anterior superior ossis ilii), and divides into anterior and posterior branches. The different branches often penetrate the fascia lata separately (Fig. 4703). The anterior branch goes to the side of the thigh, and the posterior branch goes to the skin of the side and back of the thigh.

The middle cutaneous (N. cutaneus medius) supplies a large area of skin over the median portion of the thigh and over the sartorius muscle.

The internal cutaneous nerve (N. cutaneus internus) accompanies the great saphenous vein (V. saphena magna) and sends branches to the median part of the thigh as well as the inner side of the leg.

The cutaneous branches of the obturator nerve (N. obturatorius) supply a small area of skin just above the inner condyle of the knee.

Fascia Lata—The fascia lata is the deep fascia of the thigh, and is composed of very strong fibrous tissues which completely envelop the thigh. Most of the fibres run in a circular manner, but toward the upper and outer side, where the fascia is thickest, the longitudinal fibres are especially well developed. The whole of the fascia lata forms a strong cylindrical tube containing the muscle of the thigh, and if it is broken at any point, the muscles project outward in a hernia-like fashion. It is attached above and in front to Poupart's ligament (Lig. inguinale), on the outer side and behind to the outer lip of the crest of the ilium, and on the inner side to the tuberosity and ascending ramus of the ischium, the descending ramus of the pubis and the symphysis pubis. Below, it is much thinner, and is continuous with the fascia of the leg. Above and to the side the fascia is divided into two layers, which enclose the tensor vaginæ femoris muscle (M. tensor fasciæ latæ). At this point the fascia is thickened, and runs downward like a tendon to the external tuberosity of the tibia. This thickening is known as the ilio-tibial band (tractus iliotibialis) or Maissiat's band. At the edge of Poupart's ligament the structures are further complicated by a division of the fascia lata into two layers and by the presence of the fossa ovalis. The fascia also divides and forms a sheath for the sartorius muscle. Between the fascia lata and the muscles there is a thin layer of areolar connective tissue, through which phlegmonous processes may extend under the fascia. From the inner side of the tube formed by the fascia two strong projections penetrate between the muscles of the thigh, and are attached to the lips of the linea aspera (Lig. intermusculare laterale et mediale) to form the intermuscular septa. The lig. intermusculare laterale follows the edge of the origin of the vastus externus muscle (M. vastus lateralis), and is inserted into the outer lip of the linea aspera. The groove which this forms in relatively thin subjects has already been mentioned, and it separates the vastus externus muscle from the biceps and the other extensors. On the posterior side of the thigh there is also a slip of the fascia lata that runs between the flexor group of muscles and the adductors. It joins the ligamentum intermusculare laterale, and is inserted with it into the external lip of the linea aspera, as seen in Fig. 4704. The ligamentum intermusculare mediale is fastened to the internal lip of the linea aspera, and divides the adductors and extensors. A part of it also takes part in the formation of Hunter's canal (canalis adductorius).

These fibrous intermuscular septa divide the muscles into three groups: 1. An anterior and lateral group, which includes the tensor vaginæ femoris (M. tensor fasciæ latæ), the sartorius (M. sartorius), and the quadriceps femoris (M. quadriceps femoris). 2. An inner or medial group, which contains the adductors and the gracile (M. gracilis). The femoral vessels run between the quadriceps femoris and the adductors; that is, between the anterior and inner divisions. 3. A posterior group containing the flexors (M. biceps, semimembranosus, and semitendinosus). The muscles of the thigh are very large and strong. Many of them are very long, and, in amputations involving them, it must be remembered that, other things being equal, the farther from its origin the muscle is divided the more marked will be its retraction. So in amputations of the lower part of the thigh more must be allowed for retraction than in amputations of the upper part. The position of the limb will also influence the retraction of the various groups; consequently it should be held in the same position during amputation that it is to rest in during healing. The muscles on the posterior and inner aspect of the thigh usually retract the most, and this difference may amount to 5 to 7 cm., and in amputations by the circular method the flaps should be cut so as to allow for this.

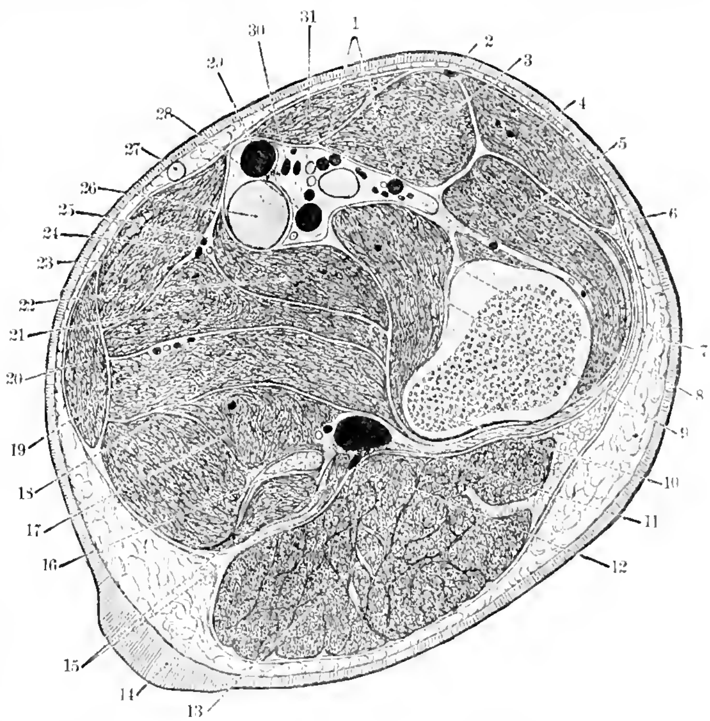

FIG. 4704.—(Toldt, Fig. 1019.) Cross-section through the Right Thigh taken at the Level of the Lesser Trochanter. Distal surface. 1,* A. Circumflexa femoris lateralis; 2, N. cutaneus femoris lateralis; 3, M. rectus femoris; 4, M. tensor fasciæ latæ; 5, M. vastus intermedius; 6, M. vastus lateralis; 7, fascia lata; 8, fascia iliopectinea; 9, M. iliopsoas; 10, trochanter minor; 11, N. ischiadicus (sciatic nerve); 12, N. cutaneus femoris posterior (small sciatic nerve); 13, M. gluteus maximus; 14, gluteal fold; 15, Mm. semitendinosus et biceps femoris; 16, M. semimembranosus; 17, M. adductor magnus; 18, M. adductor minimus; 19, N. obturatorius; 20, M. gracilis; 21, M. adductor brevis; 22, M. pectineus; 23, M. adductor longus; 24, N. obturatorius; 25, fascia pectinea; 26, V. femoris; 27, V. saphena magna; 28, A. profunda femoris; 29, A. femoralis; 30, N. saphenus; 31, M. sartorius.

* A., Arteria; N., nervus; M. musculus; V., vena.

ANTERIOR GROUP OF MUSCLES.—*Tensor vaginæ femoris* (M. tensor fasciæ latæ).—It is on the outer side of the hip. Its origin is on the anterior superior spine of the ilium (spina iliaca anterior superior) and the fascia lata. It is inserted into the ilio-tibial band (tractus iliotibialis), and its nerve supply is the N. glutæus superior.

Sartorius (M. sartorius).—It crosses the thigh in a

Thigh.

spiral manner and arises from the anterior superior spine of the ilium (spina iliaca anterior superior). It is in-

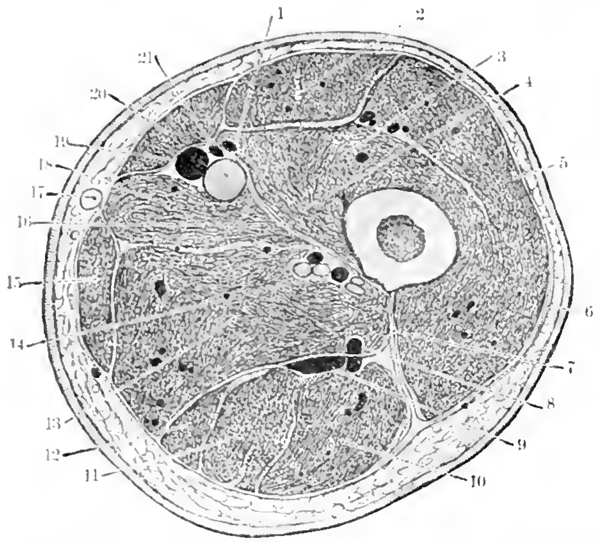

FIG. 4705. (Toldt, Fig. 1020.) Cross-section through the Right Thigh taken Somewhat Above the Middle. Distal surface. 1, V. femoralis; 2, M. rectus femoris; 3, M. vastus intermedius; 4, M. vastus medialis (lateralis); 5, M. vastus lateralis; 6, fascia lata (ilio-tibial band); 7, septum (or ligamentum) intermusculare laterale; 8, A. perforans; 9, N. ischiadicus (sciatic nerve); 10, M. biceps femoris; 11, M. semitendinosus; 12, semimembranosus; 13, M. adductor magnus; 14, A. profunda femoris; 15, M. gracilis; 16, septum intermusculare mediale; 17, V. saphena magna; 18, M. adductor longus; 19, A. femoralis; 20, M. sartorius; 21, V. femoralis.

serted into the tuberosity of the tibia. Its nerve supply is from the N. femoralis.

Quadriceps Femoris (M. quadriceps femoris).—This muscle consists of four portions (M. rectus femoris, vastus lateralis, vastus, intermedius, and vastus medialis).

Rectus Femoris (M. rectus femoris).—It arises from the inferior anterior spine of the ilium (Spina iliaca anterior inferior). It is inserted in common with the other divisions of the muscle into the common tendon.

Vastus Medius (M. vastus intermedius).—It arises from the anterior surface of the shaft of the femur and is inserted into the common tendon.

The *Vastus Externus* (M. vastus lateralis) arises from the intertrochanteric line, the lateral surface of the trochanter major, and the lateral lip of the linea aspera. It is inserted into the common tendon.

Vastus Internus (M. vastus medialis).—It arises from the inner lip of the linea aspera (labium mediale lineæ asperæ femoris) and is inserted in common with the other muscles into the common tendon that is attached to the patella. The four parts of the quadriceps femoris are all supplied by the anterior crural nerve (N. femoralis).

THE INNER GROUP OF MUSCLES.—The *pectineus* (M. pectineus) arises from the superior ramus of the os pubis and is inserted in the pectineal line on the lower part of the lesser trochanter of the femur. It is supplied by the anterior crural nerve (N. femoralis) and the obturator (N. obturatorius).

The *gracilis* (M. gracilis) arises from the inferior ramus of the os pubis and is inserted into the tuberosity of the tibia. It is supplied by the anterior branch of the N. obturatorius.

The *adductor longus* (M. adductor longus) arises from the superior ramus of the os pubis and is inserted into the inner lip of the linea aspera. It is supplied by the anterior branch of the N. obturatorius.

The *adductor brevis* (M. adductor brevis) arises from the anterior surfaces of the rami of the os pubis and is inserted into the inner lip of the linea aspera.

Adductor magnus (M. adductor magnus) arises from the anterior surface of the tuber ischium and the inferior ramus of the ischium. It is inserted into the inner lip of the linea aspera. It is supplied by the posterior branch of the obturator nerve (N. obturatorius) and the internal popliteal nerve (N. tibialis).

Scarpa's triangle (Trigonum subinguinale).—Scarpa's triangle is bounded above by Poupart's ligament, externally by the sartorius muscle and internally by the adductor longus muscle. It is important surgically on account of the number of important structures which it contains. Its apex is the point of election for ligating the femoral artery. It is here that digital pressure is applied in treating popliteal aneurism, and that a turniquet is applied in amputations involving parts of the limb below; a psoas abscess usually points here and femoral hernia appears in the upper part of it.

From the apex of Scarpa's triangle (trigonum subinguinale), on the surface of the upper part of the adductor magnus and piercing the lower part of it, we have a canal formed that carries the femoral artery, the femoral vein, and the long saphenous nerve. It is known as Hunter's canal (canalis adductorius). It is about 5 cm. long, and the upper opening is a crescent-shaped tendinous fold of the adductor magnus with the concavity directed upward. The inferior opening lies in the fleshy part of the adductor magnus, which aids in forming a tendinous border that forms a foramen known as the "adductor foramen." This opening serves to transmit the vessels to the popliteal space.

Femoral artery (A. femoralis) begins at the lower part of Poupart's ligament (Lig. inguinale) and ends at the adductor foramen, where it enters the popliteal space. For convenience of description the femoral artery is divided into three parts: (1) A superior segment in Scarpa's triangle; (2) a middle portion covered by the sartorius muscle, and (3) an inferior portion in Hunter's canal (canalis adductorius). Its general direction (see Fig. 4707) can be mapped out by a line drawn midway between the symphysis pubis and the superior anterior spine of the ilium to the posterior surface of the intercondylar process of the femur.

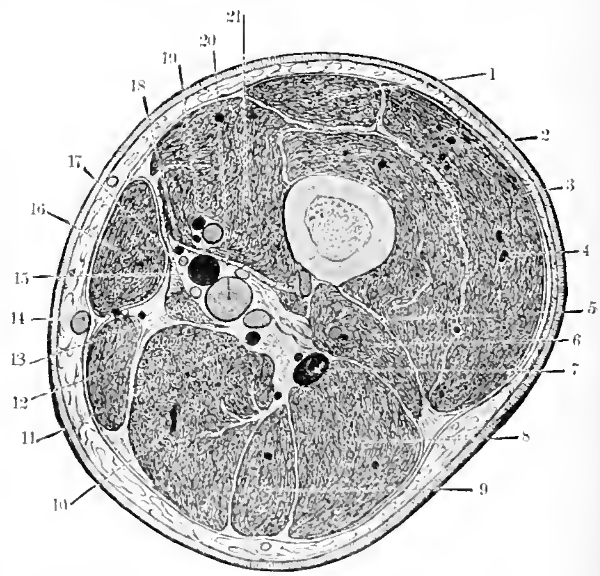

FIG. 4706.—(Toldt, Fig. 1021.) Cross-section through the Right Thigh taken Somewhat Above the "Adductor Foramen" through Hunter's Canal. Distal surface. 1, M. rectus femoris; 2, M. vastus intermedius; 3, fascia lata; 4, M. vastus lateralis; 5, septum intermusculare laterale; 6, M. biceps femoris; 7, N. ischiadicus (sciatic nerve); 8, M. biceps femoris; 9, M. semitendinosus; 10, M. semimembranosus; 11, A. perforans III.; 12, M. gracilis; 13, M. adductor magnus; 14, V. saphena magna; 15, canalis adductorius; 16, M. sartorius; 17, aponeurosis; 18, N. saphenus; 19, A. femoralis; 20, V. femoralis; 21, M. vastus medialis.

Superior Segment.—The superficial arteries given off from this division of the femoral have already been mentioned. The artery is covered here by the skin, the subcutaneous fascia and fat, the superficial lymph vessels and glands, and the fascia lata. The thickness of the fat in this region varies within rather wide limits, and this should be remembered in ligation. At the apex of Scarpa's triangle the artery lies just below and to the inside of the sartorius muscle, which is a good guide to its location. In ligating near the base of the triangle the femoral vein lies to the inside of the artery, but gradually comes to lie under it by the time it reaches the apex. No large nerves accompany this portion of the artery. The femoral nerve passes under Poupart's ligament in the sheath of the ilio-psoas muscle. The femoral artery is most easily compressed just where it emerges from under Poupart's ligament. The pressure should be downward and slightly upward to bring it against the bone. It can also be controlled at the apex of the triangle, and here the pressure should be downward and outward to bring it against the femur.

The *middle segment* of the femoral artery is the longest and is covered by the sartorius muscle throughout its length. The long saphenous nerve accompanies it, and although it is not in its sheath it must carefully be separated from the artery in ligation. The femoral vein lies under and to the outside of the artery. The position of the artery under the muscle makes it hard to control hemorrhage by digital pressure.

The *inferior segment* lies entirely in Hunter's canal (canalis adductorius). The femoral vein lies behind and to the outside and in the same sheath. The long saphenous nerve accompanies it and lies above and toward the inside, but not in the sheath.

The points usually selected for ligation of the femoral artery are, first, just below Poupart's ligament (ligamentum inguinale); second, at the apex of Scarpa's triangle (trigonum subinguinale); and, third, in Hunter's canal (canalis adductorius). In these operations the avoidance of the vein is the most important matter, although in Hunter's canal the long saphenous nerve must also be borne in mind. The muscular landmarks have already been given. The results of ligation of the femoral artery have been as follows:* In 31 cases in which the common femoral was ligated the mortality was 40 per cent.; hemorrhage 60 per cent. The superficial femoral has been ligated 204 times with a mortality of 50 cases.

Collateral Branches of the Femoral Artery.—The superficial branches of the artery have already been described. In addition to those enumerated it gives off the deep external pudic (A. pudenda subaponeurotica), but the largest artery supplying collateral branches is the profunda (A. profunda femoris). A knowledge of its exact position is very important in order that, in ligating the femoral artery, this branch may, if possible, be left undisturbed. It springs from the lateral and posterior side of the femoral artery from 3 to 10 cm. below Poupart's ligament and runs parallel with and outside of the more superficial femoral artery. It lies upon the iliacus, pectineus, and adductor brevis muscles, and then between the adductor longus and adductor magnus. It finally pierces the latter just above the adductor foramen as the fourth perforating artery (A. perforans IV.). A vein that empties into the femoral vein accompanies it for a short distance. It branches, soon after leaving the femoral, into the external circumflex (A. circumflexa lateralis), the internal circumflex (A. circumflexa medialis), and the three perforating arteries (Aa. perforantes). The external circumflex arises usually about 2 cm. from a point where the profunda leaves the femoral artery, but in a few cases it may come directly from the femoral. It divides into an ascending and a descending branch. The former goes to the upper part of the femur and anastomoses with the inferior gluteal (A. glutæa inferior), the superior gluteal (A. glutæa superior), and the deep circumflex iliac arteries (Aa. circumflexæ iliacæ profundæ). The descending branch supplies the vastus externus (M. vastus lateralis) and the vastus medius (M. vastus medialis intermedius).

The *internal circumflex artery* (A. circumflexa medialis) winds around the inner side of the femur at the height of the trochanter. It is first between the psoas and the pectineus and then between the obturator externus and the adductor brevis, and finally between the adductor magnus and the quadratus femoris. In this latter situation it

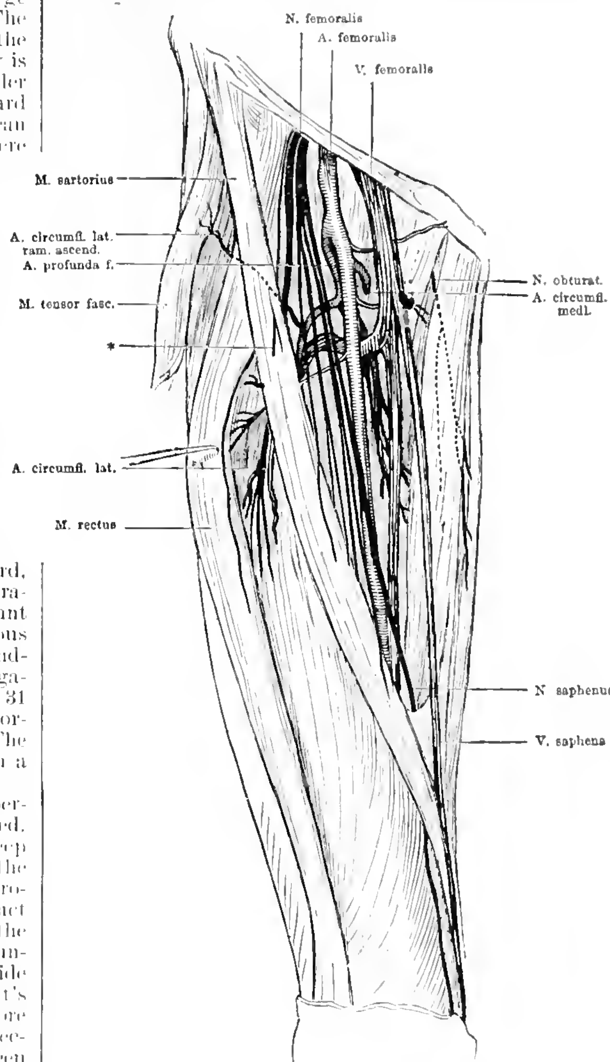

FIG. 4707.—The Surgical Anatomy of the Nerves, Veins, and Arteries on the Anterior Surface of the Thigh. (From Merkel-Henle.)

anastomoses with the sciatic artery (A. ischiadica), the external circumflex and the superior perforating to form the crucial anastomosis. It also sends a branch that pierces the capsule of the hip-joint and supplies the joint. In case of intracapsular fracture it is this branch which furnishes nutrition for the superior fragment.

The perforating arteries are usually three in number and pierce the adductor muscles near the linea aspera to supply the muscles on the posterior aspect of the thigh. The second one usually supplies the nutrient artery of the bone.

The inferior division of the femoral gives rise to the

* Joseph D. Bryant: "Operative Surgery," second edition, vol. i.

anastomotica magna artery (A. genu suprema) just before it pierces the adductor foramen. This artery divides into a superficial and a deep branch. The former runs on the vastus internus (M. vastus medialis) and aids in forming the plexus on the front of the knee. The deep branch penetrates the substance of the vastus internus and anas-

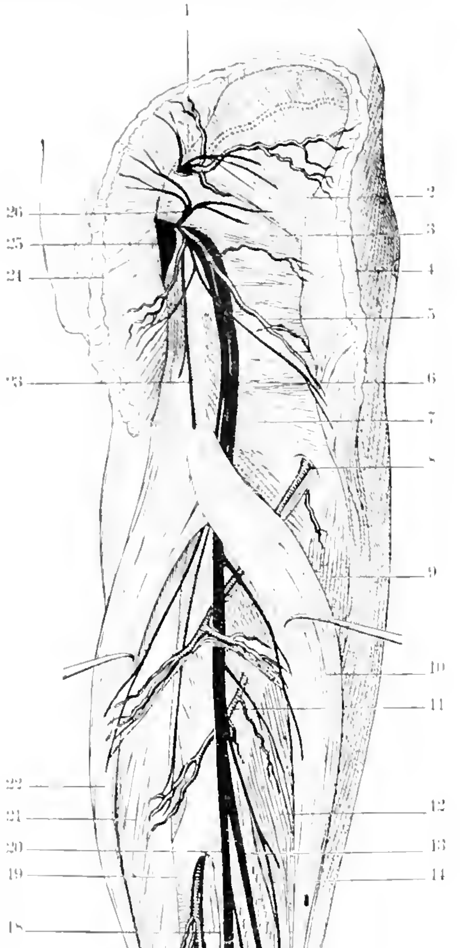

FIG. 4708.—The Relations of the Nerves, Blood-vessels, and Muscles of the Back of the Thigh. (Merkel-Henle.) 1, Superior gluteal artery and nerve; 2, M. gluteus medius; 3, M. pyriformis; 4, M. gluteus magnus; 5, inferior gluteal artery; 6, N. ischiadicus (sciatic nerve); 7, adductor muscles; 8, A. perforans I.; 9, M. biceps (short head); 10, M. biceps (long head); 11, A. perforans II.; 12, M. biceps; 13, N. peronæus communis (external popliteal); 14, superior articular branch from the external popliteal nerve; 15, inferior articular branch from the internal popliteal nerve; 16, N. cutaneus suræ lateralis; 17, N. cutaneus suræ medialis; 18, V. saphena parva (not well shown. It is represented by a part of the light area between the artery and nerve); 19, popliteal artery and vein; 20, N. tibialis (internal popliteal); 21, M. semimembranosus; 22, M. semitendinosus; 23, N. cutaneus femoris posticus (small sciatic nerve); 24, M. gluteus magnus; 25, pudic artery and nerve; 26, inferior gluteal nerve.

tomoses with the internal inferior articular branch of the popliteal (A. articularis genu superior lateralis) and supplies with them the knee-joint.

The *obturator artery* properly belongs to the pelvis, but it anastomoses with the internal circumflex artery (A. circumflexa medialis), and through the sciatic with the inferior gluteal. Through these connections it forms one of the most important channels of the circulation after ligation of the femoral.

Femoral Vein (V. femoralis).—The femoral vein lies to the inner (Fig. 4707) side of the artery and in the same sheath as it emerges from under Poupart's ligament (L. inguinale). As it passes through Scarpa's triangle (trigonum subinguinale) it passes spirally around the artery until at the apex it is directly posterior to it. In the lower part of the thigh it is below and somewhat to the lateral aspect of the artery. Two venæ comites are often present, and may be strongly developed.

Braun* has collected the following figures in regard to ligation of the vein: In 17 cases with the vein only ligated just under Poupart's ligament, 8 cases recovered and gangrene resulted in none. In 6 cases in which the ligation was concomitant with a removal of part of the vein, recovery resulted in 3 cases, gangrene in 2, and death in 1 case. In a series of 15 cases in which both the artery and the vein were ligated gangrene followed in 7.

Anterior Crural Nerve (N. femoralis).—The anterior crural passes below Poupart's ligament to the outside of the femoral artery (Fig. 4707). From this it is separated by the strong fascia iliaca. At a distance of from two to three centimetres under Poupart's ligament it divides into a number of branches to supply the skin and muscles of the anterior portion of the thigh (Figs. 4703 and 4707). The superficial branch runs under the sartorius, pierces and supplies that muscle, and pierces the fascia lata as the middle and internal cutaneous nerves. The deep branches supply the four portions of the quadriceps femoris muscle, and a small branch accompanies the internal circumflex artery to the pectineus. The anterior crural nerve also gives rise to the long saphenous nerve which accompanies the femoral artery through Hunter's canal.

Obturator nerve (N. obturatorius).—The obturator nerve reaches the inner side of the thigh by passing through the obturator foramen. It divides into a superficial and a deep branch. The superficial sends a small branch also to the pectineus, which thus obtains a nerve supply from two sources. It also supplies the adductor brevis and the abductor gracilis, and usually supplies the cutaneous branch to the skin over Hunter's canal and the lower part of the adductor longus muscle. The deep branches supply the obturator externus muscle and the adductor magnus. The obturator nerve thus supplies all of the muscles of this group except the part of the pectineus supplied by the anterior crural.

POSTERIOR SIDE OF THE THIGH.—The skin and fascia are sufficiently like those on the anterior side to need no special description. The small sciatic nerve (N. cutaneus femoris posterior) is found just under the fascia, and is distributed to the skin and fascia of the posterior aspect of the thigh, popliteal space, and leg.

The muscles found on the posterior side of the thigh have already been mentioned. They are the Mm. biceps, semitendinosus, and semimembranosus.

The *biceps* (M. biceps) springs from two heads. The long head takes origin in common with the semitendinosus from the tuber ischii. The short head has its origin in the middle third of the outer lip of the linea aspera. The two unite and are inserted into the head of the fibula. The long head is supplied by the internal popliteal nerve (N. tibialis), and the short head by the external popliteal (N. peronæus communis).

The *semitendinosus* (M. semitendinosus) has its origin on the tuber ischii and is inserted into the inner tuberosity of the tibia. It is supplied by the internal popliteal nerve (N. tibialis).

The *semimembranosus* (M. semimembranosus) arises by a long flat tendon from the tuber ischii, and is inserted into the inner tuberosity of the tibia beneath the semitendinosus. It is supplied by the internal popliteal nerve (N. tibialis).

The *great sciatic nerve* (N. ischiadicus).—This is the

* Braun: Archiv f. klin. Chirurgie, Bd. 37, Heft 3.

largest nerve in the body. It emerges under the gluteus maximus muscle and runs downward to the middle of the popliteal space (Fig. 4708). After emerging from under the gluteus maximus it is covered by the long head of the biceps. Between these flexor muscles it is buried in loose fatty connective tissue, which forms an easy path for burrowing pus from abscesses that have their origin usually in the pelvis. In this way the pus may reach the popliteal space. A line drawn from a point a little toward the median side of the centre of a line drawn from the great trochanter to the tuber ischii, to the middle of the popliteal space will lie over the nerve, and it is available as a guide in operations below the gluteofemoral crease. The nerve divides a little below the middle of the thigh into two branches, the internal (N. tibialis) and the external (N. peronaeus) popliteal branches. The great sciatic nerve supplies the muscles of the back of the thigh, as has already been described. Its size and the number of its sensory fibres make it an important nerve in causing shock. Operative procedures involving this nerve may be made less serious by the use of cocaine locally, or by manipulations that reduce the mechanical irritation to a minimum.

Arteries and Veins.—The superior portion of the back of the thigh is supplied by the inferior gluteal artery (A. glutæa inferior) (Fig. 4708). It anastomoses with the internal and external circumflex arteries and the perforating arteries. The perforating arteries (Fig. 4708) are usually three in number and supply the muscles on the back of the thigh. The deep veins of the posterior side accompany the artery.

The Skeleton of the Thigh.—The shaft of the femur is bent in the form of a bow anteriorly. This outward and anterior curve gives the adductor muscles (the adductor magnus especially) a greater angle, and this arrangement of the muscle is the cause of the lower fragment often being pulled upon the inner one in fracture. In old age the spongy bone in the neck of the femur often undergoes fatty degeneration and disappears. This is the cause of the increased frequency of fracture at this part of the bone in old age. It occurs oftener in women than in men, owing to the fact that the angle is more obtuse in women than in men, and so the strain has a greater mechanical advantage. *Mervin T. Sudler.*

THILANIN.—This title is given to a compound of sulphur and lanolin, which is said to contain three per cent. of sulphur, but whether in combination with the cholesterin or with the fatty acids is undetermined. It was introduced by Dr. Edmund Saalfeld, at the third Congress of the German Dermatological Society, as being devoid of any irritating properties and useful in cutaneous affections. *Beaumont Small.*

THIOCOL, guaiacol-sulphonate of potassium, $C_6H_3.OH.OCH_3.SO_3K$, is a white, odorless crystalline powder with a faintly bitter taste. It is soluble in water or diluted alcohol, but not in strong alcohol, ether, or the fatty oils. Its aqueous solution is turned violet blue by ferric chloride.

Thiocol, being a soluble compound of guaiacol, has the medicinal properties of this substance; but its taste is not disagreeable, it is unirritating to the stomach, and it does not "repeat" after ingestion. Being soluble it is easily administered and rapidly absorbed. Schwarz states that 15 gm. (℥ ss.) a day have been taken with no unfavorable symptoms. The results in tuberculous patients, as noted by Mendelssohn, Braun, Moir of Edinburgh, and many others, are increased appetite, lessened cough and sputum, disappearance of night sweats, moderation of the diarrhœa, and general improvement. The employment in whooping-cough and respiratory troubles other than tuberculosis has met with ardent advocates. In enteritis Schnirer studied its action in thirty-eight cases, and placed it among the valuable antidiarrhœic remedies. For children he recommends ℞ Thiocol, 0.5 c.c. (♏ viij.); syrup of orange peel, 10 c.c. (ʒ iiss.); water to make 60 c.c. (℥ ij.). Sig.: A teaspoonful every two hours. For the adult, thiocol may be administered in capsule, cachet, tablet, or solution. The dose is 0.5 gm. (gr. viij.) three times a day, gradually increased.

A ten per-cent. syrup of thiocol is marketed under the name of "*Sirolin.*" *W. A. Bastedo.*

THIOCYANATES. See *Sulphocyanides.*

THIOFORM is a basic bismuth di-thio-salicylate. It is a yellow, odorless powder containing seventy two per cent. of bismuth oxide, and is used as a dusting powder or ten-per-cent. ointment in place of iodoform. There are good reports of its employment in eczema.

W. A. Bastedo.

THIOGENOL is a compound of sodium sulphonate containing ten per cent. of sulphur. It is readily soluble in water and alcohol and is used by Jaquet in two-per cent. solution as an injection in gonorrhœa, and both pure and in twenty-per-cent. ointment for dermatitis and prurigo. It is an ichthyol substitute. *W. A. Bastedo.*

THIOL.—An artificial ichthyol, prepared by treating with sulphur the hydrocarbons having a specific gravity between 0.890 and 0.900, that are obtained from coal tar. The latter differs from ichthyol by the absence of much organic matter that supplies its objectionable qualities, their presence, it is claimed, being of no therapeutic value. After the thiol has been separated it is evaporated to an extract—*thiolum liquidum*, or to complete dryness—*thiolum siccum*.

Liquid thiol is a thin, brownish, neutral liquid, with a specific gravity of 1.080 to 1.082 at 60° F. It has a feeble bituminous odor, not disagreeable. It forms a clear solution with water, especially if glycerin be added. It is not very soluble in alcohol or ether. Aqueous solutions froth abundantly when shaken; they are not affected by the addition of strong alcohol, but soda, dilute acids, or metallic salts cause a precipitate. Dry thiol, which forms forty per cent. of the liquid form, is a dark brown or blackish mass, sometimes formed in scales, which, when heated, burns away entirely, leaving no residue. The advantages claimed for thiol over ichthyol are, that it is really a purified form of the latter, that it is devoid of the disagreeable odor, and does not stain the linen or clothing, is less irritating, and more definite in composition. The therapeutic use of thiol is the same as that of ichthyol.

Although the pure drug may be applied without causing any irritant action, a ten-per-cent. preparation is generally sufficient for all purposes. The powder may be combined with powdered starch; or aqueous or glycerin solutions may be prepared. For wounds a five- or ten-per-cent. solution in collodion is very serviceable. An ointment may be made with vaselin or lanolin.

For inflammatory diseases, and in gynecological practice, its action is increased by internal administration in addition to its local use. The dose is one grain and a half, which may be repeated up to five times a day. It is given in cachets, in pill form, or in solution in wine.

Beaumont Small.

THIOLINIC ACID, sulphurated linseed oil, thiolin, is a dark green semi-solid mass of peculiar mustard like odor, containing about fifteen per cent. of sulphur. It is insoluble in water and soluble in alcohol, and is employed as a succedaneum for ichthyol. *W. A. Bastedo.*

THIOPHENE.—C_4H_4S. This is a sulphur holding hydrocarbon, contained in coal tar benzin. In the pure state it is a colorless, clear, volatile oil, boiling at 184° F., of slight odor, and will not mix with water. Thiophene itself is not employed as a therapeutic agent, but two preparations have been introduced—*sodium thiophensulphonate* and *thiophene di-iodide*.

Sodium thiophensulphonate, $C_4H_3SNaSO_3$, is a white crystalline powder, containing thirty-three per cent. of sulphur, and having a slight but unpleasant odor. Used as a dusting powder, or applied as an ointment, ten per cent., with equal parts of lanolin and vaseline, it has proved of much service in all forms of prurigo. A lead salt has also been prepared and used with success in the same disorder.

Thiophene di-iodide, $C_4H_2I_2S$; contains seventy five per cent. of iodine and 9.5 per cent. of sulphur. It forms in fine crystalline plates, insoluble in water. The di iodide has been proposed as a substitute for iodoform, as it has a less unpleasant odor. *Beaumont Small.*

THIO-RESORCIN, $C_6H_4(SH)_2$, is a yellowish-gray insoluble powder made by fusing together resorcin and sulphur. It is a substitute for iodoform, and has been employed in skin and scalp diseases in ten-per cent. ointment. *W. A. Bastedo.*

THIO-SALICYLIC ACID, $C_6H_4.SH.COOH$, is salicylic acid with an oxygen atom replaced by sulphur. It is used like salicylic acid as an antiseptic. *W. A. Bastedo.*

THIOSAPOL, a soda soap (hard soap) containing about ten per cent. of sulphur in combination, is used in the treatment of skin diseases. *Thiosavonal* is the corresponding potash soap (soft soap). *W. A. Bastedo.*

THIOSINAMINE (*Allyl-Sulpho-Carbamide*).—This long known chemical compound has been recently introduced as a drug possessing valuable therapeutic properties. It is obtained by the action of alcohol and ammonia upon the ethereal oil of mustard, which forms a basic compound with the following formula, $C_3H_5.NH.NH_2.CS$. It forms in colorless and odorless prismatic crystals, having a bitter taste, and is readily soluble in water, alcohol, and ether.

Thiosinamine has attracted attention on account of its reputed resolvent action upon scar tissue. When injected into tissue causing deformity and disability by contracture, it is said to produce a softening and relaxation which allow the part to become free and pliable. Numerous cases of fingers and limbs that were beyond the use of the knife are reported to have been almost perfectly restored. This effect was announced by Dr. H. von Hebra, Jr., of Vienna, in 1892, at the International Congress on Dermatology. He recommends that a fifteen-per-cent. alcoholic solution be prepared, and that two injections a week be used. It has been used with success for the purpose of relaxing the cicatricial tissue of urethral strictures. It has also been used in gynecological practice to relieve the symptoms arising from the effects of perimetritis and inflammatory troubles about the appendages. In addition to its action on cicatricial tissue, it causes a decided increase in diuresis and diaphoresis, and exerts a powerful tonic effect upon the system, in consequence of which it was thought to have a beneficial resolvent action upon local tuberculosis. Upon chronic enlargement of lymphatic glands its effect was very marked. In a number of cases of lupus it was noticed to exert a beneficial action. It has been reputed as acting favorably upon corneal opacities and deafness from thickening of the membranes. The injections are made in the interscapular or gluteal regions. No constitutional effect followed the injections, but a local reaction set in after a few hours, causing redness, tension, and swelling of the affected part. A ten per cent. solution in glycerin and water may be used. The dose is from one to three grains. *Beaumont Small.*

THIRD NERVE.—See *Cranial Nerves*.

THIRST.—1. DEFINITION AND CLASSIFICATION.—Gould defines thirst as "a state manifested by a desire for drink." The Century Dictionary defines thirst as "the uncomfortable sensation arising from the want of liquid nutriment; the uneasiness and suffering occasioned by want of drink; vehement desire for drink." From these definitions it becomes clear that thirst, as understood by the lexicographers, expresses first, *a condition of body*; second, *a sensation*; third, *a desire*. The condition is the need of water; the sensation is one of dryness of the mucous membranes, especially those of the mouth and fossæ. Following this sensation there is a natural desire for the needed water to allay the sensation.

In classifying thirst among the sensations, it is necessary to remember that all sensations may be divided into objective and subjective, the objective sensations being those which arise from stimuli caused by natural substances or forces acting upon sensory nerve ends; while subjective sensations are the re-experiencing of objective sensations without any physical basis. Subjective sensations are illusory and are experienced in dreams and in certain unusual conditions of the nervous system. Objective sensations may be subdivided into two classes: First, those caused by objects or forces outside of the body, as vision is caused by light entering the eye from without, or hearing, by sound waves entering the ear from without.

The second class of objective sensations may be called *indirect objective* or *auto-objective*. This class of sensations includes hunger, thirst, suffocation, pain, fatigue, etc. It will be noted that these auto-objective sensations all arise from different conditions that exist within the system, the first three named being manifestations of needs of the body for more matter, the last two, manifestations of overstimulation or overwork.

2. PHYSIOLOGICAL CONSIDERATIONS.—In order to get a clear idea of thirst, it is necessary for us to consider briefly the need of the system for water. The first need arises in the process of digestion within the alimentary tract and absorption from the alimentary tract. Nearly all of the digestive processes are hydrolytic cleavages which involve not only the incorporation of molecules of water into new combinations, but which combinations take place far more readily in the presence of abundant water. Absorption takes place slowly and with difficulty if the digested products are not thoroughly diluted with water. Once the food is absorbed and passes into the circulation, the proportion of water in the blood must remain fairly constant, otherwise the diffusion of blood and lymph plasma carrying nutrition to the tissues is interfered with. The metabolic processes in general involve either the incorporation or the liberation of water molecules, and these processes take place freely in the presence of an ample supply of water only. Secretion and excretion from glandular epithelia are scanty except for an abundance of water in the blood.

These various needs of the system for water are manifested, first and most apparently, by decreased water in secretion and excretion. This decrease of the water contents of secretion and excretion is most noticeable to the subject in the drying of the mucous membranes of the mouth and throat. This, in fact, is the sensation usually experienced in thirst and associated with that term. There is also, however, an increased specific gravity of the blood and lymph followed by what may be termed a tissue thirst, or a need of the active tissues of the body for water. This leads to a classification of thirst into *local* or *external thirst* as experienced in the mouth and throat on the one hand, and *general* or *internal thirst* experienced by the tissues of the body, and appealing to the consciousness in a rather vague feeling of lassitude difficult to describe, but quickly relieved by a copious draught of cool water.

The nervous mechanism of the sensation of thirst is obscure. Sherrington, in his chapter on sensation (Schaefer's "Textbook of Physiology," vol. ii., p. 992) refers to a thirst centre located in the medulla in association with the nuclei of the ninth and tenth nerves, the cerebral connections passing from this centre upward, the afferent impulses coming from the distribution of the glossopharyngeus and vagus nerves in the mouth, pharynx, œsophagus, and stomach. If we accept this theory, we are driven to the alternative of supposing that the thirst centre, wherever that may be located, is influenced by the blood supplying the centre. This theory, while it might account for general tissue thirst, could not account for the local thirst arising from the dryness of mucous membranes.

Local thirst may be abated or allayed by local application of water to the mucous membranes affected. If the local thirst is, however, a local manifestation of the general condition, this method of allaying it will only be temporary and the sensation will recur a few moments after the application. General thirst may be allayed by intravenous injection of normal saline solution; by introduction of water into the stomach through a stomach tube, or by the introduction of water into the rectum. In all of these cases the water is rapidly absorbed and transported to the thirsty tissues and general thirst is thus assuaged, followed rapidly by an alleviation of local thirst. Had the water been taken in the usual way of drinking, the local thirst would have been temporarily allayed, incidentally upon the passage of the water over the mucous membranes, and this would have been followed presently by a moistening of these tissues from within by the more copious secretions. Variations of the above usual conditions may be noticed. Meteorological conditions, such as a high temperature or low humidity, will cause a profuse perspiration followed by a general increased demand for water. Muscular exercise will have a similar effect. Diet, if rich in salts or sugars, will lead to a demand for water to dilute the solutions to the normal specific gravity, while the free use of diuretic diets, as lemons or oranges, will lead to a depletion of the water of the system and be followed by thirst.

3. Pathological Considerations.—In its pathological relation thirst is called *polydipsia*, *dipsosis*, or *dipsis*. It may be said, in passing, that *polydipsia ebriaria* (thirst for intoxicants) is not real thirst in any proper use of that term, though "thirst" is much used to express a desire for alcoholic drinks. Thirst proper is a desire for water.

Polydipsia is associated with many diseases as a symptom.

First, in such diseases as diarrhœa or cholera (in which diarrhœa is a prominent symptom) much water is carried off in watery stools. In diabetes insipidus water is lost in polyuria. In hemorrhage water is lost with the blood. In all of these cases there is extreme thirst as a secondary symptom or condition. This extreme thirst may be abated with frequent draughts of cool water and a free use of liquid diet.

Second, in diabetes mellitus the thirst is a secondary symptom caused by the increased sugar in the blood, which in turn leads to a demand on the part of the tissues for water to lower the specific gravity of the blood.

The polyuria of diabetes mellitus is secondary to the polydipsia, while the polydipsia of the diabetes insipidus is secondary to the polyuria.

Third, in another class of pathological conditions belongs hysterical polydipsia, which is as inexplicable as are other symptoms that may be manifested in hysteria.

4. Dietetic and Therapeutic Considerations.—The adult of average size requires about two litres of water each twenty-four hours to make good the loss by excretion and evaporation. About one-half of this requirement is supplied by the average diet, leaving one litre (about four glasses) to be taken as a beverage. Many adults take much less than this quantity. But many adults take too small an amount of water; few take too much. There is a growing belief in the medical profession that water is a most valuable agent for flushing out accumulating excretory material from the tissues.

The sense of thirst may readily become perverted and thus fail to fulfil nature's plan as an admonisher of a need for water. Such a condition results in malnutrition.

Winfield S. Hall.

THIRY-VELLA FISTULA.—See *Succus Entericus*.

THIURET, $C_8H_7N_3S_2$, is a sulphur compound which is used as a substitute for iodoform. It is a light, odorless powder insoluble in water and soluble in alcohol and ether. In warm alkaline solution it sets free its sulphur. The compounds with hydrochloric, hydrobromic, salicylic, or sulpho-carbolic acids are somewhat soluble in water.

W. A. Bastedo.

THOMASVILLE, GEORGIA.—This well-known and desirable winter resort is situated in the southwestern portion of the State, not far from the Florida line, and about one hundred and sixty miles from the Atlantic coast, and fifty-three miles from the Gulf of Mexico. It lies in the great southern pine belt, and, like Summerville, Aiken, and other resorts in this belt, is in a forest of pines, on sandy soil, and at a distance from any body of water. It has an elevation of 380 feet above sea level, which is the highest ground in that part of the State.

The town is an attractive one, with a population of about seven thousand, with broad and shady streets, a park, churches of various creeds, an opera house, colleges, and many good schools. The place is well lighted, there is a system of sewerage, and there are water-works supplying the whole city from an artesian well nineteen hundred feet deep. The natural drainage of the town is also excellent.

The surrounding country is undulating, and besides corn and cotton, grapes are produced in abundance, and the famous "Le Conte" pear. Many other fruits are also grown here, such as peaches, plums, apples, strawberries, figs, and watermelons; and there is a profusion of flowers.

The accommodations are abundant and good, there being several first-class hotels, a large number of good private boarding-houses, and cottages and rooms to rent by the season or month for housekeeping purposes.

The tuberculous invalid, however, contemplating a temporary residence at Thomasville, must be warned of the difficulty of obtaining accommodations in the hotels or boarding-houses. As a rule such patients are not received, simply because invalids suffering from diseases other than tuberculosis, and tourists in general, will not frequent hotels or boarding-houses where consumptives are taken. The only alternative for the unfortunate tuberculous individual seems to be renting a cottage and establishing a temporary home.

The climate tempts to an almost constant out-of-door existence, and one of the chief attractions of the place is to be found in the beautiful drives through the pine forests. The roads radiate from the town in all directions, and are smooth and solid, being well adapted to cycling. A short distance from the city is the Country Club, with extensive grounds and a club-house. There are also golf links and a pack of fox hounds.

The resort is filled with visitors in the winter and early spring, and is also a stopping-place for those going to or coming from Florida. It is visited by those seeking merely change and recreation as well as by those seeking health. The hospitality of the people is particularly noted.

The climate, as will be seen from an inspection of the accompanying chart, is a comparatively dry one; its winters are warm without the enervating influences of the Florida coast resorts; "it is to a marked degree exempt from severe winds, and there is always a great preponderance of sunshine and of days which admit of out-of-door exercise on the part of the invalid."

The diseases for which such a climate is to be recommended are particularly the various catarrhal affections of the respiratory passages, and incipient or early pulmonary tuberculosis in individuals who have not the resisting power to undergo with advantage the cure in the high altitudes. Moreover, it is a favorable winter climate for very many conditions which require a mild, sunny climate, where outdoor life can be indulged in without great demands upon one's vitality. The feeble, young, or old, those temporarily weakened by sickness or hardship, can lead here a quiet, comfortable existence and, when possible, regain their former maximum of health and strength.

Access from the north to Thomasville is easy and ex-

CLIMATE OF THOMASVILLE, GA. LATITUDE, 30° 50'; LONGITUDE, 84° 10'. PERIOD OF OBSERVATION, FIVE YEARS TEN MONTHS.

	January.	February.	March.	April.	July.	October.	November.	December.	Year.
Temperature (Degrees Fahr.)									
Average monthly	52.15	56.60°	61.55°	67.79°	82.35°	69.18°	58.56°	52.70°	
Mean of warmest	61.12	66.52	72.03	77.21	91.03	77.23	68.12	62.51	
Mean of coldest	43.19	49.08	54.0	61.97	79.14	63.32	51.72	45.18	
Average daily range	17.93	17.44	18.03	15.24	21.89	13.91	16.40	17.33	
Highest or maximum	78.0	82.0	88.0	91.0	101.5	94.5	84.5	79.5	
Lowest or minimum	14.0	28.0	32.0	36.0	66.0	37.0	26.0	10.0	
Humidity—									
Average mean relative	63.7%	62.8%	62.3%	62.3%	66.0%	68.2%	66.6%	64.7%	65.16%
Precipitation									
Average in inches	3.41	3.36	3.92	5.28	4.69	5.19	2.69	3.85	51.56
Wind									
Prevailing direction	S. and N. W.	S. and N. W.	S.	S.	S.	S.	S. and S. W.	S. and N. W.	S. S. W., S. E., and N. W.
Average hourly velocity in miles	5.0	5.0	9.0	8.0	3.0	7.0	8.0	7.0	5.8
Average number of fair and clear days	23.0	22.0	24.0	21.0	20.0	24.0	24.0	24.0	26.9

peditions, either all the way by rail or by steamers from Boston or New York to Savannah, and thence by rail.

Edward O. Otis.

THOMSEN'S DISEASE. See *Muscle, Pathology of.*

THORACIC DUCT.—The thoracic duct, the large lymph channel of the body, runs from the receptaculum chyli to the left side of the neck, where it terminates at the angle of junction of the left subclavian and internal jugular veins. The receptaculum chyli is located on the anterior surface of the body of the second lumbar vertebra, and is a dilatation of the lower end of the duct, into which empty a large number of lymphatics and lacteals from the lumbar region and the organs of digestion. This pouch is not always present, its place being sometimes taken by a network of lymph vessels which unite to form the duct. This vessel has its course upward and to the right, on the anterior surface of the lumbar vertebræ, to the right of the aorta, in company with which it passes between the two crura of the diaphragm and enters the thorax. It now ascends on the dorsal vertebræ, lying between the thoracic aorta and the right vena azygos, and behind the posterior parietal pleura. At the fifth dorsal vertebra it curves to the left, and passing behind the transverse portion of the aorta, runs upward and to the left behind and slightly internal to the left subclavian artery. Passing into the neck, it now lies on the anterior surface of the scalenus anticus muscle, under the deep layer of fascia that lies over the muscle. The point to which it rises in the neck varies considerably. It may pass outward to the angle of junction of the subclavian and internal jugular veins, and empty by a single trunk into the veins as they unite to form the left innominate, never rising above the level of the upper border of the subclavian vein. This is the form which is least likely to be injured in surgical operations, as it is well protected by the deeper structures. It may ascend on the anterior surface of the scalenus anticus, as high as 6–6.5 cm. above the upper border of the first rib, or to the level of the middle of the thyroid gland. In these cases it curves downward and outward and frequently splits into a number of branches which may re-unite and form a single trunk, or may empty separately into the subclavian or internal jugular veins, or both; into the vertebral or the transversalis colli veins; or into any combination of these veins, depending upon the number of branches in the particular instance. After injecting and dissecting some fifty specimens, I am unable to state any fixed rule for the distribution of the cervical portion of the duct, or to formulate any systematic classification of the different variations of termination. It can, however, be said that, as a general rule, the higher the duct rises in the neck, the more likely it is to have terminal branches. When the duct is a single trunk, it generally lies low. The cervical portion is the only part that is of practical importance, from a surgical standpoint, as it is the only part that is exposed to surgical interference. The terminal portion of the duct, or the terminal divisions, if there are any, will always be found on the anterior surface of the scalenus anticus, or under the deep fascia covering the muscle, behind and internal to the last portion of the internal jugular vein. Where the duct rises high in the neck and presents many branches, it very frequently has a branch lying behind the clavicle, in the thorax, and emptying into the posterior portion of the

FIG. 4709.—Cervical Relations of the Duct in the Neck, showing a terminal arrangement frequently seen. The duct here divides into three terminal branches, emptying into the internal jugular (erroneously labeled "external jugular" in the cut), the subclavian and the transverse cervical veins, with a cross branch connecting the first and second branches. (From a drawing by G. R. Egeland, from a dissection from the dissecting room of the Northwestern University Medical School, Chicago.)

subclavian vein. In case of injury to the cervical portion of the duct, this branch alone would suffice for furnishing collateral circulation.

Anomalies.—Besides the multiple endings of the duct, which are so common as to be normal, the most frequent anomaly observed is that of the duct terminating in the right subclavian vein inside of the left. This has been frequently observed and is generally found associated with vascular irregularities, especially with absence of the innominate artery, with the right common carotid and subclavian arteries springing directly from the arch of the aorta. In such cases the thoracic duct takes the place of the right lymphatic duct, and the left duct has a corresponding course and relation usually found in the normal duct on the right side. Less frequently seen is a duct, double throughout, one portion going to the subclavian vein on each side, the two ducts being connected by numerous cross branches. Occasionally one finds a duct, single as far as the fourth or fifth dorsal vertebra, then dividing and sending a branch to the vein on each side. Cases of anomalous course or distribution have been reported by Thompson, Watson, Cruickshank, Krause, Paturban, Thomson, and Brinton. Thomson suggests that there are probably developmental reasons for these anomalies.

Physiology.—The function of the thoracic duct is to convey the chyle from the digestive system and the lymph from the lumbar glands to the blood of the right heart. It is not known what constitutes the force that pumps the lymph from the abdominal cavity to the termination in the left side of the neck. Weiss found that the pressure in the duct was equal to from 9 to 15 mm. of mercury. The flow of blood through the arch of the aorta, the action of expiration and inspiration, and the motion of the heart, as well as intrathoracic pressure, and the force of the flow of blood in the left innominate vein, are probably all factors in producing and maintaining the lymph flow. I have repeatedly found it impossible, in the cadaver, to inject the duct from the abdominal cavity until the heart and lungs were removed.

As to the composition of the fluid found in the duct of the human being, several analyses have been made. Rees, in 1843, analyzed the lymph taken from the duct of a recently executed criminal. Seyler took the contents of a pleuritic effusion caused by the rupture of a duct in the thorax. Hasebrook obtained and examined the fluid of a chylous pericardial effusion. Paton, in 1890, made three analyses of the fluid obtained from a chylous fistule following an operation for sarcoma of the neck. As it is impossible to say how greatly the chyle may be modified by absorption from a serous cavity, the results of the second and third observers are somewhat discredited. Rees and Paton, therefore, are best worthy of consideration. Their analyses gave the following results:

	Rees.	Paton.
Water	904.8	951.6
Solids	95.2	51.7
Organic	90.8	41.91
Proteids	70.8	12.53
Fats	9.2	26.06
Inorganic	4.4	6.49

In regard to the rate of flow, Paton found that it averaged from 1 to 3 cub. cm. per minute, or from 1,584 to 4,752 cub. cm. per twenty-four hours. The weight of the patient was 60 kgm. Therefore the flow was from 2.64 to 7.93 cub. cm. per 100 kgm. of body weight.

Frederick R. Green.

A Few of the More Important Bibliographical References.

Gage, S. H.: Proc. Am. Assn Adv. of Sci., 1879, xxviii., 425.
Paton, D. N.: Jour. Phys., 1890, xi., 109.
Quenmu and Darrier: Compt. rendus Soc. de Biol., 1887, 8 s., iv., 529.
Rees: Abstr. Phil. Trans. Roy. Soc., London, 1837, iv., 373.
Zuckerkandl; Med. Jahrb., Wien, 1883, 68.
Brown: Journ. Anat. and Phys., London, 1881, xvi., 301.
Cheston: Phil. Trans., London, 1780, lxx., 323.
Thompson: Journ. Anat. and Phys., London, 1883, xviii., 416.
Wutzer: Arch. f. Anat. und Phys. u. wissenschaftl. Med., Berlin, 1834, 311.
Moran, H.: Compt. rendus Soc. de Biol. de Paris, 1894, 10 s., i., 813.
Brinton: N. Y. Med. Journ., 1894, lix., 568.
Nattan-Larrier: Bull. Soc. Anat de Paris, 1897, lxxii., 222.
Pecquet: Phil. Trans., London, 1700, iii., 259.
Watson: Journ. Anat. and Phys., London, vi., 427.
Quain: Anatomy, tenth edition, 381.

THORACIC DUCT, PATHOLOGY OF.—Not many pathological conditions of the thoracic duct have been reported. This may be explained in part by the fact that anastomoses are frequently present, and consequently the symptoms which would have been caused are masked or absent. At other times the region in which the duct lies is examined at autopsy very superficially if at all, and consequently some pathological conditions are not seen.

Anomalies.—Anomalies of the thoracic duct are not uncommon. The duct may lie on the right side of the vertebral column; it may have two or three outlets into the subclavian vein, or it may be double throughout its entire course. In other cases the main trunk may divide to form a plexus of lymph vessels in the posterior mediastinum, the radicles uniting to form a single trunk which empties into the subclavian vein in the usual manner. Besides these more common varieties, other anomalies may occur, that reported by Svitzer[45] being one of the most peculiar. In his case the duct partially encircled the aorta and emptied into the left subclavian vein.

Hemorrhage.—Hemorrhage into the duct may result from trauma to the duct, or may be present in severe anæmias or leukæmias. In cases of congenital or acquired hæmophilia in which retroperitoneal hemorrhages occur, or in cases of injuries to the intestines, the contents of the duct may contain a variable amount of blood. In any case in which blood is present in the duct it may remain fluid, but if the quantity becomes very great, coagulation may result and a large clot form, which may cause obstruction.

Thrombosis.—According to Leydecker[1] thrombosis of the thoracic duct may follow lymphangitis, trauma, pressure from tumors, aneurisms, and exostoses of the vertebræ, or may accompany lesions of the heart valves.

Usually these thrombi are recent, as was the one seen by Turney.[2] The patient gave a history of chylothorax and chylous ascites, and at autopsy Turney found a thrombus at the mouth of the duct, extending downward a short distance and completely blocking the lumen. Below the obstruction the duct was greatly dilated, as were all its radicles. All the superficial lymphatics of the upper extremity were also dilated.

Oppolzer[46] reported a case in which no history nor signs of chylothorax nor chylous ascites were given. The patient had a valvular lesion, and at autopsy Oppolzer found that a clot obstructed the mouth and, for a short distance, the lumen of the duct.

Cayley reported a case in which a similar pathological condition was found. The patient was a young man, nineteen years old, whose chief symptoms were constipation and pain in the abdomen. He gave signs of chylous ascites, but none of chylothorax. Further examination showed the presence of a large retroperitoneal tumor which at autopsy proved to be a greatly dilated receptaculum chyli and its radicles. The thoracic duct was dilated, and at its mouth Cayley found a clot which closed the outlet of the duct.

In other cases the thrombi undergo partial or complete organization, so that the lumen may become partially or wholly occluded by a mass of connective tissue canalized by new blood and lymph vessels. Such a condition was seen by Heller.[3]

Retrograde Changes.—The only case of necrosis of the thoracic duct which has been reported as yet is the one quoted by Noehler,[4] and in the light of modern pathology his diagnosis and autopsy findings might be questioned. He diagnosed the case as "malignant epidemic fever," and at autopsy, a few hours after death, found what he called a "gangrenous thoracic duct."

Here might be mentioned two cases which are interesting, in that they show changes analogous to those found in old sclerotic arteries. Brown-Cheston[16] and Assalini[17] have reported a case each, in which they found a thoracic duct, the wall of which was converted into a calcified tube.

Aneurisms and Cysts.—Many dilatations of the thoracic duct have been mistaken for aneurisms or cysts. Some of these could be explained easily by dilatation caused by some obstruction to the flow. On the other hand, cases of dilatation have been reported which could not be explained by any increased pressure within or without the duct. Such conditions are comparable with the formation of aneurisms of arteries and veins, in that the walls become atrophied and a localized dilatation follows. Cases showing this condition have been reported by Laënnec,[33] Albers,[34] Bromann,[35] Kilian,[36] Küster,[37] Enzmann,[9] von Winiwarter,[38] Weichselbaum,[39] von Recklinghausen,[40] Bostroem,[41] Rokitansky,[42] Fitz,[43] Tillaux,[44] and Ramonet.[45]

Pigment Deposits.—In chronic obstructive jaundice the contents of the duct may become golden-brown to green in color, due to the presence of the bile constituents, and the walls of the duct may become deeply tinged also.

Progressive Changes.—Inflammations about the duct often cause secondary changes in the wall of the duct, producing localized or general thickenings, which may become so marked that the lumen is markedly occluded.

Heller[3] reported such a case in a woman, aged fifty-six, who had marked œdema of the pelvic tissues accompanied by ascites. At autopsy he found that the wall of the thoracic duct was greatly thickened throughout, and that its lumen was almost completely obliterated. He explained this thickening as inflammatory. Andrals[7] reported a similar localized finding. In his case the lumen of the duct was greatly reduced by a localized increase of scar tissue at the level of the fifth dorsal vertebra.

In cases of puerperal sepsis or general septicæmia in which the abdominal lymph vessels contain pus, or the mesenteric glands are the seats of secondary abscesses, the thoracic duct may become involved. In such cases its walls become swollen, due to congestion, œdema, and infiltration with leucocytes, and its lumen may contain pus. In these cases general pyæmia, if not already present, usually results.

Cases in which pus has been found at autopsy in the thoracic ducts have been seen by Adams,[5] Worms,[6] Andrals,[7] Gendrin,[8] Enzmann,[9] and Schweininger.[10]

Tuberculosis.—When it is considered how often the bronchial or mesenteric lymph glands are affected with tuberculosis, it seems strange that more cases are not reported in which the thoracic duct is involved secondarily, on the one hand through its close proximity, and on the other through its direct communication with the seat of infection. That the condition is not so rare as the few reported cases would indicate is shown by Stilling, who found tubercles in the thoracic duct of five in a series of eighteen cases of general miliary tuberculosis.

Cooper[11] in 1798 was the first to observe tuberculosis of the duct. His case was one of general tuberculosis, and at autopsy he found several caseous masses behind some of the valves of the duct. Ponfick,[12] in 1877, pointed out the significant fact that many cases of general miliary tuberculosis were due to a secondary involvement of the duct from tuberculous bronchial lymph glands, with subsequent dissemination of the tubercle bacilli through its stream into that of the blood. He was able to demonstrate this fact in a case which he reported, and drew the conclusion that it was possible in many cases to trace the sudden generalization of tuberculosis to a similar source. Since the report of his case, Benda[13] and Stilling[14] have made similar observations, and have confirmed the conclusions drawn by Ponfick.

In some cases the lumen may become markedly obstructed and the walls of the duct greatly thinned, owing to the presence of large caseous masses blocking the lumen. In other cases only scattered tubercles are present, either behind a valve flap or between two valves. These scattered tubercles are for the most part small semitransparent grayish nodules varying in size from a pin point to a pinhead. Sometimes many of these tubercles coalesce and form a mass, slightly elevated above the surface, about the size of a split pea. The tubercles are closely adherent to the intima, and when pulled off leave a depressed bleeding ulcer with edges slightly undermined. If the bacilli lodge behind a valve flap, tubercles form which rapidly caseate and coalesce, forming a semi-solid grayish-yellow mass which pushes the valve out into the lumen and sooner or later causes obstruction to the flow in the lumen.

Besides the observers mentioned, Talma,[15] Nasse,[18] Poney,[19] Cruikshank,[20] Hopfgärtner,[21] Lientaud,[22] Otto,[61] Weigert,[23] Brash,[65] Schurhoff,[63] and Whitla[64] have reported cases of tuberculosis of the thoracic duct.

Tumors.—As yet no cases of the mature connective-tissue tumors in the walls of the thoracic duct have been reported.

Sarcoma.—A few instances of this class of tumors have been reported. Rust,[62] in 1815, was the first to observe a sarcoma in the thoracic duct. Otto,[61] in 1824, saw another case. Both cases were secondary to a sarcoma in the testis. The third case in the literature was reported by Winkler[28] in 1898. His patient was a young man, twenty years old, who had a mediastinal tumor. At autopsy Winkler found that the wall of the duct was irregularly thickened, and in areas he found distinct secondary nodules. Microscopically the mediastinal tumor and its secondaries were found to be round-cell sarcomata. One case of metastatic sarcoma of the duct has been seen at the Pathological Laboratory of the University of Michigan. The primary was a malignant teratoma of the testis which had given rise to a secondary sarcoma in the receptaculum chyli, about the size of an English walnut. The lumen was completely occluded.

Carcinoma.—Although carcinomata of the abdominal and pelvic organs frequently give rise to secondaries in the thoracic organs, it is not common to find the thoracic duct involved by secondary growths. This may be due, partly, to the fact that the thoracic duct has but few valves, and these are rudimentary, so that cancer cells do not lodge readily; but it must be admitted that this is a very insufficient reason. In 1898 Winkler[28] collected all the cases of carcinoma of the thoracic duct, which had been previously reported. He found fifteen in all, and added eleven more of his own; but from his study of these cases he drew no definite conclusion as to this infrequent involvement of the thoracic duct, unless it be that this organ is seldom examined at autopsy, and then often very superficially.

Of the 26 cases of secondary carcinoma of the duct 10 were primary in the stomach (Acker,[24] Leydecker,[1] Hektoen,[25] Barybuhr,[26] Pannenburg,[27] Winkler[28]); 8 in the uterus (Andral,[7] Winkler,[28] Enzmann,[9] Unger[29]); 3 in the gall-bladder (Behrens,[30] Winkler[28]); 1 in the testis (Cooper[11]); 1 in the pharynx (Virchow[31]); 1 in the ovary (Senator[32]); 1 in the right adrenal (Winkler[28]), and 1 in the kidney (Winkler[28]). In all cases secondary growths were present in the retroperitoneal lymph glands. Some authors mentioned secondary nodules in the lungs or cervical lymph glands, but they were not common.

The nodules in the duct may be small and not easily outlined, or they may be so large that they partially or wholly close the lumen of the duct. In such cases dilatation occurs behind the obstruction, and unless the anastomoses can cope with the lymph thus held back, chylo-thorax, chylous ascites, or both, may result, depending upon the grade of obstruction and the location of the tumor masses.

Parasites (see article on *Parasites*).—Of the parasites found in man, cases have been reported in which cysticerci and filaria have been found in the lumen of the thoracic duct.

Rupture.—Traumatism of the thoracic duct, resulting in rupture, may be due to an injury of the thorax, or may be caused during an operation in the lower left cervical region. Traumata of the first sort are not common because of the protected position of the duct; nevertheless in severe injuries of the thorax and abdomen or as the result of severe straining, such as severe coughing, rupture of the duct may occur. Manley[49] reported a case of rupture of the duct in a young man who had received a severe blow over the abdomen, followed by symptoms of peritonitis, accompanied by a fluctuating, non-reddened swelling in the right iliac fossa, which contained chyle. This sac was drained for fifteen days and healed. Manley thought that the duct had been ruptured, but since he did not open the peritoneal cavity other than to drain the sac, it cannot be positively stated that his diagnosis was correct.

The first authentic case of rupture of the duct was one cited by Monroe[50] in 1765. The patient had had chylous ascites, and at autopsy he found a rupture of the duct at the level of the fourth dorsal vertebra. Kirchner[51] was able to find only seventeen cases in the literature in which the rupture resulted directly from trauma. To these he added another of what he considered a traumatic rupture. The patient was a child, nine years old, who had fallen against a window sill, injuring the thorax. In ten days this was followed by marked dyspnoea and ascites. Aspiration showed the presence of chyle in the abdomen. These symptoms persisted for ten days and then gradually disappeared.

Since then Eyer,[52] Port,[53] and Lyne[54] have reported cases in which there could be little doubt that the duct was ruptured, since chylous ascites and chylothorax were present in every case.

Rupture of the duct may occur during operations for the removal of sarcomatous, carcinomatous, or tuberculous lymph glands of the left lower cervical region, but that this is not a common occurrence is shown by the few cases reported and by a series of thirty-five cases cited by Cushing in which the lymph glands of this region contained secondary new growths. Rupture of the duct during their removal occurred in only two cases.

The rupture may be noticed at the time of the operation, or it may escape observation altogether until the wound is subsequently dressed. If noticed at the time of the operation, the rupture is usually recognized by a sudden gush of milky fluid. Sometimes it may be a serous fluid. If not noticed at the time of rupture, it may be recognized by the presence of a milky or opalescent fluid in the wound or on the dressings at a subsequent visit.

These ruptures are not usually fatal, although a large amount of the contents of the duct may be lost. Paton,[56] on the other hand, reported a case of rupture in which 1,584, 3,168, and 4,752 c.c. of chyle were lost on three consecutive days; death followed soon afterward. Thöle[55] in 1900 was able to find in the literature fifteen cases of rupture of the duct during operation and added a personal case. Besides those collected by them, Paton,[55] Schoff,[57] Allen and Briggs,[58] Weischer,[59] and Cushing[60] have reported cases.

Most of these surgeons either pack the wound tightly or ligate the duct, and the rupture then heals.

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LITERATURE.

1 Leydecker: Arch. f. path. Anat., 1893, cxxxiv., 118.
2 Turney: Trans. Path. Soc., London, 1893, xliv., 1
3 Heller: Deutsch. Arch. f. klin. Med., 1872, x., 141.
4 Nochber: Inaug.-Dissert., Bonn, 1831.
5 Adams: Trans. Path. Soc., London, 1849-50, ii., 279.
6 Worms: Gaz. hebd., 1859, vi., 18.
7 Andrals: Arch. gén. de méd., 1824, vi., 507.
8 Gendrin: Histoire des inflammations.
9 Enzmann: Inaug.-Dissert., Basel, 1883.
10 Schwenniger: Ann. d. münch. Stadtkrankenhaus, 1878, i., 325.
11 Cooper: Med. Records and Researches, 1798, i., 28.
12 Ponfick: Berl. klin. Woch., 1877, xiv., 673.
13 Benda: Deutsch. Med.-Zeitung, 1898, February 7th and 24th.
14 Stilling: Arch. f. path. Anat., 1882, lxxxviii., 111.
15 Talma: Ztschr. f. klin. Med., 1881, ii., 265.
16 Brown-Cheston: Philosoph. Trans., 1780.
17 Assalini: Ueber die Lymph-Gefässe und deren Krankheiten, 1792.
18 Nasse: Leichenöffnungen.
19 Poney: Cited by Boegehold
20 Cruikshank: Anat. of the Absorbing Vessels, 1790.
21 Hopfengartner: Hufeland's Journ., 1807, vi.
22 Lieutaud: Cited by Boegehold.
23 Weigert: Arch. f. path. Anat., 1879, lxxvii., 269.
24 Acker: Deutsch. Arch. f. klin. Med., xi., 201
25 Hektoen: Cook County Hosp. Rec., 1890, 115.
26 Barybuhr: Deutsch. Arch. f. klin. Med., liv., 410.
27 Pammenburg: Inaug.-Dissert., Gottingen, 1895.
28 Winkler: Arch. f. path. Anat., 1898, cli., 195.
29 Unger: *Ibid.*, cxlv., 581.
30 Behrens: Inaug.-Dissert., Strassburg, 1879.
31 Virchow: Cited by Winkler.
32 Senator: Charité-Annalen, 1895, xx., 264.
33 Laennec: Cited by Winkler.
34 Albers: Hannoveren Ann. f. d. gesammte Heilkunde, 1836, i.
35 Bromann: Arch. f. klin. Chir., 1887, i., 35.
36 Kilian: Berl. klin. Woch., 1886, xxiii., 407.
37 Küster: Naturforscherversammlung, 1882.
38 Von Winiwarter: Cited by Boegehold.
39 Weichselbaum: Arch. f. path. Anat., lxiv., 146.
40 Von Recklinghausen: Arch. f. klin. Chir., 1883, ii., 3.
41 Bostroem: Cited by Kilian.
42 Rokitansky: Path. Anat., ii.
43 Fitz: Boston Med. and Surg. Journ., 1871.
44 Tillaux: Bull. de l'Acad. de Méd., Paris, 1880.
45 Ramonet: Recueil de mém. de Méd., 1878.
46 Oppolzer: Allg. Wien. Med.-Zeitg., 1861, vi., 19.
47 Cayley: Trans. Path. Soc., London, 1866, xvii., 163.
48 Heller: Deutsch. Arch. f. klin. Med., 1872, x., 141.
49 Manley: Med. News, 1894, No. 3; Ann. Surg., 1895, xxi., 208.
50 Monroe: Cited by Kirchner.
51 Kirchner: Arch. f. klin. Chir., 1885, xxxii., 156.
52 Eyer: Med. Rec., 1891, xl., 122.
53 Port: Deutsch. Zeitschr. f. Chir., 1894, xxxix., 572.
54 Lyne: Vir. Med. Semi-Monthly, 1898, August 26th.
55 Thöle: Deutsch. Zeitschr. f. Chir., 1900-01, lviii., 95
56 Paton: Journ. of Physiol., 1890, xi., 109.
57 Schoff: Wien. klin. Woch., 1891, No. 9, March 28th.
58 Allen and Briggs: Amer. Med., 1901, September 21st.
59 Weischer: Deutsch. Zeitschr. f. Chir., 1894, xxxviii., 486.
60 Cushing: Annals of Surgery, 1898, xxvii., 719.
61 Otto: Seltene Beobachtungen zur anatomischen Physiologie, Berlin, 1824, No. 23.
62 Bust: Horn's Arch. f. med. Erfahr., 1815.
63 Schurhoff: Centralbl. f. allg. Path., 1889.
64 Whitla: Brit. Med. Journ., 1885, ii., 1089.
65 Brash: Dissert., Heidelberg, 1889.
66 Svitzer: Archiv f. Anat., Physiol. u. wissensch. Med., 1845, 21.

THORAX.—The thorax is that part of the great body cavity which is situated above the diaphragm. It contains the organs of respiration and circulation, together with many large vessels and nerves. It is in shape the form of a truncated cone with the base directed downward and formed by the diaphragm, and the truncated apex continuous with the root of the neck. Superficially the thorax presents an anterior wall, two lateral walls, and a posterior surface. The anterior thoracic wall is separated above from the anterior surface of the neck by the prominent ridge of the clavicle, joining the upper and outer angle of the first piece of the sternum to form the prominent sterno-clavicular articulation. Between the inner extremities of the two clavicles and above the upper border of the sternum, we find the deep suprasternal notch. Running downward in the median line to the tip of the ensiform cartilage is the midsternal line, which in the living subject is indicated by a furrow between the sternal attachments of the pectoralis major muscle on each side. Along the outer border of the sternum is the sternal line. At the junction of the first and second pieces of the sternum is a transverse ridge known as Ludwig's angle, which marks the attachment of the second costal cartilage to the sternum. As the first rib is not palpable, on account of its position behind the clavicle, Ludwig's landmark is commonly used in counting the ribs on the living subject. Extending vertically through the nipples on each side is the mammillary line. Half-way between the sternal line and the mammillary line and parallel to them is the parasternal line. The anterior axillary line is drawn vertically downward from the point where the anterior axillary fold, or the lower border of the pectoralis major, joins the chest wall. The posterior axillary line is drawn from the posterior axillary fold, which is formed by the latissimus dorsi. Midway between these two lines and extending downward from the highest point or apex of the axilla is the midaxillary line. The surface markings on the posterior surface of the thorax are few. In the median line we have the furrow lying over the tips of the spinous processes. The scapular line is drawn vertically downward from the inferior angle of the scapula. The spine of the scapula, running upward and outward to terminate in the acromion process, is easily felt. The inferior boundary of the thorax is formed by the costal cartilages of the lower ribs from the seventh to the tenth inclusive. These, with the ensiform cartilage, form the costal arch, which separates the anterior thoracic surface from the anterior surface of the abdomen.

The thorax has two openings, a superior and an inferior. The superior opening of the thorax is much the smaller, measuring in antero-posterior diameter about 2¼ inches (5.7 cm.). It is bounded in front by the upper border of the manubrium and the first costal cartilage; laterally by the shaft of the first rib; behind, by the body of the first dorsal vertebra and the head of the first rib. Passing through it we have the following structures: sterno-hyoid, sterno-thyroid, and longus colli muscles; the innominate, left common carotid, left subclavian, superior intercostal, and internal mammary arteries; the right and left innominate veins; the right and left phrenic and pneumogastric nerves and the left recurrent laryngeal and the right and left gangliated cords of the sympathetic, and the cervical cardiac branches of the pneumogastric; the œsophagus, trachea, and thoracic duct, with the apices of the lungs invested in pleura.

The inferior opening is bounded in front by the ensiform cartilage and the common cartilage of the lower ribs, laterally, by the eleventh and twelfth ribs, and posteriorly by the body of the last dorsal vertebra. The opening is closed by the diaphragm, which separates the thoracic cavity above from the abdominal cavity below. It is pierced by a number of structures: through the aortic opening, between the two crura of the diaphragm, pass the aorta, thoracic duct, and vena azygos major; through the œsophageal opening, the œsophagus, right and left pneumogastric nerves, and the œsophageal branches of the thoracic aorta; on the right side, through an opening of its own, the inferior vena cava; while the greater, lesser, and least splanchnics and the continuation of the thoracic gangliated cord perforate the crus on each side, and on the right side alone the phrenic nerve pierces the right leaflet of the diaphragm anteriorly and a little externally to the opening for the inferior vena cava.

The walls of the thorax are formed anteriorly by the sternum and the costal cartilage, laterally by the shafts of the ribs, and posteriorly by the bodies of the twelve dorsal vertebræ and the heads and necks of the ribs. On transverse cross section, the thorax presents a reniform outline, the deep notch at the back being formed by the intrusion of the bodies of the dorsal vertebræ into the thoracic space. The various diameters of the chest at different levels are given by Holden as follows: In the average skeleton the antero-posterior diameter at the inlet is 2¼ inches (5.7 cm.); at the outlet, 5⅝ inches (14.25 cm.); while at the junction of the manubrium and gladiolus the antero-posterior diameter is 4½ inches (11.2 cm.). The inlet measures in transverse diameter 4⅜ inches (11 cm.); it gradually increases as far as the ninth rib, where the transverse diameter measures 10½ inches (26.6 cm.). From the ninth to the twelfth rib this diameter decreases. The female thorax has a smaller capacity than the male, the sternum is shorter, the ribs are more movable, and the difference between the upper and the lower openings is less. Abnormal forms are frequently found in which the relation between the different diameters that exist in the normal thorax is disturbed. A pigeon chest is one in which the sternum and costal cartilages project forward, the antero-posterior diameter being longer and the transverse diameter shorter than normal. It is usually found as one of the results of rickets. The barrel chest is one in which the antero-posterior and transverse diameters are nearly equal and the costal angle is an obtuse angle. It is frequently found in emphysema. The flat chest is one with a long transverse diameter and a short antero-posterior diameter. The costal angle in these cases is acute.

The spaces between the ribs are called the intercostal spaces and are closed by the external and internal intercostal muscles. The external intercostals are eleven in number on each side. They begin behind at the tubercles of the ribs and arise from the lower border of each rib as far forward as the ends of the ribs in front. Their fibres pass downward and forward and are inserted into the upper border of the rib below. The internal intercostals take their origin from the ridge on the inner surface of each rib, and the under border of the costal cartilages from the sternum as far back as the angles of the ribs. Their fibres pass downward and backward, at an acute angle to those of the external intercostal, and are inserted in the upper border of the rib below. By means of the ribs and the intercostal spaces many important structures in the thorax are located. The fourth interspace is identified in the male by the nipple. The lower border of the pectoralis major muscle marks the course of the fifth rib. The apex beat of the heart is found in the left fifth interspace one inch and a half below the nipple, and three-quarters of an inch toward the median line. The surface markings for the heart, as given by Deaver, are as follows: Take a point on the third right costal cartilage half an inch from the border of the sternum; from it draw a line to a point in the second interspace on the left side of the sternum, one inch from the left sternal margin. This line will indicate the base of the heart. From a point in the fifth interspace, one inch to the inner side of and two inches below the nipple, draw a line to a point half an inch to the right of the sternum in the fifth interspace. This line will locate the lower border of the heart. Connect the two extremities of the two lines as drawn and the included quadrangle will represent the heart area. A point just behind the sternal end of the third left intercostal space will indicate the position of the aortic valve; behind the third left chondrosternal articulation are the pulmonary valves. The tricuspid valve is found in the median line on the level of the fourth intercostal space; the mitral, at the left border of the sternum behind the fourth left costal cartilage.

Contents of the Thorax.—*Pericardium.*—The pericardium is a fibroserous sac composed of two layers: an outer or fibrous, and an inner or serous. The outer or fibrous layer is continuous above with the fibrous sheath of the great vessels and ultimately blends with a layer of deep cervical fascia, which passes behind the sterno-cleido-mastoid muscle, forming a sheath in the neck for the carotid artery, internal jugular vein, and pneumogastric nerve. It is continuous below with the upper layer of the fibrous covering of the diaphragm. It is attached in front to the under surface of the sternum by the superior and inferior sterno-pericardiac ligaments. The serous portion of the pericardium, like all serous membranes, consists of two layers—a parietal and a visceral. The parietal layer lines the inner surface of the fibrous portion and forms the wall of the pericardial cavity. The visceral layer covers the heart muscle and lies in intimate contact with it. The two layers are continuous with each other at the roots of the great vessels and form a closed cavity, which contains a small amount of serous fluid, for the purpose of lubrication. When from an increase of pericardial fluid this sac becomes distended abnormally, the pericardial area can be outlined on the chest wall, and can be distinguished from the dulness due to cardiac hypertrophy by the fact that the area of pericardial dulness has its apex upward and to the right and its base downward, while an hypertrophied heart has its apex directed downward and to the left and its base upward and to the right.

If on the dissecting table, or at a post-mortem examination, the pericardium be incised in the median line and a transverse incision made at right angles to the first cut, the pericardium can be reflected in four V-shaped flaps, and the anterior surface of the heart inspected in its normal condition. The surface of the heart which presents itself will be almost entirely right ventricle, while the apex of the right auricle can be seen at the upper right border of the heart. If now the apex of the heart be drawn upward and slightly to the left, the pericardial cavity can be seen and inspected. Running from the lower right-hand corner of the pericardial space upward to the heart is the large inferior vena cava. If this be cut and continued traction made upon the heart, the right and left inferior pulmonary veins will next be seen. Above these the pulmonary arteries and the right and left superior pulmonary veins are found. It is not the purpose of this article to go into a detailed description of the structure of the heart, which will be found in a separate article under an appropriate heading. (See *Heart.*)

The Pleura.—The pleura consists of two closed serous sacs which invest the lungs and line the thoracic cavity. Each pleura consists of two layers, a parietal, which lines the internal surface of the thoracic wall, and a visceral, which is closely adherent to the surface of the lungs. The pleura extends into the neck for a distance of an inch and a half to two inches above the upper border of the first rib, where it forms a closed sac which receives the apex of the lung. Inferiorly it covers the upper surface of the diaphragm and extends down in front to the costal cartilage of the seventh rib, on the left side to the lower border of the tenth rib, and on the right to the upper border of the tenth rib; behind, it passes to the upper border of the twelfth rib, or may pass as low as the lower border of the twelfth or the transverse process of the first lumbar vertebra. The two pleuræ are not connected at any point, but touch, or may even overlap, on a level with the junction of the first and second pieces of the sternum, the left usually overlapping and lying anterior to the right. At the fourth costal cartilage the two sacs diverge, the right running almost straight downward to the ensiform cartilage, from which point it passes behind the seventh costal cartilage to the diaphragm. The left sac passes outward, downward, and to the left from the fourth costal cartilage to the left margin of the sternum, on a level with the fifth costal cartilage, from which point it passes downward and outward on the under surface of the seventh costal cartilage. The inferior lateral limits of the pleural sacs have been already described. On transverse section of the thorax the relations of the pleuræ to each other, as well as the continuity between the parietal and visceral layers, can be demonstrated. Beginning at the median line in front, the anterior parietal pleura lies on the posterior surface of the sternum, passing thence to the posterior surface of the costal cartilages and intercostal muscles, follows the curve of the costal wall and becomes the lateral parietal pleura. Following the curves of the ribs it passes to the posterior wall of the thorax, and, as posterior parietal pleura, passes to the sides of the bodies of the dorsal vertebræ. On the left side it now passes over the abdominal aorta and the left thoracic gangliated cord, while on the right side it covers over, at different levels, the superior vena cava, the inferior vena cava, vena azygos major, and right thoracic gangliated cord. It next passes to the posterior surface of the root of the lung, and thence to the posterior surface of the lung itself, becoming the posterior visceral pleura, or, as it is sometimes called, the pleura pulmonalis. It now invests the lung, covering posterior, lateral, and anterior surfaces in order, as far as the anterior border of the lung, and passing as a septum into the fissures which separate the lobes of the lung. From the anterior border of the lung it passes on to the internal surface of the lung as far backward as the anterior surface of the root of the lung, which it next covers. From this point it passes on to the external surface of the pericardium and forward to the starting-point, becoming again the parietal pleura.

The Lungs.—The lungs are the organs of respiration, and are placed one on each side of the chest, separated by the mediastinum and its contents. Each lung is conical in shape and has an apex, a base, an internal and an external surface, and an anterior and a posterior border. The apex projects into the neck for about an inch and a half above the upper border of the clavicle, and lies in the conical cavity formed by the apex of the pleura. The base is concave, to conform with the convex upper surface of the diaphragm. Its lower border is marked by a line drawn from the articulation of the sixth costal cartilage with the sixth rib to the spinous process of the tenth dorsal vertebra. Owing to the presence of the liver the right lung lies higher in the chest than the left, being on a level in front with the upper border of the fifth costal cartilage, while the lower border of the left passes down to the upper border of the sixth rib. The outer surface of the lung, or the thoracic surface, is smooth, convex, and conforms to the curve of the thoracic wall except in the portion which extends up into the neck. It is sometimes divided into an anterior, a lateral, and a posterior thoracic surface. The inner surface is deeply concave, owing to the position of the heart and pericardium. It is separated from the external surface, in front by the sharp anterior border, and behind from the posterior surface by the root of the lung. The anterior border is thin, sharp, and separates the external and internal surfaces. It overlaps the pericardium and follows closely the anterior internal border of the pleural sacs, as described above, except that the edges of the lungs do not overlap. The anterior border of the right lung reaches to the median line, while the left reaches to the left border of the sternum. The posterior border is round and broad, and lies in the concavity formed by the angle of the ribs on either side of the spinal column. It is much longer than the anterior border and becomes wide as it passes downward.

The roots of the lung are formed by the bronchi, the pulmonary arteries and veins, the bronchial arteries and veins, and the pulmonary nerves and lymphatics. These structures lie in the following order: from before backward, the pulmonary veins, pulmonary artery, and the bronchus; from above downward on the right side, the bronchus, the pulmonary artery, and the pulmonary veins; on the left side, the pulmonary artery, the bronchus, and the pulmonary veins, the bronchus lying above on the right side and in the middle on the left side.

Lobes.—Each lung is divided into an upper and a lower lobe. The division is about three inches below the apex. On the right side the upper lobe is again subdivided into two lobes by a horizontal fissure which passes forward from the middle of the first fissure to the anterior border of the lung. The right lung is also larger and heavier than the left, but its transverse diameter is greater than that of the left lung and its vertical diameter shorter. The left lung is longer than the right, but is much narrower.

Mediastinum.—The mediastinum is that portion of the thoracic cavity which is not contained within the pleural sacs. It is an irregularly shaped space bounded below by the diaphragm, in front by the sternum and costal cartilages, behind by the vertebral column, and extending above into the neck as far as the apices of the pleuræ. It is consequently limited above by the deep cervical fascia and the structures which pass through the superior opening of the thorax. It is divided, in a purely arbitrary manner, by a plane which passes through the junction of the manubrium and gladiolus in front, and the lower border of the body of the fourth dorsal vertebra behind. This plane corresponds with the upper border of the pericardium. The portion of the mediastinum above this plane is called the superior mediastinum. It is bounded in front by the posterior surface of the manubrium and the first and second costal cartilages, behind by the anterior surfaces of the bodies of the upper four dorsal vertebræ. Its lateral boundaries are the right and left pleural sacs. It contains the transverse portion of the arch of the aorta, the innominate artery, the left common carotid and subclavian arteries, and the superior intercostal artery; the right and left innominate veins, and the superior vena cava; the pneumogastric, the phrenic and cervical cardiac and left recurrent laryngeal nerves, and the upper portion of the thoracic gangliated cords on each side; the origins of the sterno-hyoid and sterno-thyroid muscles and a portion of the longus colli, the trachea, œsophagus, and thoracic duct. The inferior mediastinum is subdivided by the pericardium into three portions—the anterior, which lies in front of the pericaridum; the middle, which lies within the pericardium; and the posterior, which lies behind the pericardium. The anterior mediastinum is bounded in front by the posterior surface of the lower part of the sternum; behind, by the anterior surface of the fibrous layer of the pericardium; and below, by the attachment of the diaphragm to the ensiform and costal cartilages. It contains fat, areolar tissue, and a few lymphatic glands, which drain the inner and lower quadrant of the mammary gland. The middle mediastinum is bounded by the limits of the pericardium. It contains the heart and the roots of the great vessels. The posterior mediastinum comprises all the space bounded in front by the posterior layer of the pericardium, behind by the bodies of the lower eight dorsal vertebræ and the heads and necks of the ribs, above by the supposititious plane separating it from the superior mediastinum, and below by the upper surface of the diaphragm. It contains the following structures: the descending portion of the thoracic aorta and its branches, viz., the lower intercostal arteries, the œsophageal, bronchial, pericardiac, and posterior mediastinal branches, and the corresponding veins; the greater and lesser azygos veins, the pneumogastric and splanchnic nerves, the œsophagus, thoracic duct, and the posterior mediastinal lymphatics.

The Aorta.—The thoracic aorta is divided into three portions—the ascending portion, the transverse portion or arch, and the descending portion. The ascending aorta is about two inches long; commencing at the upper part of the left ventricle, it passes obliquely upward, forward, and to the right as far as the upper border of the second right costal cartilage, where it becomes the transverse aorta. At its commencement it is somewhat distended, and opposite the three cusps of the aortic valve presents three small dilatations, called the sinuses of Valsalva. These sinuses are placed one in front and two behind. From the anterior sinus is given off the right coronary artery, and from the left posterior sinus the left coronary artery.

The transverse aorta, beginning at the upper border of the second right costal cartilage, passes upward, backward, and to the left, lying on the anterior surface of the body of the fourth dorsal vertebra. It then curves downward and backward to the lower border of the fourth dorsal vertebra on the left side, where it becomes the descending aorta. The branches given off from the transverse portion of the aorta are the innominate and the left common carotid and subclavian. The innominate artery, or brachiocephalic, arises from the beginning of the arch of the aorta on a level with the upper border of the second right costal cartilage, and passing upward, forward, and to the right, divides behind the right sternoclavicular articulation into the right common carotid and subclavian arteries. It varies in length from one to two inches. The innominate usually gives off no other branches, but occasionally the thyroidea ima, which ascends in front of the trachea and supplies the lower portion of the thyroid gland, is found arising from it. The left common carotid arises from the left portion of the arch of the aorta, between the innominate and the left subclavian. It passes upward, outward, and to the left, behind the left sterno-clavicular articulation, and, ascending into the neck, divides into the internal and external carotid arteries, on a level with the upper border of the thyroid cartilage.

The left subclavian artery arises from the arch of the aorta behind and to the left of the left common carotid, and passes nearly vertically upward to the inner border of the scalenus anticus muscle. It then curves outward, lying behind the scalenus anticus muscle, forming the second portion of the artery, and separated by the muscle from the subclavian vein which lies in front.

The descending aorta begins at the lower border of the fourth dorsal vertebra on the left side, and passes downward and slightly to the right, curving to conform to the spine on which it rests and whose curves it follows. It lies in the back portion of the posterior mediastinum and gives off the following branches: pericardiac branches to the pericardium; bronchial branches to the substance of the lungs, usually a single one on the right side, and two on the left. The bronchial arteries pass along the posterior surface of each bronchus, and, following the course and division of the bronchial tubes, supply the bronchia, the substance of the lungs, and the retro-bronchial glands. The œsophageal arteries, varying in number from three to five, arise from the anterior surface of the aorta and pass downward on the œsophagus, which they supply, anastomosing with the branches of the inferior thyroid above and with the œsophageal branches of the gastric arteries from the cœliac axis of the abdominal aorta below. The posterior mediastinal arteries are a number of branches given off by the thoracic aorta, which supply the glands of the posterior mediastinum. The intercostal arteries arise in pairs from the posterior surface of the descending aorta. There are usually nine on each side. The two upper intercostal spaces receive their blood supply from the superior intercostal branch of the subclavian and from the anastomosis between this artery and the first aortic intercostal. The right intercostal arteries are longer than the left, as they have to pass across the spinal column to reach the right intercostal spaces. The arteries lie first between the pleura and the external intercostals; then, at the angles of the ribs, they pass between the external and internal intercostal muscles; in each intercostal space the artery passes upward to the lower border of the rib above, where it lies between the vein above and the nerve below, except in the upper intercostal spaces, where the nerve at first lies above the artery. Passing forward as far as the anterior axillary line it anastomoses with the terminal branches of the anterior intercostals from the internal mammary artery. This description applies to the upper six intercostal spaces. In the seventh, eighth, and ninth spaces the artery anastomoses with the intercostal branches of the musculo-phrenic artery, while the two lower intercostal arteries, running along the lower border of the eleventh and twelfth ribs, pass forward and downward to the muscles of the abdominal wall.

The pulmonary artery arises from the apex of the right ventricle in front of the aorta and passing upward divides into two branches, the right and left pulmonary arteries. The right pulmonary artery is longer than the left and passes outward and backward behind the ascending aorta and the superior vena cava to the root of the right lung, where it divides into branches; a large branch going to the upper lobe and a smaller branch to the lower lobe. The large upper branch gives off a branch to the middle lobe. The left pulmonary artery passes outward in front of the descending portion of the aorta to the root of the left lung where it divides into two branches, which are distributed to the upper and lower lobes. The relation of the structures in the root of the lung has already been noted.

The superior intercostal artery is a branch of the subclavian, arising from the upper and back portion of the artery, and passing downward and backward behind the pleura in front of the necks of the first two ribs. It supplies the first intercostal space and anastomoses with the first aortic intercostal to supply the second. The internal mammary artery arises from the subclavian from the under surface of the first portion of the artery. It passes directly downward behind the first costal cartilage to the inner surface of the anterior thoracic wall, lying on the costal cartilages about half an inch from the border of the sternum. In the sixth intercostal space it divides into its two terminal branches, the musculo-phrenic and superior epigastric. It gives off in its course a number of small branches which supply the anterior thoracic wall and mediastinal structures. The comes nervi phrenici or the superior phrenic artery joins the phrenic nerve and accompanies it to the diaphragm, where it anastomoses with the phrenic arteries from the internal mammary and abdominal aorta. The mediastinal arteries are small branches, six to eight in number, which are distributed to the lymphatic glands of the anterior mediastinum. The pericardial branches supply the anterior surface of the pericardium. The sternal branches supply the triangularis sterni muscle and the posterior surface of the gladiolus. The anterior intercostal arteries pass outward in the intercostal spaces and anastomose with the terminal branches of the aortic intercostals. They lie first between the pleura and the internal intercostal muscles and then between the internal and external intercostals. The perforating or mammary branches arise from the internal mammary artery in the upper five intercostal spaces. Piercing the intercostal muscle they pass directly forward and outward and supply the pectoralis major muscle and the under surface of the inner half of the mammary gland. In the male these arteries are small and comparatively unimportant, but in the female, especially during pregnancy and lactation, they are of large size. The musculo-phrenic artery, a terminal branch of the internal mammary, passes downward and outward from the sixth intercostal space behind the costal cartilages and terminates opposite the last intercostal space. It gives off the lower anterior intercostal arteries and branches to the costal margin of the diaphragm and to the portion of the abdominal wall which lies immediately below the costal arch. The superior epigastric artery is the continuation in line of the internal mammary artery. It passes between the costal and sternal attachments of the diaphragm, and, penetrating behind the rectus abdominis muscle, supplies it; at the same time it anastomoses with the deep epigastric from the external iliac, forming a deep circle of anastomosis in the substance of the abdominal wall, between the subclavian artery above and the femoral artery below.

The internal mammary artery is sometimes wounded in stab or gunshot wounds. It can be reached and tied by an incision in the centre of any of the upper six intercostal spaces, parallel to the costal cartilages, and the artery ligated about half an inch external to the outer border of the sternum.

Veins.—*Inferior Vena Cava.*—The inferior vena cava is formed at the lower border of the fourth lumbar vertebra by the junction of the right and left common iliac veins. It passes upward on the right side of the vertebral column, receiving tributaries from all of the pelvic and abdominal viscera except the organs of digestion. It perforates the central tendon of the diaphragm on the right of the median line, and, entering the pericardium, where it is covered by the serous layer, it terminates in the lower and posterior portion of the right auricle. The portion of the inferior vena cava lying in the thorax is short, and is best seen, after incision of the pericardium, by drawing the apex of the heart upward and to the left.

Innominate Veins.—The right and left innominate veins are formed by the junction of the subclavian and internal jugular veins on each side, just behind the sterno-clavicular articulation. The left is much longer than the right, being about two and a half inches in length, and passing from the left sterno-clavicular articulation downward and to the right to the junction of the first costal cartilage with the right border of the sternum, where it joins the right innominate vein to form the superior vena cava. The right is shorter and smaller and passes from the right sterno-clavicular articulation almost directly downward to its junction with the left. The tributaries of the right innominate vein are the right vertebral, internal mammary, inferior thyroid, and superior intercostal veins. Those of the left are the corresponding veins on the left side of the body with occasionally some veins from the thymus gland and the pericardium.

Superior Vena Cava.—The superior vena cava, formed by the junction of the right and left innominate, passes vertically downward and, piercing the pericardium, enters the upper part of the right auricle on a level with the upper border of the third right costal cartilage.

Azygos System.—The azygos veins serve to connect the superior and inferior venæ cavæ. They are three in number. The right azygos vein, or vena azygos major, is formed in the abdomen by branches of the lumbar veins, enters the thorax through the aortic opening in the diaphragm and passes up through the posterior mediastinum, lying on the right side of the vertebral column. At the upper border of the fourth dorsal vertebra it passes forward over the root of the right lung, receives the right bronchial vein, and empties into the superior vena cava at the point where the latter pierces the pericardium. It has as tributaries the right superior intercostal vein, the intercostal veins of the right side, the vena azygos minor, the right bronchial vein, and a portion of the veins from the œsophagus. The left, or vena azygos minor, is formed by a branch from one of the lumbar veins, or by a tributary from the left renal. Entering the thorax through the left crus of the diaphragm it passes up on the left side of the vertebral column as high as the ninth dorsal vertebra, where it curves to the right across the vertebral column behind the aorta and thoracic duct and empties into the right azygos vein. Its tributaries are the lower intercostal veins on the left side and the mediastinal and œsophageal branches. The left upper azygos vein, sometimes called the azygos tertia, or superior azygos, is not always present. When found it varies inversely in size with the left superior intercostal vein. It drains the upper left intercostal spaces and empties into the azygos major above its junction with the minor. When this vein is absent the space usually occupied by it is drained by the left superior intercostal vein. The internal mammary vein accompanies the artery and has tributaries corresponding to the branches given off by the artery. It is frequently found to be double, forming venæ comites lying on each side of the artery and connected at short intervals by cross branches. When the artery is tied care should be taken in passing the needle not to include the veins in the ligature. The two veins when present unite to form a single trunk, which empties into the innominate vein on either side.

Nerves.—The pneumogastric, or tenth cranial nerve, enters the thorax between the subclavian vein and artery, lying on the right side just behind the junction of the internal jugular and subclavian, and on the left side between the left carotid and subclavian arteries. Owing to the obliquity of the arch of the aorta the relations of the nerve on the two sides differ. On the right side it descends along the side of the trachea to the posterior portion of the root of the lung, where it gives off the posterior pulmonary branches which spread out to form a plexus, from which two cords descend on the œsophagus, breaking up into a network of branches, which, uniting with similar branches from the nerve on the opposite side, form the œsophageal plexus. Lower down on the œsophagus the fibres again unite to form a single cord which, running along the posterior surface of the œsophagus, passes with it through the œsophageal opening in the diaphragm and is distributed to the posterior surface and greater curvature of the stomach, communicating with the solar, splenic, and cœliac plexuses. The left pneumogastric nerve crosses in front of the arch of the aorta, giving off at this point the left recurrent laryngeal, which, winding around the arch of the aorta from before backward, passes upward in the groove between the œsophagus and trachea and enters the larynx, being distributed to all the muscles of the left side of the larynx except the crico-thyroid. As the recurrent laryngeal nerve on the right side comes off behind the sterno-clavicular articulation and winds around the first portion of the subclavian, and supplies the muscles of phonation on the right side of the larynx, an aneurism of the first portion of the right subclavian would cause pressure paralysis of the right vocal cord, while an aneurism situated in the arch of the aorta would cause a paralysis of the left vocal cord. The left pneumogastric nerve passes behind the root of the left lung, gives off the posterior pulmonary branches to the pulmonary plexus, as described, and the main portion of the nerve, descending along the anterior surface of the œsophagus, passes through the œsophageal opening in the diaphragm and is distributed to the anterior surface and lesser curvature of the stomach, joining branches from the hepatic plexus. The only other thoracic branch of the pneumogastric nerve besides those mentioned is the anterior pulmonary nerve, which passes in front of the root of the lung, and, joining filaments from the sympathetic, forms the anterior pulmonary plexus.

Phrenic Nerve.—The phrenic nerve arises from the third, fourth, and fifth cervical, passes diagonally downward and outward across the anterior surface of the scalenus anticus muscle, and then, continuing its course between the subclavian artery and subclavian vein, enters the thorax, lying on the right side just external to the superior vena cava and on the left side external and anterior to the subclavian artery. Passing in front of the root of the lung, it lies between the pleura and the pericardium, to both of which it gives off branches. It is longer on the left side than on the right, on account of the oblique position of the heart and because the left nerve forms a loop in passing around the left side of the pericardium. On the right side it breaks up into from three to seven branches about 1 cm. above the upper surface of the diaphragm. These branches, piercing the diaphragm, supply it, while the innermost branch passes down to communicate with the right semilunar ganglion of the solar plexus. On the left side the nerve does not perforate the diaphragm, but ramifies in its substance.

Intercostal Nerves.—The intercostal nerves, twelve in number, are derived from the anterior division of the dorsal nerves. The anterior division of the first dorsal nerve divides into two branches, the larger of which joins the eighth cervical to form the lower trunk of the brachial plexus. The smaller branch forms the first intercostal nerve. The anterior divisions of the second, third, fourth, and fifth dorsal nerves form the intercostal nerves for the respective intercostal spaces. They pass forward between the pleura and the external intercostal muscles, as far as the angle of the ribs, where they pass between the external and internal intercostal muscles as far as the middle of the shaft. Here they enter the substance of the internal intercostals and run through their substance as far as the costal cartilages, where they lie between the internal intercostal and the pleura. Breaking up into branches, they send cutaneous filaments to the front of the chest and the mammary gland, forming the anterior cutaneous nerves of the thorax. At the midaxillary line each one of the six upper intercostal nerves except the first gives off a lateral cutaneous branch which pierces the external intercostal and serratus magnus and divides into two branches, an anterior and a posterior. The anterior branch passes forward, supplying the anterior lateral surface of the chest and the skin over the external surface of the mammary gland. The posterior branches pass backward and supply the skin of the scapular region and over the latissimus dorsi. The lateral cutaneous branch of the second intercostal does not divide into two branches, but passes diagonally outward across the axilla, forming the intercostal humeral nerve, and, uniting with the nerve of Wrisberg, it supplies the skin of the inner and back portion of the arm above the elbow. This nerve is occasionally missing, or there may be two intercosto-humeral nerves, the second coming from the third intercostal.

The anterior divisions of the seventh, eighth, ninth, tenth, and eleventh dorsal nerves form the lower or abdominal intercostal nerves. They have the same relations in the intercostal spaces as the upper, but are distributed to the integument and muscles of the anterior abdominal wall, forming the anterior cutaneous nerve of the abdomen.

Sympathetic Nerves.—The thoracic gangliated cord is continuous above with the cervical gangliated cord, and enters the thorax on each side of the spinal column, lying along the heads of the ribs behind the great vessels covered over by the parietal pleura. The ganglia are twelve in number and are connected by nerve fibres forming cord like prolongations derived from the substance of the ganglia. The external branches from each ganglion communicate with the dorsal spinal nerves. The internal branches from the upper five ganglia enter into the formation of the posterior pulmonary plexus. The internal branches from the lower seven ganglia unite to form the three splanchnic nerves. They are called the greater, lesser, and least or renal splanchnic. The greater splanchnic is formed by the internal branches from the ganglia from the fifth to the tenth. These fibres unite to form a large nerve, which descends obliquely in front of the bodies of the lower dorsal vertebræ, pierces the crus of the diaphragm on each side, and terminates in the semilunar ganglion of the solar plexus, sending branches to the renal and suprarenal plexuses. The lesser splanchnic nerve is formed by the internal branches from the tenth and eleventh ganglia. It pierces the diaphragm and joins the solar plexus. The least or renal splanchnic arises from the twelfth ganglion, pierces the diaphragm, and joins the renal plexus.

The Œsophagus.—The œsophagus begins at the upper border of the cricoid cartilage, opposite the substance between the fifth and sixth cervical vertebræ, and enters the thorax in the median line lying between the vertebral column and the trachea. It passes downward and to the left in the posterior mediastinum, and, piercing the diaphragm to the left of the median line, expands into the stomach at the cardiac orifice. Its relations in the thorax are as follows: It lies behind the arch of the aorta, separated from it by the trachea. It passes downward and to the left, lying on the right of the aorta to a point just above the diaphragm, where it crosses to the left, passing in front of the artery and piercing the diaphragm. The pneumogastric nerves lie in close contact with it, the left lying in front and the right behind.

The Thoracic Duct.—The anatomical relations of the thoracic duct are described in the next article but one preceding this.

Trachea.—The trachea begins at the lower border of the cricoid cartilage and descends into the thorax, lying in front of the œsophagus, as far down as the upper border of the fifth dorsal vertebra, where it divides into the right and the left bronchus. The point of division is on a level with the junction between the first and second pieces of the sternum. The thoracic portion of the trachea therefore lies in the superior mediastinum. It has lying in front of it, besides the first piece of the sternum and the origins of the sterno-hyoid and sterno-thyroid muscles, which form the anterior thoracic wall at this point, the thymus gland, deep cervical fascia, and transverse aorta. On the left side lie the left common carotid artery, pneumogastric nerve, recurrent laryngeal nerve, and the pleura; on the right side, the innominate artery, right pneumogastric nerve, and pleura. The bronchi lie in the posterior mediastinum, entering into the formation of the roots of the lungs. The right bronchus is shorter and of larger size than the left, and passes more horizontally, the two bronchi diverging to form an angle of one hundred and thirty degrees. The left bronchus crosses in front of the œsophagus, the descending aorta and the thoracic duct, passes under the arch of the aorta, and enters the lung behind the pulmonary artery. The right bronchus passes horizontally to the right lung, passing above and then behind the pulmonary artery on that side. The relation of the structures that form the root of the lung has already been noted.

I desire to acknowledge my indebtedness, for much of the material to be found in the above account, to the standard writers on anatomy, principally Gray, Morris, Quain, Gerrish, Deaver, and McClellan.

Frederick R. Green.

THORAX. SURGERY OF THE.—Injuries of the Thorax.—Injuries of the chest include contusions and wounds.

Contusions of the thorax are caused by the action of blunt violence, and may result in injury of either the thoracic wall or the thoracic contents, or both. The usual injuries of the thoracic wall are contusions of its soft parts and fractures of the ribs or sternum. The intrathoracic lesions include injuries of the pleura, lung, pericardium, and heart.

The variation in the nature and extent of the specific injuries makes possible a great variety of symptoms in these subcutaneous traumatisms. The symptoms of a local injury may be lost sight of in the general symptoms of shock, which always accompany the most severe forms of thoracic contusions. A condition known as "concussion of the thorax" may occur without demonstrable injury to the walls or contents of the thorax.

Slight ruptures of the parenchyma of the lung, or a mild effusion of blood into the pleural cavity may cause very insignificant clinical symptoms. The patient may expectorate a little bloody mucus. Severe ruptures of the lung and excessive hemorrhage into the pleural cavity will cause marked symptoms of dyspnœa and sometimes extreme anæmia from loss of blood. Injury of a large bronchus may cause pneumothorax. On account of the injury of important organs the prognosis of severe contusions of the thorax is serious. Should, however, the patient withstand the primary shock and the immediate effects of injury of internal viscera, other secondary consequences, such as infection, are not of frequent occurrence.

The treatment of contusions of the thorax is largely expectant and symptomatic. Rest in bed, morphine, ice bags on the chest, and possibly a venous infusion of salt solution are all the measures necessary in most cases. In cases of extreme hæmothorax aspiration of the pleural cavity may be indicated. Arrest of hemorrhage from a large intrathoracic vessel by ligation is usually out of the question.

Wounds of the thorax may be either non-penetrating or penetrating. The former are of special importance only in case of injury of a large artery in the chest wall, such as the internal mammary, or one of the intercostals. Such an injury may result from a stab or gunshot wound. The symptoms would be those of anæmia with local escape of blood, or flatness on percussion over that part of the chest. In order to arrest the resulting hemorrhage it will often be necessary to resect a portion of one or more ribs and their cartilages. In place of ligation of the artery packing the wound with gauze may be substituted. Subsequent removal of the gauze must be done very carefully to avoid secondary hemorrhage. Penetrating wounds of the thorax may cause injury of the pleura, lung, pericardium, heart, or one of the large vessels inside the chest. Injury to the pleura alone or combined with injury of other organs is of very serious moment, both on account of the primary pneumothorax or hæmopneumothorax and of the possible secondary infection of the pleural cavity. Extreme degrees of pneumothorax may be fatal from pressure; but fortunately this is not often the case, the air in the pleural cavity being gradually absorbed. In case of infection of the pleural cavity the resulting exudation may cause pressure on the heart and lungs, resulting in dyspnœa and cardiac weakness. There will also be the general manifestations of sepsis.

Wounds of the lungs may involve penetration of the entire thickness of one or both organs, or merely a superficial surface wound. Most of the wounds are caused by sharp-pointed knives or by fire-arms. The modern bullet frequently traverses the whole thickness of the lung. The primary symptoms of injury of a lung are those of shock from which the patient gradually recovers unless some large vessel has been wounded. In addition dyspnœa is often very pronounced, due usually to a serious hæmo- or pneumothorax. Hæmoptysis is a characteristic symptom, and varies in amount from a little bloody and frothy mucus to abundant hemorrhage.

Emphysema, starting in the vicinity of the external wound, is present in some cases. It is usually confined to the region of the wound, but may in rare cases extend over the greater part of the body. In case of a large wound prolapse of the lung may occur. Symptoms due to infection of the pleura (empyema, abscess of the lung) may arise subsequently, but under expectant treatment are not common. In case a foreign body, such as a bullet, splinter, or tip of a knife-blade, remains behind in the lung, the tendency to abscess formation is more marked. A bullet may heal up in the tissues without marked reaction, and at some subsequent time give rise to severe disturbances. Gunshot injuries of the lung have become much less formidable since the introduction of small calibre projectiles. These bullets make a cleaner cut and smaller channel. In many cases the bullet passes entirely through the lung, leaving behind but slight damage to the parenchyma of the lung and an aseptic wound canal.

The diagnosis of injury to the lung can usually be made from the history of the injury, the position of the wound (in the case of gunshot wounds the location of the entrance and exit), hæmoptysis, pneumothorax, extensive emphysema. The *x*-ray may demonstrate a bullet or other foreign body in the interior of the lung.

The treatment of injuries of the pleura and lung is largely expectant and symptomatic. The use of the probe for determining the depth of the wound should be discarded. The danger of infection is materially increased thereby. The wound and its vicinity should be thoroughly disinfected and a sterile dressing applied without suture of the wound. In case of active hemorrhage from a vessel in the thoracic wall resection of a rib, followed by ligation or packing, may be necessary. Bleeding from a large vessel in the lung is beyond the surgeon's control. Rest and the application of ice bags to the chest will be efficient to stop mild hemorrhages in the lung. Hypodermic injections of morphine are of value for the pain and restlessness. Aspiration in case of hæmothorax is seldom necessary, and should be performed only when the symptoms of pressure are very urgent. The same is true of the pneumothorax. Subcutaneous emphysema usually disappears of itself under an occlusive dressing. If it shows a tendency to spread, it may be treated by multiple incisions into the subcutaneous tissue. The secondary empyema, which is a rare complication, is treated by resection of a rib and drainage. In making an incision for the purpose of drainage, the original wound may if practicable be made use of; otherwise, the incision is made at the place usually chosen for empyema operations. (See farther on, in the section relating to empyema.)

Wounds of the pericardium without involvement of the heart are comparatively rare, and the diagnosis can usually not be made before operation or autopsy. The hemorrhage into the pericardium is not severe as a rule, and does not require special treatment. There may be sufficient to cause indistinctness of the heart sounds and increase in the area of cardiac dulness. Severe pressure symptoms with alarming heart weakness and dyspnœa from excessive hæmopericardium usually mean a wound of the heart itself. Infection of the pericardium may later give rise to a large exudate within the pericardium, which will produce symptoms of pressure and sepsis and demand incision and drainage.

Wounds of the heart may be either superficial or penetrating; in the latter instance one or more cavities of the organ may be opened. Wounds of the apex are the most favorable. The symptoms of a wound of the heart may be sudden collapse and death from hemorrhage. The less severe wounds, however, may give characteristic symptoms and be susceptible of recovery either spontaneously or after operation. The external wound does not show anything typical. There may be little or no hemorrhage from it; or, in case of large wounds, large amounts of arterial or venous blood may escape. The position of the wound is important in making the diagnosis of injury of the heart. Hemorrhage into the pericardium gives rise to more or less marked symptoms of pressure upon the heart and lungs. The heart sounds are inaudible. The pulse becomes irregular and weak and there is severe dyspnœa. The patient is restless and has a feeling of anxiety. In case the patient survives the primary shock and the effects of hemorrhage, the secondary symptoms of infection, particularly of the pericardium, may supervene. Suppurative pericarditis, though fortunately a rare complication, may prove a dangerous one, and its early recognition is imperative. The symptoms of pressure of the purulent exudate upon the heart and the signs of sepsis are usually sufficiently well marked to make the diagnosis possible. Bullets may remain within the heart or pericardium for years without producing circulatory disturbances or infection. G. Fischer collected 452 cases of wounds of the heart with 380 deaths and 72 recoveries. Death was immediate in 104, and in 270 it occurred after intervals varying from one hour to nine months.

The treatment of wounds of the heart is usually symptomatic, but in some cases active interference becomes necessary. Complete rest in a recumbent position is combined with the administration of morphine, the application of an ice bag over the heart, and, when necessary, the judicious use of some heart stimulant, such as digitalis. In extreme collapse the infusion of salt solution may be called for. Severe pressure of the blood within the pericardium upon the heart may demand aspiration or incision. Different points in the chest wall have been chosen for making the incision to expose the pericardium. A favorite place is the fourth or fifth intercostal space close to the sternum, with resection of the fourth or fifth costal cartilage. The point of entrance of the instrument which inflicted the wound may be made use of in making the incision. Incision is preferable to puncture, as it is much more effective and involves less danger of injuring the heart. Furthermore, an incision of the pericardium makes possible suture of the heart, should this be necessary. The insertion of sutures into the heart is usually a difficult procedure, but has been successfully accomplished in a number of instances. Silk or catgut may be used. The introduction of one or two long sutures facilitates the insertion of the other stitches. The sutures should pass only through the muscle tissues and not enter the cavity. The most favorable wounds for suturing are the smaller ones of the anterior surface of the right or left ventricle. Wounds of an auricle or those which pass through both ventricular walls cannot as a rule be sutured. The indications for attempting suture of the heart are progressive bleeding into the pericardium, or externally, with increasing anaemia or symptoms of pressure on the heart. Out of 34 cases of heart suture collected by Sherman, 5 died on the operating table of hemorrhage, 10 died very soon after operation, and 13 recovered.

For fractures of the ribs and sternum see under *Fractures*.

Inflammatory Diseases of the Chest Wall.—Cold abscesses are generally tuberculous in origin and arise usually from some carious process in a rib. The thoracic and dorsal muscles easily permit of gravitation and burrowing of the pus so that the original focus in the bone may be a considerable distance from the abscess itself. The symptoms are slight. The abscess causes a fluctuating swelling, varying in size, over which the skin is normal. The treatment may be either aspiration with injections of iodoform and glycerin, or incision and drainage.

Osteomyelitis of the Ribs and Sternum.—Acute osteomyelitis of these bones is rare. Typhoid fever is occasionally complicated by subacute osteomyelitis of the ribs. The treatment is in general the same as in other bones.

Tuberculous osteomyelitis is far more commonly localized in the ribs or sternum. The process leads to the formation of a tuberculous abscess, which either breaks through the skin in the vicinity, forming a fistula leading down to the focus in the bone, or burrows under the muscles, forming a cold abscess, which comes to the surface at some more distant point.

The treatment consists in dividing the fistulous tracts and resecting the rib. In case of long fistulous tracts the injection of iodoform emulsion may be substituted. Extensive resections of the sternum are sometimes necessary.

Surgical Diseases of the Pleura.

Empyema.—Inflammations of the pleura belong in the province of surgery only when the exudate is purulent in character. The purely serous exudates and transudates are treated by internal medication and aspiration (paracentesis thoracis). Should, however, a serous exudate become suppurative, the more radical surgical measures of thoracotomy, with or without resection of a rib, have to be resorted to.

The *ætiology* of empyema is varied. The infection may gain access to the pleura through an external wound, through the blood or the lymphatics, and finally by direct extension from a neighboring organ, most commonly the lungs. It may thus represent a purely local suppurative process or be a part of a general sepsis. An abscess within the abdomen may rupture through the diaphragm and cause an empyema, or a suppurative process in the neck or chest wall may extend directly or through the lymphatics to the pleural cavity. The bacteriological examination of the exudate has shown the presence, in different cases, of the pneumococcus, the streptococcus, the staphylococcus, and the bacillus of tuberculosis. Pneumococcus infections are the most common ones in children, while in adults the streptococcus is the most frequent cause, with the bacillus tuberculosis next. The character of the infection determines to a large extent its virulence. Tuberculous cases are by far the most unfavorable.

The *symptoms* of empyema are those of pressure produced by a fluid contained in a closed cavity, and the manifestations of absorption of septic materials. Pressure may cause displacement and interference with the functions of the lungs and heart. The septic absorption causes fever, emaciation, and ultimately death unless the pus finds a spontaneous or artificial escape. Spontaneous discharge of pus, which is unusual, may take place through a bronchus or the chest wall. Even when such an outcome occurs the escape of pus is not complete, and in order to heal a resulting fistula or expectoration of pus, an operation is usually necessary. The longer the operation is delayed the greater the danger of sepsis, and in case of recovery the longer the healing process will be. In chronic cases the pleural surfaces become enormously thickened, the lung, from continued pressure, becomes greatly contracted, and the enclosed abscess cavity tends to persist owing to the rigidity of its walls.

The *treatment* of empyema consists in prompt and thorough evacuation of the purulent exudate, followed by drainage of the cavity (thoracotomy). For this purpose resection of a portion of a rib is advisable in order to gain better access to the cavity and secure more complete drainage. In children incision through an intercostal space may be sufficient. The rib chosen for resection may be either the eighth, ninth, or tenth posteriorly, to the outer side of the long dorsal muscles, or the fifth or sixth in the axillary line. The advantage of the first location is that the abscess cavity is opened at its lowest portion and in the usual recumbent position the drainage is the best possible. On the other hand, the ascent of the diaphragm may tend to displace or compress the drainage tube. In the axillary line the ribs are more accessible, thus making the operation easier, but the drainage is inferior and hence the healing process will be slower. In either locality the portion of rib in question is exposed by an incision along the rib, three or four inches in length. The periosteum is divided in the line of the skin incision and separated from the outer and inner surfaces of the rib by means of a pericostal elevator. Care must be taken not to injure the intercostal artery which runs along the lower border of the rib. The latter having been exposed, a piece, two inches in length, is removed with bone-cutting forceps or a Gigli saw. The exposed pleura should now be punctured with an aspirating needle to make sure that pus is really present; and if pus is found, a pointed knife is thrust into the distended cavity. The finger may now be inserted for the purpose of exploring the cavity and removing solid pieces of lymph which might obstruct the drainage tube. The pus having been evacuated, irrigation with 1 to 10,000 bichloride solution or 1 to 4 peroxide of hydrogen followed in most cases by salt solution may be practised, although this is not necessary except when the exudate is very foul. One or two thick-walled drainage tubes are now inserted and a safety-pin is passed through their outer end to prevent them from slipping into the cavity. Finally a voluminous gauze and cotton dressing is applied and held in place by a muslin bandage or binder. During the after-treatment the cavity may be washed out with some harmless solution and the drainage tubes gradually shortened. In order to accelerate expansion of the lung expiratory exercises, such as blowing air into a rubber ball, may be employed. Healing of the thoracic opening may be very slow, but ordinary cases heal even after the lapse of months. Cases which had existed a long time before operation and tuberculous cases may not heal, and will then require further operative treatment. The cause of failure of healing in those cases is the existence of a chronic abscess cavity with rigid walls which can neither be filled up by expansion of the lung nor contract by shrinkage of the surrounding parts. In case the cavity persists the patient suffers from the effects of septic absorption, particularly if the fistulous opening becomes stopped up. In case of tuberculosis the general symptoms are more marked and the local process may spread to the neighboring ribs and other adjoining parts. For this reason it is desirable to bring about a radical cure of the conditions which otherwise may continue indefinitely. Several operations have been devised for this purpose which have as their common object the contraction and obliteration of the abscess cavity. *Estlander's operation* (thoracoplasty) consists in the subperiosteal resection of a piece from all the ribs covering the cavity. The number resected will depend upon the size of the cavity, but it is better to resect too many than too few. Removal of a portion of the ribs in question makes the thoracic wall much more movable, and thus enables it to come in contact with the visceral pleura, and finally unite with it. *Schede's thoracoplasty* consists in removal not only of portions of the ribs, but also of the thickened parietal pleura as well. For this purpose a curved incision is made from the outer border of the pectoralis major muscle at the level of the fourth rib to the tenth rib in the posterior axillary line. From here the incision ascends in a curve and runs along the vertebral side of the scapula. The skin and muscles are dissected up, exposing the ribs, which are removed subperiosteally from the costal cartilage to the tubercle. The thickened parietal pleura is now removed with forceps and scissors, leaving behind a shallow gutter-shaped cavity which is scraped out and then covered with the flap of skin and muscle. The wound is sutured in front, but left open and packed behind. This operation is the most successful one for large cavities: smaller ones can usually be covered by the Estlander method. Délorme practised "decortization of the lung" for chronic empyema, and a number of cures by this method have been reported. His operation consists in reflecting a flap of skin, muscle, and bone, and then removing both pleural surfaces with the finger or scissors. The flap is then returned to its place. The hemorrhage from the surface of the lung is often excessive and requires postponement of the operation to a second sitting. Most cases of chronic empyema can be cured by one of these forms of operation. Estlander's is sufficient for the smaller cavities, while Schede's is designed for the extensive cavities and the tuberculous cases. Délorme's operation is still in the experimental stage.

Surgical Diseases of the Lung.

The most important diseases of the lung for the surgeon are abscess, gangrene, and bronchiectasis. Tuberculous cavities are only seldom adapted to operative treatment.

Abscess of the Lung.—The causes of pulmonary abscess are acute pneumonia, infectious embolism, foreign bodies in the lung, wounds, and perforations of a suppurative process in the neighborhood. The characteristic sputum of abscess of the lung is pure creamy pus without marked odor. Microscopic examinations show the presence of elastic fibres and hæmatoidin crystals. Fever is present and there are physical signs of a cavity in the lung which is alternately full and empty. Without operation the prognosis is unfavorable.

The treatment consists in opening the abscess as soon as the diagnosis is made. The prognosis of operation is best in case of abscess following pneumonia and much worse in one due to a foreign body or to embolism. The thorax is opened by an incision similar to that made for empyema, one or two ribs being resected for the purpose of gaining more room. In place of resecting ribs a flap consisting of skin, muscle, and bone, can be reflected and then replaced after completion of the operation. The costal pleura having been exposed it should be determined whether or not adhesions exist between this and the visceral pleura. Such adhesions are necessary to prevent a pneumothorax or escape of infectious contents into the cavity. To determine the presence or absence of adhesions a fine aspirating needle may be thrust into the pleura. If it moves back and forth freely there are no adhesions present. In case of adhesions the movements of the needle are slight or absent. If not already present they should be artificially produced by packing gauze upon the costal pleura, and leaving it in place for several days, or by suturing the two surfaces. The adhesions having been obtained the presence of pus is ascertained by means of an aspirating needle thrust into the cavity. If pus is present an opening into the lung is made with a pointed knife or the thermo-cautery. The latter method is followed by less hemorrhage and the opening is more likely to remain patent. A drainage tube is inserted into the abscess cavity and gradually shortened as the healing process progresses.

Gangrene of the Lung.—When circumscribed, gangrene of the lung may be the object of surgical treatment. Its etiology is much the same as that of abscess; it occurs particularly in alcoholic or diabetic patients, or those in poor general health. It is distinguishable from abscess chiefly through the character of the sputum. This is extremely foul-smelling and contains particles of broken-down lung tissue. The different forms of gangrene can be treated only by medicinal means, such as inhalation of carbolic acid or turpentine, and the internal administration of creosote, etc. The prognosis in these cases is usually hopeless, the patients succumbing to the septic absorption. Localized foci of gangrene should be attacked in the same way as abscess by thoracotomy and resection of one or more ribs. The good effects upon the general condition of free evacuation of the contents of the gangrenous cavity are almost instantaneous, and the removal of the foul odor and taste is an immense boon to the patient. Tupper's statistics show 74 cases of pneumotomy for gangrene with 60 per cent. recoveries. Lenzbarzt has collected 118 cases that were operated upon, of which 94 were cured and 54 died—*i.e.*, 63.5 per cent. of cures. Villière's statistics show that with internal treatment from 75 to 80 per cent. die. This seems an excellent showing for the operative treatment.

Bronchiectatic Cavities.—In recent years the drainage of cavities resulting from bronchiectasis has been performed in a number of instances with satisfactory results. This is true only of a single cavity, or of two or more which lie closely adjacent. The diagnosis is made chiefly from the history, the character of the sputum, and the physical examination of the chest. The odor is not so intense as in gangrene, and there is an absence of degenerated tissue elements. The technique of the operation is much the same as in abscess and gangrene. After exposing the pleura adhesions are produced by packing or by sutures and the pus is sought for with an aspirating needle. The thermo-cautery is the best instrument for cutting through the layer of healthy lung before entering the cavity. Drainage is provided for in the usual way. The beneficial effects of removal of the purulent focus are often surprising. Some bronchorrhœa is likely to persist, but it can be kept under control by proper hygienic measures and and by the use of expectorants.

Diseases of the Mediastinum.—The diseases of the mediastinum are acute and chronic mediastinitis, and mediastinal tumors.

Mediastinitis.—The etiology of inflammations in this region includes traumatism, extension from adjacent organs, and tuberculosis. The anterior mediastinum is by far the most frequently attacked. The symptoms of the acute and chronic forms are much the same except that in the former they are more intense. Pain is present in all cases and is located behind the sternum, from which it radiates to the shoulder blades. The sternum is often tender on pressure and may become red and œdematous. Fever is present particularly at the beginning, and in the acute cases may be accompanied by chills and sweating. As soon as pus has formed pressure symptoms may make their appearance, including dyspnœa and heart weakness. The abscess may finally work its way to the surface and point either in some intercostal space close to the sternum or at some more distant part. Rupture into the diaphragm, trachea, or pleural cavity may also occur. The treatment consists in evacuating the pus at the place where the abscess points, or in opening the anterior or posterior mediastinum. The anterior mediastinum is opened by resection of one or more ribs or costal cartilages, and the adjacent sternum. The posterior mediastinum has only seldom been attacked. On the cadaver it has been shown that removal of a transverse process of a vertebra and the underlying piece of rib gives a good opening for the discharge of pus.

Tumors of the mediastinum include the benign and malignant. Glandular enlargements form a goodly percentage of these new growths. Some of the tumors are primary, others are secondary. The benign tumors include fibroma, lipoma, and dermoid cysts. The malignant tumors, both carcinoma and sarcoma, may have their origin in the bronchial glands or in the bronchi themselves. In all varieties the symptoms are practically the same, and are chiefly those of pressure. The heart, lungs, large vessels, nerves, œsophagus, and trachea may be compressed and their function impaired. Furthermore, the chest wall may be pushed forward and ultimately the tumor may come to lie beneath or perforate the skin. Malignant tumors run a more rapid course than the benign, and may cause death before the tumor has appeared externally. Percussion is dull or flat over the tumor when it is situated close behind the sternum. Pressure upon the recurrent laryngeal nerve causes paralysis of the vocal cord on the same side. Pressure on the pneumogastric may result at first in slowing of the pulse, later in acceleration of the same.

The differential diagnosis from aortic aneurism can usually be made from its history and from the presence in the latter of arteriosclerosis, aortic insufficiency, friction sounds, etc.

As regards the prognosis the differentiation of the benign from the malignant tumors is of extreme importance. The malignant are the more common, and whether primary or secondary can usually be recognized by their more rapid growth, by the presence of glandular enlargements, by the greater severity of the pain, and by the rapid loss of flesh and strength.

The treatment may be begun by the internal administration of potassium iodide or arsenic, and in case of syphilitic lymphomata, malignant lymphomata, and some sarcomata a diminution in the size of the tumors will result. Other cases will call for active surgical treatment, and this should not be delayed too long either in the malignant or in the benign forms. The operation is the same as in suppurative mediastinitis, except that more room will be necessary for removing the growths than for opening the abscess. Excision of several ribs and part of the sternum or temporary osteoplastic resection of ribs by means of a flap of skin, muscle, and bone furnishes a good exposure of the anterior mediastinum. Through such an opening the tumor masses are enucleated, care being taken not to injure the pleura or the pericardium. If such an accident occurs, the opening is closed at once by suture or the wound packed, and the operation put off to a second sitting. Excessive hemorrhage may be another reason for postponing the completion of the operation. The benign as well as the malignant tumors may require extensive dissection, although adhesions with adjacent structures are more intimate in the malignant forms.

Diseases of the Pericardium.—As in the pleura exudations occasionally take place within the pericardium. Of these the suppurative form will demand surgical interference. Collections of serum or of blood may be removed by aspiration,but, should this not be sufficient, incision may be resorted to. Purulent collections, just as in empyema, require for a cure incision and drainage. Puncture and aspiration are frequently resorted to in making the diagnosis of the presence and character of the exudate. A safe place for puncturing the pericardium is at a point between the fifth and sixth ribs, close to the sternum. The third or fourth intercostal space can also be chosen. Care must be taken not to injure the internal mammary artery which lies at a distance of from 1 to 2.5 cm. to the outer side of the sternum. Puncture is performed with an aspirating needle or a trocar. As the heart may be pushed forward by the exudate behind and thus lie close to the anterior thoracic wall, care must be exercised in not injuring that organ. The instrument is thrust in cautiously in an upward direction, and it is often possible to feel the heart come in contact with the point of the needle. Délorme collected eighty-two cases of puncture of the pericardium with twenty-eight cures.

Incision of the pericardium may be performed through a variety of incisions. Ollier's incision seems the simplest and answers the purpose. The incision runs from the middle of the sternum along the centre of the fifth costal cartilage. The latter is dissected free, resected with a knife or bone-cutting forceps, and the internal mammary artery tied. In case sufficient room is not obtained, a piece of the sternum is resected. Another incision (Délorme) begins 1 cm. from the left border of the sternum and runs from the fourth to the seventh costal cartilage. Two short lateral incisions are made outward from each end of the longitudinal one, and the flap is turned back. The cartilages of the fifth and sixth ribs are resected, care being taken not to wound the internal mammary artery. Drainage is provided for by means of a rubber drainage tube inserted into the cavity. Among thirty-five cases of suppurative pericarditis operated upon by incision and drainage, Kobert found that forty-three per cent. recovered.

Benjamin T. Tilton.

THOROUGHWORT.—(*Eupatorium* U. S. P.; Boneset.) The dried leaves and flowering tops of *Eupatorium perfoliatum* L. (fam. *Compositæ*). This is a widely spread species, growing in the greatest abundance about the borders of ponds and brooks, and in wet places generally, from Canada to Florida, and from the eastern to the western side of this country. It is a handsome, large, perennial herb, with a hairy, rather simple stem, growing from two to four or more feet high, large, dark green and completely connate pairs of rough hairy leaves, and flattened, complex, cymose clusters of small heads of minute creamy-white flowers.

Description of Drug.—Leaves opposite, the two united by their broad bases, the uppermost often distinct, those of the inflorescence mostly alternate and greatly reduced; 8–15 cm. (3–6 in.) long and 1.5–5 cm. (⅔–2 in.) broad, tapering regularly from near the base to an acute apex, crenate-serrate, above bright green or somewhat yellowish-green, rugose and finely bullate; underneath yellowish gray green, densely short hairy and resinous dotted, the prominent, rounded, crooked, fine veins conspicuously reticulated; flower-heads very numerous, in broad corymbs, the branches rough hairy; mature involucre campanulate, the imbricated scales lance-oblong, obtusish, green, hairy, the inner longer and with whitish tips and margins; flowers of the head about ten to sixteen, tubular, yellowish white, the pappus in a single row, white, bristly; odor weak, aromatic; taste bitter, astringent, aromatic.

The constituents of thoroughwort are chiefly the bitter glucoside eupatorin, which is soluble both in alcohol and in boiling water, a very small amount of volatile oil, a glucosidal tannin, which constitutes the coloring matter, and another tannin. There are also gum, resin, and ordinary plant constituents. The presence of an alkaloid has been reported, but this subject requires further investigation.

USE.—Boneset has been long used in the United States as a tonic and antiperiodic, and even as an emetic, but always more of a family medicine than one prescribed by physicians. Since the beginning of the last century it has fallen very much into disuse. In small doses thoroughwort is a mild bitter tonic, like the chamomiles and others in the same family, but with less aromatic character than most of them. It is also a good deal like horehound in the *Labiatæ*. In larger doses, especially in hot infusion, it is diaphoretic, possibly diuretic, and is still occasionally used, followed by a sweat under blankets, to abort colds, and in the beginning of most acute diseases. In very large doses (an infusion of an ounce or so) it is a nauseating emetic. Doses as large as can be borne by the stomach, repeated for some days, have had a considerable reputation in the country, and have a little real value, in the treatment of intermittent fever and other malarial manifestations.

In domestic practice thoroughwort is usually given in the form of a decoction, especially when its diaphoretic, antirheumatic, or antiperiodic action is desired. Physicians also often prescribe it in that way, though more often at the present time in the form of the fluid extract. The dose of the latter, of which 1 c.c. is the equivalent of 1 gm. of the drug, is 10–15 minims as a tonic, 1–4 c.c. (fl. ʒ $\frac{1}{4}$–i.) as a diaphoretic and antiperiodic, and two or three times as much as an emetic.

ALLIED SPECIES.—The genus *Eupatorium* comprises many hundreds of species, a large number of which, in various countries, are employed similarly to the above. Numerous plants belonging to related genera have similar properties. (See *Compositæ*.) *Henry H. Rusby.*

THREE SPRINGS.—Huntingdon County, Pennsylvania.

POST-OFFICE.—Three Springs. Hotels and sanitarium.

ACCESS.—Take the Pennsylvania Railroad (main line) to Mount Union, Pa.; thence take East Broad Top Railroad to springs.

The village of Three Springs is located in a valley formed by Jack's Mountain, 2,220 feet high, and Care Hill, 2,210 feet in altitude. The place takes its name from the presence of three mineral springs, situated about one hundred feet apart, and forming the corners of an equilateral triangle. The springs are known as "No. 1," "No. 2," and "No. 3." They have been known and used for many years, but it was not until 1891 that they came under control of the present proprietor, who has brought them to an advanced state of development as a resort. Spring No. 1, the most important of the group, flows about one thousand gallons of water per hour, having a temperature of 55° F. It is used commercially under the name of the Hygeia Natural Mineral Water, and is shipped in five-gallon demijohns. The following analysis was made in 1895 by Prof. G. G. Pond, of the Pennsylvania State College:

Spring No. 1 (Three Springs). One United States gallon contains (solids): Calcium bicarbonate, gr. 31; calcium sulphate, gr. 53.63; magnesium sulphate, gr. 33.51; sodium sulphate, gr. 5.91; sodium chloride, gr. 0.35; lithium sulphate, gr. 0.02; potassium sulphate, a trace; silica, gr. 1.15. Total, 128.6 grains.

Gases: Carbonic acid, cub. in. 5.47; oxygen, cub. in. 1.72; nitrogen, cub. in. 3.85. The water is bright, sparkling, and palatable, and entirely free from organic impurities. It is an efficient laxative and mild diuretic and has been found beneficial in cases in which activity of the emunctories is desirable. The water has been used with success in cases of obesity and in uræmia and general anasarca, as well as in local dropsies. In habitual constipation a systematic course of the water is often curative. It is also beneficial in other disorders requiring a sulphureted saline water. The sanitarium at Three Springs is kept open all the year. *James K. Crook.*

THROMBOSIS. DEFINITION.—Thrombosis is a pathological state or process in which there is a deposit within the heart or vessels, during life, of solid material originating in transformation of the blood.

The solid mass or plug thus produced is called a *thrombus*.

It used to be taught that thrombosis was caused by the coagulation of the blood, but fuller researches, more especially those of Eberth and Schimmelbusch, have proved that many thrombi, at least at first, are due to the agglutination of blood platelets or of corpuscles without fibrin formation, so that it is more correct to adopt a wider definition, such as that given above.

VARIETIES OF THROMBI.—Any or all of the formed elements of the blood or their derivatives may enter into the composition of thrombi, viz., red corpuscles, leucocytes, blood platelets, and fibrin.

Red Thrombi.—These are produced in stagnating blood and are strictly comparable to clots formed outside the body, being composed of fibrillated fibrin, red and white cells, in much the same proportion as in ordinary clots.

White Thrombi.—Thrombi deposited from the circulating blood are generally of the white variety. The characteristic color, whence they derive their name, is due to the presence in excess of fibrin, leucocytes, and platelets. It is not, however, uncommon to find *mixed thrombi* in which there is an admixture of red cells, giving them a somewhat reddish tint. When recent, white thrombi under the microscope are composed of granular material having the form of clumps or strands of irregular size and shape which are embedded in fibrin, leucocytes, and a certain number of red cells. The granular matter in question is composed of altered blood platelets. The fibrin has frequently a distinct fibrillated structure, and is particularly abundant at the periphery of the masses of platelets, sending anastomosing branches into their substance or forming a loose meshwork in which red cells are entangled.

Fibrin Thrombi.—These are not infrequently found in inflamed areas, usually in the smaller vessels. They may be seen particularly well in the vessels of the lung in croupous pneumonia. According to K. Zenker, who has described them in detail, whorls or brush like tufts of coarse fibrin may be seen springing from the wall of the vessel. These appear to radiate from a definite centre composed of degenerating material, such as endothelial cells, leucocytes, blood platelets, or débris. The amount of deposit is not usually sufficient completely to block the vessel. In old white thrombi also the cellular elements degenerate and are replaced by fibrin.

Leucocytic Thrombi.—As has been already hinted, leucocytes enter into the formation of a large proportion of white and mixed thrombi; but thrombi composed almost entirely of white cells are also to be met with, particularly in areas that are acutely inflamed. In this case the condition is really a capillaritis, arteritis, or phlebitis, and the plug is due to the accumulation of leucocytes attracted to the spot by chemotaxis. Somewhat similar masses are seen within the vessels in cases of leukæmia, but these are perhaps not strictly to be regarded as thrombi.

Hyaline Thrombi.—For the recognition of this form we are indebted to von Recklinghausen. Hyaline thrombi are found chiefly in the capillaries, but also in the smaller veins and arteries. The lumen of the affected vessel is filled with a homogeneous, translucent, and refractile substance, without color, or at most having a faint yellowish tinge, which gives the microchemical reactions for fibrin. This variety is found more especially in toxic and infective conditions and after exposure to heat and cold. The most striking examples of it, according to Welch, are to be found in the renal capillaries of swine dying of hog cholera. It is also met with in pneumonia, hemorrhagic infarction, frost-bite, and eclampsia.

The Chemico-Physics of Thrombosis.—Until we are able to give a more complete explanation of the process of coagulation of the blood, we shall still be more or less in the dark as to the nature of thrombosis. As with all vital and semi-vital processes, the subject is beset with difficulties. According to the most painstaking investigators coagulation is a chemical process whereby the interaction of certain substances results in the precipitation of insoluble material. According to Schmidt ("Zur Blutlehre," Leipsic, 1893) the following are the determining factors: (1) Soluble proteids of the nature of globulin, with their derivative fibrinogen. (2) A fibrin ferment to act upon the substances just mentioned. (3) Various neutral salts, but especially those of calcium, which form insoluble compounds. Arthus and Pages (*Arch. de Phys.*, ii., 1890) have shown that without the intervention of calcium salts fibrinogen cannot give rise to fibrin, for if potassium oxalate be added to fresh blood in sufficient amount to precipitate the calcium salts, clotting will not occur; while if calcium salts be restored, clotting will rapidly take place. Pekelharing (*Festschrift f. Virchow*, Berlin, 1891, and *Deutsche med. Woch.*, 1892), basing his opinion on the fact that a nucleo-albumin can be isolated from the plasma, which when brought in contact with fibrinogen and salts of calcium produces a typical clot, believes that the fibrin ferment or "thrombin" of Schmidt is a combination of nucleo-albumin and calcium. When this is brought into contact with fibrinogen the calcium radical unites with a portion of the fibrinogen molecule to form an insoluble salt, fibrin. Fibrinogen and calcium salts are to be found in the blood plasma, while the nucleo-albumin is a product of the disintegration of the leucocytes and perhaps the hæmatoblasts. In terms of this theory, then, fibrin is an end-product of the chemical interaction of nucleo-albuminate of calcium and fibrinogen.

Besides this, however, the researches of Lister, Brücke, Baumgarten, and Freund have proved that certain mechanical principles enter into the question of coagulation. If, as was done by Lister, a section of a large vessel containing blood be isolated between double ligatures and removed, the blood will remain fluid for hours; and further, if the vessel be divided transversely into two so as to form, as it were, two test tubes, the blood may be poured from one portion to the other almost indefinitely without coagulating. The reason for this is not entirely clear. But Freund has shown (*Wiener med. Jahrb.*, 1888) that, provided decomposition be prevented, blood which has been received into glass vessels smeared with vaseline will remain fluid for a long time. A similar result follows if blood be dropped into some perfectly bland fluid such as oil. Freund thinks that when the vessel is not lubricated in this way the surface of the glass destroys some of the red corpuscles, and that this initiates coagulation. However this may be, the experiment at least shows that what are at first sight trivial changes in the condition of the vessel wall are sufficient to induce coagulation. However, something more than mere contact with a foreign surface appears to be necessary. Changes must be present of such a nature as to promote adhesion between the vessel wall and the corpuscles, especially the red cells. Small glass balls, presenting a smooth, unirritating surface may be introduced into the blood vessels with impunity, as in Zahn's experiment (*Festschrift f. Virchow, Internat. Beitr.*, ii., p. 199); while if needles or other sharp objects be inserted, the blood platelets are precipitated and thrombosis is rapidly induced. Anything, therefore, that impairs the integrity of the vessel wall, be it in the slightest degree, may on occasion determine thrombosis.

It may be asked why it is that coagulation of the blood does not take place under the conditions of normal existence. All the elements for the production of fibrin are in fact present, for there is constant disintegration of the red cells with liberation of nucleo-proteid; but so long as the vessel walls remain intact, the amount of nucleo-proteid is but small, and it is quickly neutralized or metamorphosed and thus rendered innocuous. The fact that it is difficult to produce thrombosis by the injection into the circulation of nucleo-albumins proves that up to a certain point the body is able to protect itself against coagulation. Lilienfeld has further shown that under certain circumstances during disintegration of leucocytes a proteid is formed, which he terms *histon*, that has the power to prevent clotting.

Numerous experiments, as well as clinical observations, have led us to realize that a variety of factors are concerned in the process of thrombosis. Most are, I think, agreed that the following points are of cardinal importance, although there is not always unanimity as to the relative value of each: (1) Alterations in the vessel wall, whereby the blood is brought into contact with an abnormal surface. (2) Slowing or other irregularities of the blood current. (3) Changes in the blood itself. As the sequel will show, it is beyond question that the action and reaction of the various factors mentioned are intimately bound up together.

It may be inferred, and rightly, from the experiments above referred to, that gross physical changes in the condition of the vessel wall are of powerful import in the causation of thrombosis, particularly if they be such as to impair the continuity of the intima or produce obstruction. Injuries or disease of the vessel walls, and foreign bodies of all kinds within the lumen, such as needles, bones, wire, lime salts, bits of tumor, and parasites, may act in this way. Advantage is taken of this fact in the well-known treatment of aneurisms by the insertion of fine wire. The thrombus itself often acts as a foreign body, a fact which explains its tendency to spread. Yet it is frequently observed at autopsies that the most extensive disease with roughness of the intima may exist, as in atheroma, without the formation of a thrombus. Again, Zenker has noted that degenerating endothelium often forms a nucleus for the deposition of fibrin, so that a star-like clot is formed. If, too, we inflict an aseptic injury on the valves of the heart in an experimental animal, relatively little thrombosis results. Should we, however, inject pyogenic micro-organisms at the same time, we get the most pronounced effects. Such observations suggest that in thrombosis, besides mechanical factors, chemical changes have to be taken into account, and it would appear necessary to assume certain specific properties on the part of the intimal cells and the injured tissue. This is further indicated by numerous experiments which have proved that certain substances introduced into the blood have the power of inducing coagulation. Such are thymus extract, laky blood, defibrinated blood, ether, tissue juices, snake venom, and biliary salts, among others. These substances probably act by affecting the vitality of the intimal cells, or possibly, as some think, by liberating the fibrin ferment. It is by no means proved, however, that the clots thus produced are identical with ordinary thrombi. In fact, there is every reason to think that they are not. It must, nevertheless, I think, be admitted that circulating toxins or perverted metabolism in the blood induce important alterations in the properties of the intimal cells, for, as we know, there is a decided tendency in many infective and cachectic states for thrombosis to occur. It is, perhaps, mainly in this way that the so-called "ferment thrombi" are produced.

Slowing of the blood stream has been referred to as one of the factors concerned in the production of thrombi. This in itself cannot be of prime importance since numerous experiments, notably those of Glénard and Baumgarten, have shown that the circulation may be completely obstructed within a vessel, by the application of aseptic ligatures, without thrombosis resulting. It is, nevertheless, a fact that thrombi are apt to form just where the circulation is feeblest, as in the veins and diverticula of the vascular apparatus. It would seem to be necessary, however, that some lesion of the vessel wall should exist as well, and this as a matter of fact is generally present, owing to the impoverished nutrition resulting from the impaired blood flow. A slow circulation, therefore, determines the place rather than the fact of thrombosis. Baumgarten, indeed, attributes more importance to eddies in the blood than to mere slowing of the stream, and has laid stress upon the fact that thrombi are commonly formed in culs de sac, dilated chambers (dilatation thrombi of Virchow), and about the valves of the veins, in fact, where eddies are naturally produced. He has, moreover, shown that a carefully tied ligature, leading as it does to stagnation of the blood, need not necessarily result in the formation of a thrombus unless the inner lining of the vessel be ruptured.

Two main forms may be differentiated in this group of so-called "stagnation" thrombi, viz., those found in conditions of great prostration and cardiac weakness, called by Virchow, who regarded them as due to marasmus, "marantic" thrombi, and those due to local circulatory disturbances, as in aneurisms and varices, and in obstruction of the vessels. Not all the so-called "marantic" thrombi can be rightly attributed to marasmus, as it is impossible in such cases to exclude vitiated conditions of the blood and degenerative changes in the lining endothelium. Many of them are, no doubt, toxic in nature, due to accidental or terminal infection.

Little is known as yet with regard to the changes in the blood that favor thrombosis. Changes are, however, undoubtedly present in such cases as the infectious fevers, in snake-bite, arsenical poisoning, severe burns, and trauma. Weir Mitchell long ago pointed out that one of the characteristic features of snake-bite was the agglutination of the red corpuscles, and similar properties have been abundantly shown by more recent experiments to be possessed by a number of substances of which may be mentioned abrin, ricin, the blood serum of another race of animal, the toxins of certain bacteria as those of typhoid, hog cholera, pneumonia, and diphtheria. It is probable, therefore, that the so-called "ferment" thrombi and the agglutinative or hyaline thrombi are largely due to a toxin acting upon the red cells so as to destroy them and produce a uniform conglomerate.

In other ways, too, thrombosis may be promoted. In some diseases in which there are marked leucocytosis and an increase in the fibrin content of the blood, thrombosis is not infrequent. In others, like typhoid, in which there is leucopenia, thrombi are rare, at least during the height of the disease. When they are present in typhoid, it is only in the later stages, when the circulation is feeble, the vessels are relaxed, and there is an increase in the number of leucocytes, with possibly a secondary infection. It is here, again, impossible to exclude changes in the endothelium.

THE MODE OF DEVELOPMENT OF THROMBI.—It is a common event to find within the heart and great vessels at autopsy large soft clots of varying appearance. These are produced during the death agony or shortly after. When clotting has been rapid, a uniform, dark red, soft coagulum is formed, not differing specially from that produced in the process of extravascular coagulation. In cases in which clotting is slower, the red cells, being specifically heavier than the white, sink to the bottom, and the uppermost layers of the clot form a soft, yellowish, or buffy portion, while the deeper parts are of a reddish, raspberry-jelly-like appearance. In cases in which during life leucocytosis has been marked, as in inflammatory rheumatism and pneumonia, large yellowish, oily looking clots are produced. Such clots are readily distinguished from those produced during life by the fact that they lack the firm granular structure, and are only loosely adherent to the wall of the heart or vessel.

Very different are the real thrombi. When the blood is stagnating or the circulation prevented, red thrombi are formed, provided that the ordinary conditions favoring the deposition of fibrin are operative. Under the microscope these thrombi consist of masses of red cells, among which coarser or finer strands of fibrin can be seen together with an occasional leucocyte. At first the thrombus is soft and juicy, but later it becomes firm and dry, and presents a paler or a brownish or rusty appearance.

Zahn's researches (*Arch. f. path. Anat.*, Bd. xcvi., 1884) have shown that the essential factor for the production of a white thrombus is a continuous circulation. In the circulating blood stream two regions are to be distinguished, an axial and a peripheral. The axial stream contains the red and white cells, while the more slowly moving peripheral current is chiefly plasma with an occasional leucocyte floating in it. Should the rapidity of the circulation be diminished, the number of the white cells in the peripheral zone is notably increased, and in the more extreme cases blood-platelets begin to make their appearance. The exact part played by the blood-platelets has given rise to much debate. Bizzozero (*Centralb. f. d. med. Wiss.*, 1882, 1883) believed that in the course of their destruction they liberated the fibrin, but his conclusion has been by no means generally accepted.

If, as Eberth and Schimmelbusch did (*Arch. f. path. Anat.*, Bd. ciii., cv., cviii.), we injure the mesenteric vessels in a warm-blooded animal, as, for instance, by silver nitrate, blood platelets are quickly deposited and become massed at the site of injury (conglutination), and eventually are fused into a more or less coarsely granular or homogeneous material (viscous metamorphosis). In some cases these deposits are cast off into the general circulation, but frequently they keep on enlarging until the lumen of the vessel becomes occluded. An occasional red or white cell can be made out in the mass, but these are clearly accidental, and have nothing to do with the initiation of the process. Very early in the experiment, namely, within fifteen or twenty minutes, as Welch has shown (Trans. Path. Soc. of Phila., xiii., 1887), leucocytes make their appearance in considerable numbers, and must now be regarded as taking an important part in the process. The leucocytes are chiefly of the polynuclear variety, and tend to accumulate at the edge of the clumps of platelets and to some extent between them. As soon as this takes place fibrils of fibrin are formed in close relationship to the white cells, while they are absent near the conglutinated platelets. Sooner or later, the period varying in different cases, a plug is formed consisting of platelets, leucocytes, and fibrin, in which a number of red cells are entangled, reproducing with great accuracy the appearance of the thrombi found in the human subject. No doubt all thrombi do not develop in this way, for there are some, notably the white mural thrombi, that are chiefly composed of white cells, as are those found in the small vessels of an acutely inflamed area. In the latter case the leucocytes are attracted by chemotaxis, and the whole process is obviously inflammatory.

As the white thrombus increases in size it gradually encroaches upon the axial stream, with the result that red cells become entangled in it and a mixed thrombus is produced. A somewhat similar result is brought about by alternating slow and rapid coagulation of the blood, such as occurs in aneurismal sacs, where the clots are commonly found to be laminated, or where the thrombi contract and leave crannies into which the red cells may penetrate. When occlusion of the vessel has taken place, a red thrombus may be superadded upon the white or mixed one (secondary or propagated thrombus).

A thrombus in its early stage, when simply attached to one side of a vessel wall, is called a *parietal* or *mural thrombus;* but when by continuous accretion it has filled up the entire lumen of the vessel, it is called an *occluding* or *obstructing thrombus.*

THE FATE OF THROMBI.—The thrombus in its original situation is called a *primary* or *autochthonous thrombus*, but it is quite a common event for the process to spread until a considerable section of the vascular district is involved—*secondary thrombosis*. As a rule, thrombi grow in length in the direction of the blood stream, but exceptions occur. The advancing end has usually the shape of a flattened blunt cone, and the process extends as far as the next lateral branch. The appearances produced in an advancing thrombus are very striking. The primary thrombus is white or mixed, while the secondary thrombus is red. The secondary thrombus extends along the vessel to the nearest collateral branch, where it comes into contact with the circulating blood, with the result that a white thrombus is formed. This in turn grows until the mouth of the collateral vessel is occluded and a red clot is again formed, and so on almost indefinitely. In this way the circulation may be gravely interfered with over large areas.

Small thrombi may be absorbed and disappear, but the larger ones, provided the patient live, undergo various interesting transformations. Within a very few days of the formation of the thrombus notable changes set in, of which may be mentioned hyaline-granular transformation, organization, simple softening, and puriform liquefaction.

The *hyaline-granular transformation* is marked by the disintegration of the red and white cells. The hæmoglobin is dissolved out, diffuses itself among the fibrin, and is deposited or metamorphosed in various ways. The cells, fibrin, and platelets become finally a granular mass in which the granules become increasingly fine and are eventually fused into a homogeneous, translucent, hyaline-looking material. The chromatin of the leucocytes is liberated, and the thrombus shrinks, becomes more solid, and often assumes a reddish or reddish-brown color. Old thrombi not infrequently become fissured and fragmented, so that fresh reddish clot is deposited in the interstices. In the peripheral portions, too, inflammatory leucocytes and wandering cells from the vasa vasorum may be observed. By this method the thrombus may become so reduced in size that the lumen of the vessel may be reopened and, if these changes occur in an area upon which an operation has recently been performed, secondary hemorrhage may result. As a rule, the thrombus remains firmly attached to the vessel wall, but occasionally it breaks loose and forms an embolus with its ordinary results.

In cases in which the thrombus is bland and not infected it becomes organized into connective tissue. Starting at the place where the clot adheres to the vessel wall a thin layer of endothelium, derived from the lining of the intima of the unaffected parts near by, extends over the surface of the thrombus. Underneath this investment a zone of connective tissue is developed, apparently due to the proliferation of these endothelial cells. The endothelial cells divide and the newly formed cells invade the substance of the thrombus and secrete an intercellular substance. Synchronously with this process the thrombus becomes vascularized from the vasa vasorum and also from the endothelial investment. Fibrous tissue cells are carried in along with the capillaries and form an adventitia to them. The new-formed connective tissue, according to Thoma ("Text-book," vol. i., Eng. trans., p. 285, 1896), is thus a product of the vessel walls. In time the newly formed channels, derived from the endothelial lining on the one hand and the vasa vasorum on the other, meet and vascularization is complete. The portion of the original thrombus between the capillaries is gradually absorbed and the whole mass becomes transformed into a fibrous plug, which undergoes cicatricial contraction. In some cases, as a result of this process, only a few traces are left of the original thrombus in the form of small nodular thickenings of the vessel wall or a few delicate bands traversing the vessel. Not infrequently, however, absorption is not so complete, and new vascular channels are tunnelled through the thrombus. These become lined with endothelium and thus restore more or less completely the integrity of the circulation—the so-called "canalization" of the thrombus.

In *simple softening* the thrombus is converted into a pulpy dirty looking mass. This probably results from the action of unorganized ferments contained in the clot; but it is not always possible in these cases to exclude the action of micro-organisms. Simple liquefactive necrosis is particularly well seen in the case of the "ball thrombi" of the heart cavities, where central softening is occasionally found. Such softening may result in the formation of something like a cyst. The soft material is composed of the degenerated and granular components of the clot, and has a creamy-whitish or grayish-yellow appearance, not unlike pus, whence it has been called by some puriform softening.

Septic softening is usually found in cases of thrombophlebitis, and is a true suppuration of the clot due to the action of pyogenic micro-organisms, among which the streptococcus is a common offender.

Putrid liquefaction is due to the presence of putrefactive germs, and in this case the clot assumes a dirty brown or green color and emits a foul odor. The softening of septic thrombi and the subsequent dissemination of the infected products in the general blood stream is one of the common causes of systemic septicopyæmia.

Many thrombi undergo calcification. This is found commonly in the prostatic plexus, the broad ligaments, and in the spleen, in which localities there are formed small spherical concretions which lie loosely in the vessel. When present in the veins they are called *phleboliths*; when in the arteries, *arteriolitls*.

Localization of Thrombi.—Thrombi may be formed in any part of the vascular or the lymphatic system. Consequently we may conveniently divide them into *cardiac*, *arterial*, *capillary*, *venous*, and *lymphatic thrombi*.

The site of election of thrombosis is in the medium-sized veins where the various anatomical and mechanical peculiarities before referred to, viz., a slow blood current, eddies, and counter-eddies in the stream, obstructions and dilatations, are found in the greatest perfection. Here such questions as the length and obliquity of the venous channels, the presence of valves, the fixation of the vessel walls to fascia, the flow of the blood from a smaller into a larger cavity, play an important rôle. Marantic thrombi are apt to be formed in the veins, particularly of the extremities, and in the large venous sinuses, while those due to infection and angiosclerosis are commonly in the arteries. Numerous exceptions to this generalization, however, might be cited.

Clinically speaking, the most frequent points for the development of thrombi are the vessels of the extremities, especially the lower, the cerebral arteries and sinuses, the portal vein, the inferior vena cava, and occasionally the renal and mesenteric vessels. Many conditions of extensive thrombosis, however, lead to no clinical symptoms, and the presence of thrombi may not even be suspected. Consequently a study of the subject from a post-mortem point of view reveals a somewhat different state of affairs. In this case intracardiac thrombi, and next to these the mesenteric, iliac, and cerebral, are more in evidence.

Leaving out of account post-mortem clots, which are not to be classed with the true thrombi, and cases of acute endocarditis, I have made an analysis of the fatal cases that have occurred at the Royal Victoria Hospital, Montreal, in 688 autopsies of which I have notes. Thrombosis occurred 66 times, or in nearly 10 per cent. of the cases. These were localized as follows: Intracardiac 16, mesenteric 9, aneurismal 8, common iliac veins 7, cerebral arteries 6, inferior vena cava 5, ovarian veins 4, portal 3, splenic vein 3, meningeal, left axillary vein, crural veins, coronary arteries, 2 examples of each; the aorta, pulmonary artery, popliteal vein, brachial vein, pelvic and omental veins, once each. In many cases, however, the thrombi were diffuse or multiple.

We may say in general terms that thrombosis in the arteries is due, in the vast majority of cases, to disease of their walls, usually sclerosis, while that in veins is brought about by inflammation, pressure, or marasmus.

Cardiac Thrombi.—Care should be taken not to confound the soft clots so commonly found at autopsies with true thrombi. These clots are merely coagula identical in origin and structure with the clots that form in blood withdrawn from the body. It is usually taught that they are produced during the death agony, but according to Welch they are more probably formed after death. In diseases, such as lobar pneumonia and acute rheumatism, in which the fibrin content of the blood is high, they are often very abundant, and of a soft gelatinous and often oily appearance.

Intracardiac thrombi are apt to be found in chronic diseases of the heart or its valves, and of the lungs, arteries, and kidneys. The chief factors here are sclerosis of the valves or heart wall, myomalacia, and dilatation of the cavities. Changes in the composition of the blood and the influence of toxins do not play so important a rôle as in the case of the peripheral thromboses. Good examples of intracardiac thromboses, although not usually classed as such, are the vegetations in acute endocarditis. The verrucæ are nothing more nor less than small granulations capped with fibrin, leucocytes, and blood platelets. A very common site for intracardiac thrombi is in the auricular appendages and between the columnæ carneæ, where they may be rather firmly attached. They may also be found upon the surface of the valves. Mural thrombi are usually attached to some area of degeneration of the heart wall, such as is produced by atheroma, infarct, partial aneurisms, and gummata. The commonest form of intracardiac thrombi is the globular, which are usually multiple, and vary in size from that of a pea to an egg; they are sessile or pedunculated. The surface is smooth or again finely lined or ribbed. The interior is frequently converted into a grayish or grayish-brown detritus, or may present puriform softening. The curious rib-like markings found on intracardiac thrombi have attracted the attention of numerous writers, and were referred to by Bristowe as far back as 1855. The appearance has been attributed to wave-like or oscillatory movements in the blood.

A striking and interesting form, to which more than a passing glance should be directed, is the so-called "ball-thrombus." It is found invariably in the left auricle, and in association generally with mitral stenosis. According to Welch a true ball-thrombus presents the following characteristics: (1) Entire absence of attachment, and consequently free mobility. (2) Imprisonment within the cavity in which it is found. (3) Such consistence and shape that the thrombus must not of necessity lodge as an embolus in the ostium just ahead of it. Ball-thrombi vary in size from that of a walnut to a hen's egg and are usually spherical or ovoid in shape. They commonly show central softening, but organization has never been proved to occur. With regard to the clinical effects of such a condition, Wickham Legg has expressed the view (Trans. Path. Soc. Lond., 1878, xxix.) that "a loose thrombus in the left auricle would at any time be ready to act as a ball valve and stop the circulation in the mitral orifice." Contrary to what one would expect this is distinctly a rare event, although it has occurred, as in a case reported by Welch from Osler's clinic. Besides ball-thrombi pedunculated polyps of the heart wall have been described. Some of these are only organized or partially organized thrombi, while others resemble not a little fibromata and myxomata. Some, according to Bostroem, are thrombosed varices or local areas of hemorrhage. Ewart and Rolleston have recorded a case in which a pedunculated thrombus, arising from the fossa ovalis, passed through the mitral orifice and gave rise to the clinical signs of stenosis (Clinical Soc. Trans., vol. xxx.).

Arterial Thrombi.—Here the common causes are disease of the vessel wall or the lodgment of an embolus. Thus sclerosis of the vessel, particularly if associated with a solution of the continuity of the intima, frequently gives rise to the condition. Proliferating endarteritis, as von Manteuffel has shown, is often accompanied by an organizing thrombosis that in time leads to complete occlusion of the vessel.

The most frequent site for arterial thrombosis is, in my experience, in the arteries of the brain; but it is also often met with in the lower extremities, the coronary arteries, the mesenterics, and the aorta and its main branches. Arterial thrombi are to blame for a certain proportion of the cases of gangrene of the extremities. Apart from arteriosclerosis cases of arterial thrombosis are undoubtedly to be referred to inflammation of the vessel walls, a true arteritis. Probably of this nature are the cases sometimes met with in infective diseases like typhoid, typhus, scarlatina, pneumonia, endocarditis, septicæmia, smallpox, and tuberculosis. Nevertheless, it must be admitted that primary arterial thrombosis is to be met with in certain infective, cachectic, and anæmic states in the absence of gross disease of the vessel walls. It is, moreover, not always easy to exclude the possibility that some at least of the cases regarded as primary thrombosis are secondary to a previously occurring embolism.

Thrombosis of the pulmonary artery is believed by Welch not to be particularly uncommon, although cases of obstruction of this vessel have almost invariably been attributed to embolism. It is not unlikely that embolism of the smaller branches at least may be further complicated by thrombosis.

Of more importance is thrombosis of the coronaries of the heart, which is a condition that should be looked for in all cases of sudden death. It is usually due to sclerosis of the vessel or to atheroma of the aorta, aortitis, or to vegetations on the aortic valves; in fact, to any affection that causes obstruction in the vessel. The smaller branches of the coronary arteries are terminal or end arteries, and occlusion of these leads to marked changes in the heart wall, of the nature of infarction or coagulation necrosis. For this condition the term "myomalacia cordis" has been proposed by Ziegler. Provided the patient live long enough, reactive inflammation sets in, the patch softens, and there may be produced a local aneurism of the heart wall, an abscess or even rupture. It is common to find a thrombus on the endocardium of the affected region and sometimes also pericarditis. In some cases healing takes place with the formation of a fibrous scar.

The anastomoses between the main trunks of the coronaries are, however, more complete than has been usually taught, although in fact they are not always sufficient to restore the circulation where it has been suddenly interfered with. I have met with a case in which the orifice of the anterior coronary was completely occluded by sclerosis without the usual consequences of the condition, owing to a free communication with the posterior vessel at the apex of the heart.

Capillary Thrombi.—These are commonly of the fibrinous or hyaline variety, and are as a rule associated with necrosis or gangrene of the tissues. They are met with in the lungs in pneumonia and in hemorrhagic infarcts. In systemic toxæmia and infection they are to be found in the kidneys, the liver, and the lungs, and have also been described in the liver in cases of eclampsia, where they give rise to ischæmic infarcts and necrosis. They have also been described in connection with frost-bite and ergotism.

Venous Thrombi.—The most common site for thrombosis is in the veins. This is accounted for largely on the ground of certain anatomical and functional peculiarities. Chief among these may be mentioned the low blood pressure, the slow stream, the increased carbonic-acid content of the blood, and the presence of valves. While, as has been pointed out by Lancereaux, thrombosis is more liable to occur at regions where there is stasis of blood, this is not in all cases an entirely satisfactory explanation. It is more likely that von Recklinghausen's opinion, before referred to, is correct, viz., that a main factor is eddies in the blood (*Wirbelbewegungen*). These are specially liable to occur where the blood passes out from a small channel into a relatively larger one. In many cases local conditions play a part, as phlebitis, phlebosclerosis, varix, trauma, and compression.

In general, it may be said that venous thrombosis due to sepsis begins in the finer radicles, being produced in the first instance by a local inflammatory infiltration, while the so-called marantic thrombi are more common in the sinuses and medium sized veins. An important feature in this connection is, that once they start, throm bi tend to spread centripetally into the larger vessels. Thus, with the few exceptions due to pressure, thrombosis of the portal vein and the inferior vena cava is brought about by extension from the mesenteric and iliac veins. Local thrombosis in such large vessels as the portal vein and inferior cava is as a rule due to the pressure of enlarged glands or new growths. Two cases of this kind, occurring in my series, were due, the one to a secondary retroperitoneal carcinoma, the other to a new growth in the diaphragm compressing the vessel just outside the heart. One interesting case of local portal thrombophlebitis was due to the presence of an abscess at the hilus of the liver originating in a septic cholecystitis. It is by no means unknown, however, for a thrombus to propagate itself in a peripheral direction in opposition to the blood stream. An example of this was seen in one of my series where a thrombophlebitis of the mesenteric and portal veins extended into the splenic. In view of this fact it is not always easy to determine the exact spot at which a thrombus originated. Careful study of the appearance of the thrombus will, however, in some cases reveal the truth. Thus, the autochthonous portion of the thrombus is firmer, often granular, and adherent, of grayish or grayish-red color, while the propagated thrombus is soft, red, and somewhat loosely attached. A curious fact also is that an occluding thrombus may cause such disturbance of the blood stream that multiple discontinuous coagula are found in the neighborhood of the original one, or these may be connected by red or mixed thrombi. In some few cases also, as shown by my series, multiple primary thrombi may be produced in parts of the venous system utterly remote one from the other, and having no anatomical or functional relationship. In such cases we must assume that there is a systemic disturbance at the back of the condition.

Common sites for primary venous thrombi are in the mesenteric, crural, prostatic, and ovarian veins.

Thrombosis of the mesenteric veins is practically always due to some inflammatory lesion of the intestines, such as appendicitis or colitis and is really a thrombophlebitis. In some few cases it has been due to cachexia or marasmus, and without lesion of the intestine. Curiously enough it is distinctly rare in typhoid fever, which seems to have a predilection for the crural veins, although it has occasionally been met with.

The majority of cases are associated with perforative appendicitis, and here it is the superior mesenteric vessel that is first and chiefly affected, a fact that is readily explained by the position of this vessel which leads directly from the ileo-cæcal angle. The complication is important as it frequently leads to necroses and abscesses in the liver. In such cases the portal vein, although not invariably, is thrombosed as well. The converse has occasionally been observed, viz., that a portal thrombosis has extended into the mesenteric vessels.

Thrombosis of the crural veins, involving not infrequently the iliacs as well, is encountered in tuberculosis, carcinoma, the various cachexias, but more especially in phlebitis of the puerperium, chlorosis, typhoid, and other infective diseases. Many of the cases are associated with marasmus, but it is hard to exclude a local infective cause. The affection is more common on the left side, owing, as has been supposed, to the greater length and obliquity of the left common iliac vein and its passage under the right common iliac artery. As is well known, the condition is not uncommon in typhoid fever during the later stages. There has come under my notice a curious instance where a man had suffered from an attack of typhoid some fifteen or twenty years previously, and had experienced, during this attack, a swelling of the left leg. He contracted a second attack of fever, from which he died, and in this attack, there was again evidence of thrombosis in the same limb. At autopsy there was found a canalized fibrous cord in the crural vein representing the former lesion, while the vessel was completely obstructed by a recent clot which had formed just above the old thrombus.

Portal thrombosis is commonly secondary to thrombosis of the mesenteric or splenic veins. When primary, it is usually due to pressure, as from cirrhosis, syphilis, tumors of the liver, enlarged glands, gall stones, abscesses, chronic peritonitis, or disease of the vessel walls.

Thrombosis of the splenic vein may be brought about by infarcts or abscesses within the organ or by the extension of morbid processes from the pancreas. It is one of the rarest complications of typhoid fever (Köster).

Thrombosis of the inferior vena cava is occasionally met with. When autochthonous it is commonly due to the pressure of a new growth. Three instances have come under my notice at autopsy. In two it was to be attributed to the pressure of a secondary retroperitoneal carcinoma, and in one of these it was propagated from the iliacs. In the third there was a tumor, the size of an orange, in the diaphragm that led to occlusion of the vessel just before it entered the heart.

Thrombosis of the renal veins is rather common in children with cerebral disease or marasmus, but is also met with in adults in chronic nephritis and in malignant growths of the kidney.

Thrombosis of the superior vena cava has been observed a number of times. It is nearly always due to the pressure of mediastinal tumors, aneurisms, or enlarged glands.

Thrombosis of the innominate, subclavian, and jugular veins is usually due to pressure, to cardiac disease, and rarely to infection, empyema, acute rheumatism, tuberculosis, traumatism, and marasmus

Thrombophlebitis of the veins of the broad ligaments is common in septic endometritis. It must in many cases be a rather mild affection and often recovered from, at least if the presence of phleboliths in this situation is any proof.

Thrombosis of the pulmonary veins is secondary to some affection of the lung, such as tuberculosis, abscess, gangrene, tumors, infarction, and pneumonia. It may on occasion lead to embolism in the arterial system.

A rare form of thrombosis, and one chiefly of pathological interest, is that occurring in the adrenal vein, as in a case recently recorded by Woolley from the Montreal General Hospital (*Jour. Med. Res.*, March, 1902, p. 231). It was found in a child of eleven months that had suffered from measles, and led to infarction of the organ.

The Results of Thrombosis.—The morbid changes and symptoms produced by thrombosis are attributable, in the first place, to the obstruction of the circulation due to the clot, and, secondly, to the special character of that clot and the condition of the vessel wall. Much depends upon the position of the occluding plug, the rapidity and extent of the obstruction, the formation and the effectiveness of the collateral circulation, the nature of the thrombus, and the local and systemic peculiarities. Obstruction of arteries, particularly when of the terminal variety, is more likely to be followed by marked results than is obstruction of veins, where the anastomoses are as a rule much more abundant. If the collateral circulation be quickly established, no pathological or clinical effects are produced and *restitutio ad integrum* may be complete. When the condition sets in gradually, the symptoms are slow in developing, but frequently increase in intensity. In parts unfavorably constituted the symptoms are acute and the results serious. Obstruction of arteries leads often to necrosis and softening; that of veins to congestion and œdema, followed also, it may be, by gangrene or necrosis. Should infective micro-organisms be present, a local abscess, or even systemic infection, may occur.

With regard to the clinical signs, everything depends on the localization of the thrombus. Should it occur in some vital organ, like the heart, death may occur immediately or very soon. Should it affect important districts, like the cerebral cortex or internal capsule, peripheral palsies result that direct the attention to the position of the lesion. Or, again, localized œdema or the dilatation of superficial vessels will suggest its presence. While it is true that many thromboses occur in what may be called "blind" regions, those of important vessels, such as the cerebral arteries and sinuses, the crural veins, the portal vein, and the inferior vena cava give rise to fairly characteristic signs which render them amenable to ordinary methods of diagnosis. The effects differ considerably according to the part of the circulatory system involved.

The presence of intracardiac thrombi may at times perhaps be suspected, but can rarely if ever be diagnosed with certainty. Except for providing emboli, the globular thrombi can hardly produce any definite symptoms. The presence of thrombi in or near the various ostia of the heart may occasion murmurs and thrills identical with those resulting from valvular disease. Unless, however, the orifices are encroached upon, few or no symptoms are produced that will suggest the presence of thrombi. Even in the case of "ball thrombi" the signs are indistinguishable from those of mitral stenosis, and sudden death is rare, contrary to what one would expect.

The clinical manifestations of arterial thrombosis are in many cases indistinguishable from those of embolism. Where the circulation is cut off slowly a collateral anastomosis may be established, even in the cases of the main trunks like the femorals, iliacs, and aorta, and the results may be trivial. Should, however, the occlusion be brought about suddenly, as not infrequently happens, particularly in the case of organs like the brain, spleen, and kidneys, where many of the arteries are "terminal" or end arteries, the consequences may be serious. Furthermore, the possibility of a collateral circulation being established depends largely upon the condition of the vessel walls and the vigor of the systemic circulation. The differential diagnosis between arterial thrombosis and embolism is beset with difficulties. The most important points are the sudden onset in embolism and some condition of the heart or vessels which could give rise to embolism. Mistakes, however, readily occur.

In the case of thrombosis of the arteries of an extremity, as for instance the leg, the first symptom is pain, which is often agonizing and paroxysmal. The limb becomes pale, cold, mottled with livid patches, numb, and paretic. Tactile sensibility is lost, although there may be increased susceptibility to painful impressions. The limb becomes œdematous and the skin moist. Should the collateral circulation not be established gangrene sets in, usually of the dry variety, unless the veins also become blocked or the limb become infected. This form is often due to arteriosclerosis and is met with in diabetes.

Charcot's syndrome, "intermittent claudication," has been observed in cases of thrombosis of the femoral and iliac arteries, and the abdominal aorta. It is more common, however, in simple arteriosclerosis. In this condition the lower extremities during rest receive enough blood for their needs, but not during active exercise. Consequently after exercise some muscular weakness and numbness of the limb may be observed, and in the severer cases the symptoms are very pronounced, with the addition of pain and cramps in the leg, which becomes cold, pallid, and sometimes cyanosed. After a short rest the symptoms disappear, only to reappear on occasion.

Thrombosis of the pulmonary artery may be entirely latent, or again may cause rapid or immediate death. In some cases the affection is subacute or chronic, and is characterized by dyspnœa, cyanosis, incompetency of the heart, and hæmoptysis.

Thrombosis of the coronary arteries of the heart is not uncommon, and is a more frequent cause of infarction of the heart than is embolism. Sudden death may result, but, when the patient lives, symptoms practically identical with those of fibroid degeneration of the myocardium may be produced. These are a slow irregular pulse, dyspnœa, precordial distress, and anginal attacks.

Thrombosis of the cerebral arteries leads to ischæmic softening with all its consequences—loss of consciousness, hemiplegia, mental degradation, and the like.

Capillary thrombosis, owing to the free anastomotic communications, does not give rise to symptoms unless large areas are involved. Necrosis is the common result but it is probably more usual for this to be a cause of thrombosis than the reverse. The association of these thromboses with burns, frost-bite, ergotism, and various infections has been before referred to. Welch has observed the condition in the bases of gastric ulcers.

The most frequent examples of thrombosis are afforded by the venous system, for reasons that have already been sufficiently entered into. The venous anastomoses are, however, so abundant in most parts of the body that the most extensive vascular occlusion may occur without the production of serious consequences. Much depends on the localization of the clot and the rapidity of its formation. The varying and often apparently contradictory results produced by venous thrombosis are to be explained, however, not entirely on these grounds, but by a reference to other factors, such as anæmia, cachexia, and infection. Phlebosclerosis and phlebitis also play a part. As we meet it in, say, the extremities, the most constant and characteristic symptom of venous obstruction is œdema, sometimes (although by no means invariably) combined with hemorrhage. In the case of the cerebral, splenic, and mesenteric veins necrosis may occur. This event is excessively rare in the case of the extremities. In addition to the mechanical effects should be mentioned inflammation, which is often secondary to the thrombotic process, or indeed may be the cause of it, as in the case of phlebitis. This often leads to active hyperæmia, pain, and constitutional disturbance.

The most familiar example of venous thrombosis is that which occurs in the extremities, usually the lower. The affection may be unsuspected or give rise only to trifling signs, such as slight œdema of the limb. In other cases there may be pain as well, sometimes with a little fever (phlegmasia alba dolens), or again there may be chills and high fever with even evidences of septicopyæmia. Some observers (Mahler, Wyder, and Singer) have called attention to the increased rapidity of the pulse, which may even be present before actual thrombosis takes place, and may persist after the temperature has fallen. In a typical case the affected limb is swollen, there is more or less pain, usually more severe in the groin, the inside of the thigh, the popliteal space, and the calf. There may be sensations of numbness or tingling. The limb becomes swollen and firm, the skin is tense and white, often showing distended veins, and the tissues are hard and elastic. In other cases the skin is livid and congested. More or less phlebitis commonly results. The great danger of thrombosis of the veins of the lower extremities is in detachment of the clot and fatal pulmonary embolism. This is by no means an infrequent termination. It is perhaps more common in puerperal and septic cases. In cases that recover the limb may remain swollen for many months. Necrosis of the part only exceptionally occurs, and is due probably to some arterial complication. Pain and other nervous phenomena in some cases have led to the recognition of a neuralgic type of the affection (Graves, Trousseau, and Quenu). A mild peripheral neuritis has also been observed. Rare sequels of crural thrombosis are varicose veins, ulcers, elephantiasis, hypertrophy or atrophy of muscle, and club-foot.

Unless due to some continually acting cause, such as an intrathoracic tumor or aneurism, thrombosis of the arms is a less severe affection than that of the lower extremities.

Thrombosis of the inferior vena cava is an affection of some importance, and is in my experience frequently overlooked. It may occur without any special symptoms, but when present they are usually characteristic. In the cases that I have seen the thrombosis frequently began in one leg and was followed by thrombosis of the other. Later, there was more or less abdominal pain with extension of the œdema to the abdominal and lower thoracic wall. In one case the œdema was extreme, and curiously localized to that part of the body which is below the breasts, at which level the line of demarcation was sharply defined. The most important sign, however, is the presence of distended veins in the abdominal and lower thoracic walls. The veins are sometimes tortuous and varicose, and may reach the size of the little finger. The anastomosis is performed by the superior and inferior superficial epigastric, the long thoracic, the superficial circumflex iliac, the external pudic, the lumbo-vertebral anastomotic trunk of Braune, and various other veins. There is also communication through the visceral veins and the azygos. When the anastomosis is chiefly through the deep vessels to the exclusion of the superficial ones, the diagnosis becomes much more difficult, if not indeed impossible. Should occlusion of the renal veins occur as well, hæmaturia and albuminuria may be present, yet these are more often absent than present. The diagnosis is rendered still more probable when one is able to determine the presence of retroperitoneal new growths in the upper part of the abdomen or of tumors at the hilus of the liver. Schlesinger (*Deutsche med. Woch.*, S 460, 1896) has pointed out that in a few cases the obstruction is in one leg only. This may be due to the existence of a collateral circulation on one side due to a former iliac thrombosis; to complete occlusion of the iliac on one side with a parietal thrombosis of the inferior cava; or to congenital duplication of the cava.

Thrombosis of the portal vein is perhaps more commonly of the septic variety (portal pylephlebitis). This is one of the common accompaniments of abscesses of the liver. The affection as a rule extends from the mesenteric vessels and is not uncommon in appendicitis. Simple portal thrombosis when it develops gradually is hardly to be diagnosed. When present the symptoms are those of portal obstruction, viz., ascites, hæmatemesis, enlargement of the spleen, dilatation of the superficial abdominal veins, and progressive emaciation. The symptoms may, however, be far from characteristic, or indeed may be absent. In general, however, the acute onset, the intensity of the portal obstruction, and particularly the quick return of the ascites after tapping are very suggestive. These points are of all the more importance when the signs develop in a hitherto healthy person or in the course of some affection not ordinarily associated with portal obstruction.

Thrombosis of the mesenteric veins is usually due to ulceration or other inflammatory lesion of the intestines. It is rather common in appendicitis. As a rule the superior mesenteric vein is first and chiefly affected. The condition is frequently a thrombophlebitis. There may be no symptoms, but generally there are intense abdominal pain, tympanites, vomiting, sometimes bloody, melæna, and collapse.

Thrombosis of the renal veins is comparatively common, especially in children with marasmus. It may extend from the vena cava, but may be primary. Contrary to what one would expect, hæmaturia and albuminuria are rather more often absent than not.

Thrombosis of the splenic vein is rare. It is usually associated with abscess or infarction of the spleen, or disease of the pancreas. In some cases the process spreads in a retrograde manner from the mesenteric and portal veins, as in one of my cases. Welch has met it also in calcification of the splenic vein, and Köster in typhoid. Infarction and necrosis of the organ may result, as in a case arising from torsion of the pedicle, described by Osler.

Obliteration of the superior vena cava is excessively rare as an autochthonous condition. Generally it is due to the pressure of a mediastinal growth enlarged glands, or an aneurism The symptoms, when characterisitic, are cyanosis and œdema of the face, arms, neck, and thorax, and dilatation of the veins over the anterior aspect of the thorax and upper part of the abdomen.

Thrombosis of the pulmonary veins is usually secondary to lesions of the lungs, such as gangrene, tumors, abscess, emphysema, pneumonia, and tuberculosis. It may rarely give rise to emboli in the general arterial system

Thrombosis of the innominate, subclavian, and jugular veins is met with in connection with cardiac disease and compression. Occasionally it is seen in acute rheumatism, tuberculosis, empyema, traumatism, marasmus, and infection. Thrombosis of the jugular frequently originates in thrombosis of the lateral sinus in cases of mastoid suppuration, and may give rise to general infection. The symptoms in the various forms are analogous to those already described.

TREATMENT.—Cases must be treated on their merits. Marasmus, enfeebled circulation, and infection being the important etiological factors, one should endeavor to promote nutrition, to strengthen the heart, and to prevent complicating infection. In the last event, should the focus of infection be accessible, it should be treated on surgical principles. We are, however, unable to control the process of thrombosis directly, so that our further efforts should be directed to assisting the establishment of collateral circulation, in order to minimize the effects of congestion and to prevent gangrene. These measures are, however, only applicable to the affection when it involves the extremities. In the case of venous thrombosis of the lower extremities the *utmost care must be taken to avoid detaching the clot*, on account of the imminent risk to life from pulmonary embolism. Here "masterly inactivity" is the watchword. Absolute rest must be enjoined, suitable diet prescribed, and the limb fixed in a proper position. In the case of the lower extremity the patient should lie on the back, with the limb on an inclined plane. The limb should be wrapped in cotton-wool. If pain be severe, applications of lead and opium should be employed or morphine be given internally. All manipulation and even palpation of the limb should be strictly avoided. Massage is absolutely contraindicated. I have known death to result from this irrational procedure. To insure fixation of the limb plaster of Paris may be applied to the hip. The patient should be confined to bed in an average case for at least six weeks. The danger can hardly be said to be past, however, for two weeks longer. During convalescence gentle bandaging should be adopted or a long stocking worn.

Should gangrene result, the case must be treated on ordinary surgical principles. *Albert George Nicholls.*

THRUSH. See *Mouth, Diseases of*, in THE APPENDIX.

THYMACETIN.—An analgesic, prepared and named by Hoffman, of Leipsic, and brought to the notice of the profession in 1892 at a meeting of the Berlin Association for Psychiatria and Nervous Diseases, by Prof. F. Jolly (*Cent. f. die gesam. Ther.*, February, 1892). It is closely allied to phenacetin, bearing the same relation to thymol that the older drug does to phenol. It occurs as a white crystalline powder, only slightly soluble in water. Professor Jolly described the results of a series of experiments upon animals, with this drug, and its use in a number of cases of nervous and mental diseases. He did not find that it had any antipyretic action, but its analgesic and hypnotic properties were undoubted. He found it of most service in headaches and pain of a purely nervous character, but when there was any organic disease it failed to produce any beneficial effects. He considered its action equal to that of phenacetin. As an hypnotic it was administered with success. The dose ranged from three and three-quarters to fifteen grains. No toxic action was noticed, but it produced an acceleration of the pulse and a complaint, in some cases, of a fulness, beating, and noises in the head. *Beaumont Small.*

THYME or **GARDEN THYME.**—(*Herba Thymi*, P. G.; *Thym*, Cod. Med.). The dried herb of *Thymus vulgaris* L. (fam. *Labiatæ*).

The common garden thyme is a low, slender, more or less hairy, much-branched shrub, a foot or less high, with brown, nearly cylindrical branches, minute, opposite, narrowly oval or lanceolate leaves, and blunt, interrupted, spike-like clusters of violet-colored flowers terminating the branches. Flowers small. Calyx and corolla both labiate. Stamens four, sometimes short and equal, at other times long, exserted, and in pairs. It is a native of Southern Europe, but cultivated there and elsewhere for centuries.

Thyme has but little history as a medicine, being mostly used as a condiment and flavor for soups, etc. It has, however, far more important medicinal properties than others of its class. Since these are almost wholly due to the volatile oil and its contained thymol, they are considered below in connection with those substances. It contains about two and a half per cent. of volatile oil, with a small amount of tannin and other unimportant constituents. The dose of thyme is 2–4 gm. (gr. xxx.–lx.).

FIG. 4710.—Thymus Vulgaris. Flowering branch, about half natural size. (Baillon.)

Oil of Thyme (*Oleum Thymi*, U. S. P.) is thus described by the Pharmacopœia.

"A yellowish or yellowish-red liquid, having a strong odor of thyme, and an aromatic, pungent, afterward cooling taste. It becomes darker and thicker by age and exposure to the air.

"Specific gravity: 0.900 to 0.930 at 15° C. (59° F.).

"It does not fulminate with iodine.

"The oil is soluble in half its volume of alcohol, forming a clear solution which is neutral or only very slightly acid to litmus paper. The oil is also soluble, in all proportions, in carbon disulphide, and in glacial acetic acid.

"With a drop of ferric chloride T.S. the oil yields a greenish-brownish color, which changes to reddish.

"If 1 c.c. of the oil be shaken with 10 c.c. of hot water, and, after cooling, the liquid be passed through a wet filter, the filtrate should not assume, with a drop of ferric chloride T.S., a bluish or violet color (absence of *carbolic acid*)."

The oil thus described is what is known commercially as the *brown* or *red oil*, besides which there is a *white oil*. The latter was formerly described by the Pharmacopœia, but is, as a matter of fact, medicinally inferior to the former, though it is preferred for those purposes in which absence of color is an object. The commercial oil varies most widely in its characteristics, even when genuine, and the official description should be carefully observed. Although oil of thyme is of complex composition, its properties are essentially those of its thymol, of which the amount should be from twenty to twenty-five per cent. Occasionally a larger or smaller part of this is naturally substituted by carvacrol. *Cymene* and *thymene* are also present. The dose of the oil is one to five, or even ten minims.

Thymol ($C_{10}H_{14}O$) is also official, and is defined as "a phenol occurring in the volatile oils of *Thymus vulgaris* L., *Monarda punctata* L., and *Carum Ajowan* (Roxb.) B. et H., and is thus described:

"Large, colorless, translucent crystals of the hexagonal system, having an aromatic, thyme-like odor, and a pungent, aromatic taste, with a very slight caustic effect upon the lips.

"Its specific gravity, as a solid, is 1.069 at 15° C. (59° F.), but when liquefied by fusion it is lighter than water. It melts at 50° to 51° C. (122° to 123.8° F.), remaining liquid at considerably lower temperatures. When triturated with about equal quantities of camphor, menthol, or chloral, it liquefies.

"Soluble in about 1,200 parts of water at 15° C. (59° F.), and in less than its own weight of alcohol, ether, or chloroform; also readily soluble in carbon disulphide, glacial acetic acid, and in fixed or volatile oils.

"Its alcoholic solution is optically inactive.

"If a very small crystal of thymol be dissolved in 1 c.c. of glacial acetic acid, and then six drops of sulphuric acid and one drop of nitric acid be added, the liquid will assume a deep bluish-green color.

"If 1 gm. of thymol be heated in a test tube, in a water-bath, with 5 c.c. of a ten per cent. solution of sodium hydrate, a clear, colorless, or very slightly reddish solution should be formed, which becomes darker on standing, but without the separation of oily drops (absence of *thymene*, or lævogyrate *pinene*, $C_{10}H_{16}$). If to this solution a few drops of chloroform be added, and the mixture agitated, a violet color will be produced.

"When a crystal of thymol is heated in an open capsule, or in a watch glass, on a water bath, it should gradually volatilize, leaving no residue (absence of *paraffin*, *spermaceti*, etc.)."

Thymol, besides its important properties as a carminative and intestinal and general stimulant, shared by the volatile oils of the *Labiatæ* in general, is one of the most useful antiseptics which we possess. It is of the greatest service both for its application to the outer surface of the body and to all mucous surfaces, and especially in purulent and other septic catarrhal disorders, and as an intestinal disinfectant. Its value for the latter use depends upon the energy and permanence of its effects, it being superior in these respects to carbolic acid, yet possessed of but very slight poisonous properties, large doses being required for the production of poisonous effects. It is the principal active constituent of "listerine," with which the *Liquor Thymoli Compositus*, or *Antiseptic Solution*, is practically identical. The dose of thymol is one to five grains. An ointment of thymol, strength five per cent., is frequently of great value in relieving itching.

Henry H. Rusby.

THYME, WILD, or *Serpyllum*, is the herb *Thymus Serpyllum* L., native of the Old World and sparingly naturalized in the United States. The stems are much more slender even than those of garden thyme, partly prostrate, and usually reddish and pubescent. The leaves are shortly petioled, opposite, scarcely one-fourth of an inch in length, and about half as broad, ovate, the flowers small, pale, and darker-spotted. Its odor and taste are similar to those of garden thyme, and it contains a volatile oil practically identical with that of oil of thyme, with which its properties agree.

Henry H. Rusby.

THYMOFORM is a yellowish, tasteless powder composed of formaldehyde and thymol and smelling feebly of the latter. It is insoluble in water, mineral oils, or glycerin, but dissolves in alcohol, ether, chloroform, and olive oil. It is an antiseptic dusting powder.

W. A. Bastedo.

THYMOL CARBONATE AND THYMOL-URETHANE. See *Thymotal*.

THYMOL CHLOR-METHYL-SALICYLATE is a white crystalline powder which is insoluble in water, but is soluble in alcohol, ether, acetic ether, and in dilute solutions of the alkalies. It is used as an antiseptic.

W. A. Bastedo.

THYMOTAL.—Tyratol, thymol carbonate—is prepared by passing phosgene gas ($COCl_2$) through a twenty-per-cent. solution of sodium hydroxide in which thymol is dissolved. It is a white, nearly tasteless crystalline body with a faint thymol odor. It passes through the stomach unchanged, but probably splits up in the intestine. It is employed as an anthelmintic in dose of 0.5–1 gm. (gr. viij.–xv.) for children, and 2 gm. (gr. xxx.) for adults.

Pool, of Dutch Guiana, says it is better than thymol for the anchylostomum duodenale.

Thymol urethane has a similar use and dosage.

W. A. Bastedo.

THYMUS.—INTRODUCTION.—The thymus gland (also known in English as the thymus, or popularly as the neck or throat "sweetbread"; in German as the Thymus, Thymusdrüse, Brustdrüse, Bries or Briesel; in French as thymus) enjoys the unique distinction not only of being a transitory organ of extra-uterine life in man, but also of existing in three or possibly four distinct and different morphological conditions during its life history.

COMPARATIVE ANATOMY.—This organ is not, however, peculiar to man, being present in all vertebrata, including the lampreys (cyclostomata) in which its existence was considered doubtful until recently. Its development does not proceed so far in some of the lower vertebrate animals as in mammals, being often arrested at the epithelial stage as seen in certain fishes where, during life, the thymus is an epithelioid organ, or rather an epithelial, mucus-secreting gland. In other fishes, in reptiles, and in birds it usually attains the condition of a lymphadenoid structure and persists through life, though it may undergo retrograde metamorphoses. In mammals the thymus passes through certain changes leading to its complete transformation into indifferent tissue before adult life is attained, but to this rule there are many exceptions, as one may discover by careful dissection of such animals as the rabbit, guinea-pig, dog, cat, cow, and horse. It is by no means uncommon to find large, well-developed thymus glands apparently quite like the "sweetbread" of the calf or lamb among adult animals of the varieties mentioned. This is the case in man, as we shall see later.

EMBRYOLOGY.—Until comparatively recent years the embryology of the thymus was obscure; but the observations of Renaut, Kölliker, Stieda, Born, Rabl, and Mall have pretty thoroughly established the developmental history of the organ. The generally accepted idea now is that in the higher orders, and probably in all vertebrata, the thymus develops as a paired organ from the third pair of gill clefts, and according to most authorities from the endodermal lining of these clefts, though His first held that the ectoderm furnished the component cells of the thymus anlage, and Kastschenko maintained that both ecto- and endodermal cells participated in forming the primary organ. The anlage of the thymus is a pouch of endoderm forming in the third gill cleft, and in a human embryo of the fifth week His found this pouch open. Originally the thymic pouch communicates with the fore gut or pharynx, but this connection is soon lost and the elongated sac with thickening epithelial walls, first lying transversely across the future neck, becomes free from its moorings to the gill clefts and shifts toward the tail, the larger dorsal end becoming the future head of the organ. The lumen of this cylindrical sac remains open, how long is still unsettled, though the twelfth week in man is the period usually assigned, after which the anlage becomes a solid cord of cells with numerous buds. Thus in its first appearance this organ is similar to a secreting tubular or acinous gland. A shifting of the endodermic anlage continues in the direction of the future thoracic cavity along the vagi and carotid arteries, reaching almost to the heart, finally making the lobes into which the fully formed organ is divided.

But the anlage does not long enjoy a strictly endodermal structure, for blood vessels push in from the mesoderm and soon after round cells, presumably also of mesodermic origin, insinuate themselves into the epithelial cords, while others gather about to form investing masses which soon predominate. As we shall see later, these mesodermic cells form the larger bulk of the fully developed thymus, which, even in the fœtus, attains great size.

The preceding account represents the most widely accepted views relative to the origin of the thymus in man, though such points as the possible participation of other (the fourth) gill clefts and of the ectoderm should be mentioned. In vertebrates below mammals variations are seen, the second gill cleft in the frog, the first four in fishes, and the second, third, and fourth being at times called upon. The questions as to the time of closure of the lumens of the tubules in the anlage and the relation of these tubules to the corpuscles of Hassall (*vide infra*) are still under discussion.

It is at least worthy of passing notice that some similarity exists in the development of the thymus and several organs in its immediate neighborhood, like the tonsils, thyroid, and parathyroids, though the full details regarding their embryology have not been established.

ANATOMY.—The fully formed human thymus makes an organ of considerable size lying in the anterior mediastinum at or near the median line. It generally consists of two broad and flat lobes more or less closely united with vascular connective tissue, and enveloped by a continuous sheath of fascia partly from the deep fascia of the neck and in part a reflection of the cephalic portion of the pericardial sac. As this smooth capsule is stripped from the organ several layers of loose areolar tissue come into evidence, the deeper ones of which send offshoots into the substance of the gland. The cephalic extensions of the thymus bring it almost in touch with the lateral lobes of the thyroid, to which it is united by a cord-like mass of dense connective tissue containing branches of the inferior thyroid artery and some veins. Downward, the thymic lobes reach well upon the pericardium, a distance of two or three finger-breadths, and to the interval between the second and fourth ribs. Its ventral surface is separated from the manubrium sterni by loose areolar tissue. Dorsally, its thoracic portion lies in relation to the arch of the aorta, the aortic branches, and the left innominate vein. The body and edge of the right lobe adjoin the innominate artery, superior vena cava, and right phrenic nerve; while the left lobe comes close to the common carotid artery and left phrenic nerve. Both vagi and the recurrent laryngeal nerves lie well behind the lobes of the thymus, and this is the case with the carotids in the cervical region. Here, also, the continuation of the organ brings it to lie beneath the origin of the sterno-hyoid and sterno-thyroid muscles, and in front of the trachea, everywhere more or less separated by loose connective tissue and fat. Thus it is seen that the thymus lies partly in the neck and partly in the chest, its thoracic portion being the expanded leaflets or lobes, its cervical portion consisting of the narrow finger-like extensions of these lobes. The organ might aptly be compared to two small, rather thin hands in the index attitude, the two fingers lying closely together and pointing upward. As a whole the organ is loosely held in position; it can be easily moved sidewise and lifted somewhat, and, after severing its thyroid connections, it shortens and sinks into the chest.

The blood supply of the organ is derived principally from the mediastinal branches of the internal mammary artery, and from the inferior thyroid. Its dorsal surface, applied to the pericardium, is penetrated by minute branches of the pericardial arteries. All its arteries are comparatively small, thus differing from those feeding the thyroid. On the contrary, the thymic veins are large, making a stem 3 mm. in diameter lying between the lobes and terminating in the left vena innominata (Dwornitschenko).

The lymphatics are numerous and large. They enter the glands of the anterior mediastinum and, according to Astley Cooper, two large vessels proceed, one from each lateral lobe, to open by one or more orifices into the internal jugular vein (Quain's "Elements of Anatomy," tenth edition, vol. ii., pt. ii., p. 556).

When fully exposed by dissection the thymus, in the height of its development, is a soft, smooth, pinkish, or pinkish-gray, bilobed, flattened organ, slightly concave dorsally where it lies against the heart's sac, widest below and tapering above. Because of the penetration of connective-tissue bands into its substance it is mapped out into distinct lobules and sublobules, giving it the "sweetbread"-like appearance, not unlike that shown by the pancreas or the salivary glands. Within the lobules it is often possible to make out distinct rounded or polygonal follicles. A milky juice has been described by the older anatomists as coming from the cut organ especially in young children, or in adults in whom the organ was persistent and enlarged, and this circumstance has recently been alluded to as possibly of pathological significance. Probably, however, this condition is the result of a post-mortem softening; one of the artifacts to which the organ is prone. Of the same nature is the central canal with its lateral branches, or the "central cavity" so persistently mentioned in descriptions of the human thymus even in some present day treatises on anatomy.

At the height of its normal growth the thymus attains a length of 9.5 cm., a width of 5 cm., a thickness of 1 cm., and weighs 20 gm. It sinks in water with a displacement of 21 c.c. But the organ may depart widely from the average standard; it may be larger or smaller. Its relations will vary according to its size, and it may lie to the left or right of the median line. A bridge of true thymic tissue may come in direct contact with the thyroid gland, or 3 or 4 cm. may intervene between the thyroid lobes and the cephalic extensions of the thymus. Sometimes the distinct divisions into lobes may be lost, or one lobe may greatly exceed its fellow in size. Multiple lobes, from three to seven or eight, may at times be found. Small lobes or islets of thymus tissue are sometimes found at a considerable distance from the organ proper, making *accessory thymuses*, as also seen in the case of the spleen and thyroid.

Histology.—The connective-tissue envelope of the active thymus sends offshoots or septa into the gland, dividing the lobes into lobules, and these again into secondary lobules from 4 to 11 mm. in size, finally separating the lobules into smaller, roughly spherical foci of solid thymic tissue termed follicles or acini, from 0.4 to 0.7 mm. in size. Ordinary white fibrous tissue mixed with elastic fibres makes the principal part of the enveloping sheath or capsule surrounding the thymus; in this more or less fat is mixed, depending upon the proportion of adipose tissue in the body at large. In the finer septa isolating the follicles or acini only loose white fibres with delicate elastic fibrils are present (Mall).

The follicles consist throughout of adenoid tissue, giving the impression made by the follicles of the lymph glands, even to the extent of showing a lighter central portion and darker periphery. This resemblance is heightened by the fact that the vast proportion of the elements composing the thymic acini are lymphoid cells. But more careful examination with higher magnifying powers brings out an evident difference between the central portion or medulla, as it is called, and the germinal centre seen in the follicle of lymph nodes. The darker, more solid peripheral portion of the acinus (cortex) is quite similar to the bulk of tissue composing the follicle of a lymph gland.

The cortical and medullary portions of the thymic acini are not sharply circumscribed. In general the reticulum of the medullary substance forms a network or framework of branching cells whose processes communicate with each other and with the walls of the blood-vessels. The nuclei of these radiating cells are 6–8 μ in size and rather poor in chromatin. In the meshes of the network lie small mononuclear leucocytes with nuclei 3–5 μ in diameter (lymphocytes); larger leucocytes with polymorphous nuclei are more seldom present, along with the eosinophilous cells described by Schaffer, which are also found along the blood vessels of the interlobular connective tissue. Multinuclear (giant) cells are also to be found in the medulla, which, according to Watney, are derived in part from the cells of the framework. But, as Schaffer finds, there are also multinuclear cells which are united with the capillaries at the ends of which they are located and with whose retrogression they are related. At certain points the constituent cells of the framework press closely together, making flattened polyhedral objects whose arrangement resembles that of stratified epithelium. Here the extraneous (multinuclear) cells are entirely absent or only sparingly found. These nests or cords of epithelium, deprived of blood-vessels, show, at certain places where they adjoin the connective tissue, a layer of higher cells which resemble those in the basement layer of a stratified epithelium. That the medullary substance of the thymic follicle arose from an epithelial anlage cannot well be doubted from the outspoken epithelial nature of the cells just described, which must be regarded as direct descendants from the anlage. It is more difficult to decide whether the radiating cells of the medullary framework are epithelial in origin. In preparations stained after Van Gieson's method a portion of the medullary framework shows connective-tissue fibres, indicating that a part at least of this network is mesodermic in origin.

Besides the epithelial islets just described one finds in the thymus of advanced embryos, in greater numbers in the fully developed organ, and in the early stages of its retrogression, numerous characteristic objects varying in size and condition. These bodies are known as the concentric or lamellated corpuscles of Ecker, Hassall's corpuscles, or thymic corpuscles. They abound in the medulla exclusively. In the simplest form they are spherical bodies 13–22 μ in diameter, with a central portion feebly refractive, homogeneous, or granular, surrounded by shell-like flattened ep helial cells. The nuclei of the epithelial cells are plainly discernible, or they may be swollen, with their chromatin dispersed or even entirely missing. Here and there between the constituent cells leucocytes appear which may even penetrate to the central mass of the corpuscle. These bodies closely resemble the epithelial cell-nests or pearls seen in epitheliomas. Their nature and origin was long obscure, but the embryological studies of His and Stieda have thrown light on the question, which is not, however, even now definitely settled. According to the authorities just quoted the formation of these bodies is due to the separation of the primary thymic epithelium into isolated portions by the ingress of mesodermic elements, the pressure apparently producing their spherical contour, after which a degeneration of the central cells ensues, though this degeneration does not follow a uniform course. Usually a homogeneous refractive mass appears; at other times refractive granules, droplets, or flakes form. Whether the homogeneous substance is colloid, or not, is undetermined, though the microchemical test of Amman shows the same color-reaction as that given by the colloid of the thyroid gland. The substance is compared to that of prostatic stones by Kölliker. It certainly is a proteid and not a fatty substance, though both fatty and calcareous changes occur in Hassall's corpuscles. Frequently concentric corpuscles are seen in which the nuclei have entirely disappeared and the cell substance has become reticulated; or it undergoes transformation into soft masses which give a mucin reaction.

Along with the simple concentric corpuscles, bodies appear with multiple centres from which the cell layers radiate. Irregular forms, spindle- or club-shaped, or variously bent and knotted, also abound. But in all these corpuscles the concentric disposition of the component parts is retained. These bodies may reach a size of 0.1 mm. It is important not to confuse with these true thymic corpuscles epithelial cell masses devoid of the concentric arrangement, found especially in individuals of advanced age, in which the thymus is well along in its retrogression; they attain a diameter of 0.2–0.3 mm., and may be designated epithelial spherules.

In poorly fixed or macerated specimens the Hassall corpuscles and epithelial spherules readily fall out during preparation; and where several of them have been in contact, a space is left which may easily be mistaken for a central canal. The loss of large epithelial spherules from the medulla may give the impression of considerable cavities here, but these artifacts are not to be confounded with cavities clad with ciliated epithelium, first noticed by Remak, which are of embryonic origin due to imperfect closure of the primitive epithelial canals of the thymic anlage. It is also advisable to have in mind the occasional presence of aberrant parathyroids which may find their way into the medulla of the thoracic portion of the thymus.

The cortical portion of the thymic follicle is characterized by the possession of abundant blood capillaries, and has much similarity with the structure of lymphatic glands. It has a delicate reticulum whose meshes are packed with cells which are for the most part small, mononuclear lymphocytes. In sections stained with nuclear dyes this preponderance of lymphocytes gives the cortex a dark hue, plainly outlining it from the lighter medulla. As to the nature of the reticulum, whether entirely cellular or partly fibrillar, it is a question still undecided, as is the case in reference to the lymph glands. Watney holds that the reticulum is a dual structure, both cellular and fibrillar. It is highly probable, however, that it does not develop from the ectodermic thymic anlage.

In conjunction with the cortical reticulum and lymphoid elements one finds the eosinophilic cells, described by Schaffer and by Sultan, scattered through the whole cortex, especially along the surface and in the neighboring connective tissue. Further, there are peculiar round or branching cells reaching a diameter of 12–30 μ thickly disposed about the capillaries, and containing strongly refractive granules, differing from those of eosinophilic cells, but more closely resembling the colloid-like droplets in the centre of the Hassalian corpuscles because of their insolubility in acids and alkalies. These granules vary in size, the average being 4 μ in diameter; they stain but faintly in eosin and differ from fat by their insolubility in ether. These cells can most readily be demonstrated by treating sections of thymus hardened in alcohol with dilute caustic soda, which clears the tissue, bringing out the granules in the cells that lie along the capillary walls of the cortical portion only.

Of especial importance is the fact pointed out by Schaffer that in smear preparations of the thymus nucleated red blood corpuscles are to be found, as is the case in the spleen and bone marrow. They are hard to find in sections. They are especially abundant in the cortex, though present in the medulla.

As first pointed out by Kölliker, the blood-vessels of the thymus are peculiar. The arteries following the central cords in the interior of the lobules penetrate the follicles and pass into a network of capillaries along the inner side of the cortex. The central portion of the medulla is largely free from capillaries. The branching arterial capillaries at the border of the medulla pass into capillaries which mostly penetrate perpendicularly, making a radial network with numerous anastomoses. Immediately beneath the connective-tissue envelope this radial capillary network becomes a narrow-meshed plexus of rather wide capillaries which surround the cortex and communicate with numerous venous branches passing into interlobular veins. Together with venous trunks coursing along the surface of the cortical substance numerous veins and arteries are found in the medulla. In consequence there exists a double venous system, a superficial one between the adjoining cortices and a deeper one in the medulla; there is also a double capillary plexus, one superficial, the other radial.

The lymphatics of the thymus are still but little understood, our knowledge remaining practically where it was after His completed his studies upon the thymus of the calf, supplemented by the contributions of Watney and Renaut. According to His the larger blood vessels, which run along the central cord (calf's thymus) are accompanied by two or more lymph vessels, which receive one or more rootlets from each acinus. When these lymph vessels are traced, it is seen that in their further branching in the interlobular septa they soon lose their valves and muscular coat and become delicate-walled lymph spaces. These spaces plentifully surround the follicles. The lymph spaces provide an easy avenue for the thymic cells which are numerous in the thymic lymph

The nerves accompanying the thymic arteries are easily discovered. According to the investigations of Boveri, who employed the Golgi method, the nerves form a fine plexus upon the vessels and in the interlobular connective tissue, from which some fibrils penetrate into the medulla, terminating there with slightly swollen extremities (A. Kölliker).

Retrogression of the Thymus.—It has already been mentioned that the thymus is a temporary organ in man; that is to say, it does not remain in its condition of morphological (and presumably, therefore, physiological) perfection during life. That the thymus disappears more or less completely in adult life has long been known, but data relative to the exact time at which it passes away, and as to the stages leading to its backward metamorphosis, were not available until recent years. Indeed, even at the present time authorities are far from being in accord on all these points.

The views of Friedleben, whose work now over half a century old must be regarded as the classic on the thymus, are most generally accepted. He held that the organ reached its complete development at birth, remained in this condition (with some increase in size) until the second year of life, then gradually altered and atrophied, the retrograde process being well advanced by puberty. Variations in the course of these changes are by no means rare, and some of these are still misunderstood.

Accepting 20 gm. as the ordinary weight of the thymus, this remains fairly constant, under normal conditions, throughout life. But even with the unaided eye it may be seen that there is a marked difference between the thymus of a young child and that of an adult. In the first case the organ has a solid, flesh-like appearance, a uniform pinkish color, with well-defined and closely approximated follicles. No great excess of connective tissue is present, and but little fat occurs in the gland proper. In the case of the adult, however, all this is changed, and the organ appears as a fatty mass approximating the size and shape of the original organ. In this so-called "thymic fat body" of Waldeyer, reddish or dark yellowish foci, more or less discrete are to be seen up to the thirtieth year, and the microscope shows these foci to be remnants of the once voluminous gland. A marked change in the specific gravity of the thymus occurs with advancing years, as Dwornitschenko has shown, it being higher for the first thirty years and then becoming less. This is shown by its sinking in water during the first period and afterward floating, the fatty alteration being largely responsible for this variation. Such is the usual conduct under normal conditions, but the changes in the gland are profoundly affected by the general state of nutrition, and it also sometimes happens that the involution of the organ is retarded so that one finds in the adult an apparently perfect thymus, a solid mass of thymic tissue unchanged by fatty overgrowth, constituting the so-called "persistent" thymus. Persistent thymus is almost invariably an accompaniment of the dyscrasia known as status lymphaticus. (See *Status Lymphaticus*.)

So far as macroscopic evidences go we may summarize by stating that at the second year of extra-uterine life the thymus reaches its anatomical perfection, being a solid mass of adenoid tissue about 20 gm. in weight and sinking in water. From this period to puberty the organ gradually becomes smaller and distinctly tougher, owing to the increase of connective tissue in its substance; and at the same time its pinkish color fades. Between puberty and the twentieth year little change in bulk is noted, but it may be seen that adipose tissue is gradually appearing in the thymus, isolating the thymic substance into separate masses. This fatty alteration becomes more pronounced during the next two decades, the foci of thymic substance becoming smaller and more widely separated until finally a mass of yellowish fat, preserving the shape of the thymus, is all that the eye can detect—a mass that equals in bulk that attained at puberty, but that floats in water after the thirtieth year.

Histologically the evidences of a profound structural change during the retrogression of the thymus are well marked, and differ strikingly from what has been portrayed as the microscopic anatomy of the thymus at the period of its perfect development. These changes, which begin at the second year, have been particularly studied and described by Friedleben, Watney, Waldeyer, Schaffer, Sultan, Dwornitschenko, Lochte, and others. By these studies it has been determined that several distinct metamorphoses manifest themselves, the most pronounced being the connective-tissue, endothelioid, and fatty; that is to say, the process is one that affects both the framework and the parenchyma of the organ.

One of the earliest changes is the increase of interlobular tissue by which the acini become more widely separated, and, even before pronounced alterations occur in the acini, fat begins to make its appearance in the framework. There being no increase in volume of the organ, it follows that the proliferation of connective tissue produces a shrinkage or atrophy of the proper thymic elements, and in this the fat also plays a part, as Waldeyer has claimed. But while it must be regarded as a factor, pressure-atrophy is not the only condition incidental to the retrogression of the thymus. There is an atrophic change seemingly inherent in the cells of the thymic parenchyma. Sultan has directed attention to the other important retrogressive process—the endothelioid, which seems to be present at some stage during the transformation of the adult thymus in all individuals. From the endothelial cells lining the small blood-vessels and capillaries, and from those of the adventitia, endothelioid cells proliferate and appear both at the border and at the centre of the thymic acini. Sultan believes that some of these cells undergo a metamorphosis into fat cells. Later, spindle cells largely replace the endothelioid elements. A distinctly glandular or epithelioma-like appearance may be given to the thymus at the height of its endothelioid transformation.

Physiology.—The function of this organ, whose life history is so peculiar, is still much in the dark. Apparently its functional activity continues only during the stage of lymphadenoid development, though even at this time the presence of the thymus does not seem essential to life and well-being, since, according to the testimony of Friedleben and other experimenters who have followed him, the organ may be extirpated in young animals without causing any serious disturbance. Apparently contradictory to this conclusion are the results obtained by Thiroloix and Bernard in thymectomized rabbits, which died in three or four weeks with hypopyrexia and convulsions.

A number of authors have looked upon the thymus as a blood-forming organ, and Schaffer is the most recent advocate of this view. He believes, from his studies upon cats and rabbits, that the hæmatopoietic function is, like that of the spleen, liver, and bone marrow, a temporary one corresponding to certain growing periods; and, furthermore, he believes that the spleen and thymus maintain a reciprocal relationship, in that a rich supply of nucleated red blood cells in one is attended with a sparseness in the other. Carbone believes that the hæmatopoietic function of the thymus is limited to intrauterine life.

Since Friedleben's time the possibility of the thymus influencing the growth and nutrition has been considered. This point has been raised anew by Seydel, who, finding the thymus much atrophied or absent in infants dying from impoverished nutrition, concludes that the organ supplies blood or nutrient fluid. Tarulli, from his extirpation experiments, believes that increased appetite with augmented ingestion of food follows the operation, in spite of which the growth is retarded. There is also a diminution of hæmoglobin and of red blood cells with leucocytosis and eosinophilia. Von Braunschweig concurs with Tarulli in so far as denying a leucocyte-forming function to the thymus.

Experiments with extracts of the thymus have been made, particularly by Svehla, who used a ten-per cent. aqueous extract of the organ from man, dogs, swine, and cattle, and experimented on dogs by injection into the portal vein. He noted a fall of blood pressure, presumably caused by paralysis of the vaso-motors, acceleration of the pulse due to direct action on the heart, and death in narcotized subjects. In non-narcotized animals small doses caused restlessness and dyspnœa, while larger doses caused death with pronounced dyspnœa. Svehla compares the symptoms of experimental thymus intoxication with those of thymic sudden death (see *Status Lymphaticus*), and concludes that the fatal ending in the latter affection is caused by hyperthymization of the blood. Before accepting fully the conclusions reached by Svehla we should recall the fact that Cunningham has found that the toxicity of thymus and thyroid extracts is largely determined by the post-mortem changes in the glands after their removal and before subjected to the extractive process.

Pathology.—Besides various anomalies in the size, shape, and anatomical location of the thymus or portions of it, the organ may be completely absent. A typical example of this congenital abnormality has been reported by Clark in a baby of eight months; and while this reporter concluded from his observation that no serious nutritive disturbance followed the anomaly, he endeavored to show a relationship between the absent thymus and a form of hæmophilia from which the infant was suffering.

Circulatory disturbances as part of general vascular disease occur in the thymus. Venous hyperæmia is particularly prone to occur in the well-developed thymus with its large venous trunks, and has been repeatedly observed in asphyxia of the new-born. Punctate hemorrhages are found in some cases of sudden death in victims of status lymphaticus, and in the persistent thymus of lymphatic epileptics dying of asphyxia. They have also been noted in some cases of ordinary suffocation and in fatal phosphorus poisoning.

Atrophy of the thymus is a coincidence of general wasting of the body like that accompanying exhausting acute diseases or various chronic diseases attended by cachexia and marasmus. A well-developed thymus in an infant or a persistent one in an adult may shrink until little more than a fibrous-tissue mass remains to mark the place it once filled. This fact is important in connection with the anatomical diagnosis of status lymphaticus, a condition in which persistent thymus is associated with general lymphadenoid hyperplasia; for, under the conditions just mentioned, the organ atrophies and practically disappears, and, as a rule, the other lymphadenoid accumulations suffer the same fate.

Hypertrophy with hyperplasia of the thymus, which has had an overwhelming amount of attention in the literature concerning diseases of this organ, is almost invariably associated with the general condition known as status lymphaticus (see *Status Lymphaticus*), and should not be regarded as an independent affection. Even in the several cases in which the thymus has been reported as enlarged in Basedow's disease, myxœdema, Addison's disease, and acromegaly, other evidences of status lymphaticus have usually been disclosed.

Acute non-suppurative inflammations of the thymus are not common, and while the organ may participate in an inflammatory affection involving contiguous anatomical structures, it usually escapes. Biedert has reported a case of primary acute inflammation of the thymus unknown in origin. In general hæmatogenous infections the specific micro-organism may find its way to the thymus; and in certain pyæmic affections metastatic abscesses may occur in the thymus. There are also several cases on record in which single or multiple abscesses of the organ were found, with no evidence of a primary suppurative process elsewhere. In the cases of this character reported by Schlossman, Demme, and Helm, the enlarged thymus with its abscesses was apparently responsible for the sudden death.

Primary tuberculosis of the thymus is unknown, unless the questionable case of Carpenter's is so considered; but a number of instances of secondary infection, either in the form of miliary tubercles or in that of caseous tuberculous foci, have been noted

The thymus is the seat of various kinds of tumors, and is the starting-point of a considerable number of the neoplasms located in the anterior mediastinum. Various teratomas have been found in connection with it, the most common one being a dermoid cyst with hair, epithelium, and fatty contents similar to the dermoids of the ovary. A more frequent variety of thymic tumor is one taking a lymphoid structure and designated lymphoma or lymphosarcoma, depending on its extent and the production of metastases. However, since the lymphatic glands in the anterior mediastinum and about the bronchi may also become the seat of these tumors, it often becomes difficult to decide whether the thymus has been primarily or secondarily affected. The question may at times be determined histologically by the discovery of Hassall's corpuscles in the primary tumor. Besides the small celled lymphosarcoma, other varieties of sarcoma may occur, and carcinoma, presumably originating from the remaining foci of epithelial tissue, is occasionally encountered.

Extensive lymphoid infiltration and enlargement of the thymus may attend leukaemia and pseudoleukaemia.

Peculiar cysts of the thymus, probably at one time misunderstood and consequently designated Dubois's abscesses, have been carefully studied by Chiari, who regards them as originating from a growth of thymic tissue into the corpuscles of Hassall. Besides these spurious abscesses there are cavities with softened contents, properly called Dubois's abscesses, due to the softening of syphilitic nodules (small gummas). Syphilitic infection of the thymus may also manifest itself by a hyperplasia of the organ, or by a diffuse connective-tissue overgrowth with consequent induration. *A. P. Ohlmacher.*

LITERATURE.

As has already been mentioned, much of the literature upon the thymus, especially as to its hypertrophy and hyperplasia, should properly be classed with that bearing upon status lymphaticus. A particularly valuable paper giving the historical references is Ducrot's thesis ("De la Mort subite chez les jeunes enfants par hypertrophie du thymus au point de vue médico-légal," Paris, 1901). A more extensive work dealing with the thymus as a whole is Friedleben's monograph ("Die Physiologie der Thymusdrüse in Gesundheit und Krankheit," 1858). A thorough summary of the more recent literature is to be found in Klein's review ("Neuere Arbeiten über die Glandula thymus," *Cent. f. allgemeine Pathologie*, Bd. ix., Nos. 16, 17, 1898). From these three sources the student can obtain a reference to most of the literature dealing with the thymus except as pertains to certain special aspects of the embryology, anatomy, and histology, for which the standard text-books may be consulted.

THYROID.—ANATOMY.—There are few organs in the body that show normally so many and so great variations in structure, both gross and minute, as the thyroid. This is to be explained by the fact that it has its origin in three independent embryonal structures, so that in their fusion there are many opportunities for variations. Again, the absence of any excretory duct probably permits of wider variations than might otherwise occur, for no matter how arranged or where located the gland can accomplish its entire function, provided only that it has proper circulation. Ordinarily it presents two lateral lobes connected by an isthmus, which latter lies across the trachea from the second to the fourth tracheal rings, inclusive. This isthmus is absent in from ten to fifteen per cent. of individuals When present, it may merely consist of a mass of fibrous tissue containing a minimum of gland tissue, or it may form the largest of the three lobes, with all possible intervening variations. Quite rarely, *i.e.*, in about one per cent., the isthmus exists as an independent lobe. When the isthmus is absent the lateral lobes are often so closely applied that the absence of the isthmus may be completely overlooked. At the level of the isthmus, the recurrent laryngeal nerve lies in the angle between the œsophagus and the trachea, being covered externally by the lateral lobe on each side. In front, the gland is covered by the sterno-hyoid, the sterno thyroid, and the omo hyoid muscles. Laterally, the lobes extend outward in front of the common carotid arteries. The lower end of each lateral lobe is usually at the fifth or sixth ring of the trachea, and the upper end is at the middle of the thyroid cartilage. The lower edge is embedded in a mass of fatty connective tissue, which is of some surgical importance, since it passes without any demarcation into the anterior mediastinum. Behind, it is attached by tough fibrous tissue to the larynx and trachea, so that it moves with them in swallowing. When the head is thrown back, the distance of 2 mm. that lies between the lower border and the sternal notch is doubled (Sappey).

Frequently a conical process, called the "pyramid of Lalouette," extends upward to be attached to the hyoid bone, thyroid cartilage, or thyro-hyoid membrane. This may arise from the isthmus or from either or both lateral lobes, its shape and size also presenting wide variations. Its frequency varies greatly according to different observers. Marshall found it in 26 out of 60 thyroids, or 43 per cent.; Streckeisen in 104 out of 153; Zoja in 109 out of 147, or 74 per cent.; while the writer found it with 36 of 60 thyroids, or 60 per cent. In 10 of these last it arose from the right lobe, in 12 from the left, in 8 from the isthmus, in 5 from both lobes, and in 1 from the left lobe and from the isthmus. In 21 it was attached to the thyroid cartilage or thyro-hyoid membrane, and to the hyoid bone in 15. In one instance the pyramid was split up into a chain of isolated masses of gland tissue, which would have to be classified as accessory thyroids. In structure the pyramid generally consists of regular gland tissue near its base, but the colloid material disappears as it ascends, and the vesicles become mere groups of epithelial cells, which are gradually replaced by fibrous and muscular tissue, until near the upper part of the pyramid they disappear entirely. If the muscle fibres are numerous the upper part is considered a separate muscle, and called the *levator glandulæ thyroideæ*. The pyramids are considered by Bland Sutton to represent part of the original thyroglossal duct.

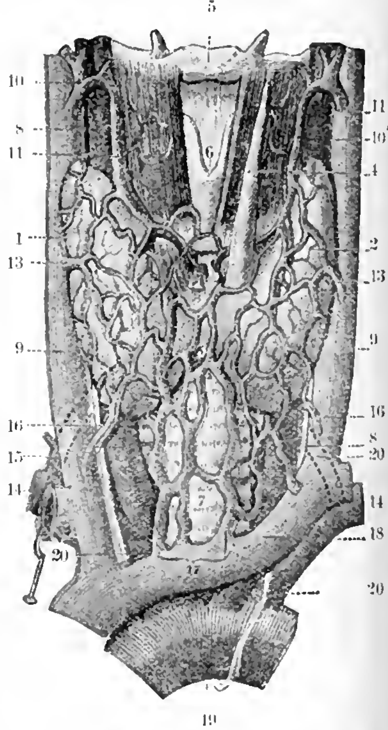

FIG. 4711. The Thyroid Gland and its Relations. (Testut.) 1, Right lobe; 2, left lobe; 3, isthmus; 4, pyramid of Lalouette; 5, hyoid bone; 6, thyroid cartilage; 7, trachea; 8, carotid artery; 9, internal jugular vein; 10', superior thyroid vein; 10, thyro-lingual-fascial vein; 11, superior thyroid artery; 12, inferior laryngeal vessels; 13, median thyroid vein; 14, subclavian artery; 15, inferior thyroid artery; 16, lateral inferior thyroid veins; 17, median inferior thyroid veins; 18, left brachiocephalic vein; 19, arch of the aorta; 20, pneumogastric nerve.

In proportion to its weight the thyroid has perhaps the largest blood supply of any organ of the body, the blood reaching it through the superior and inferior thyroid arteries on each side, and occasionally from the thyroidea ima. Following the trabeculæ these vessels break up into a rich meshwork of capillaries about the vesicles. In some places these capillaries even penetrate the basement membrane and come into direct contact with the secreting cells. So great is the vascularity, that when an active dilatation of its vessels occurs the gland increases noticeably in size, and in this condition a distinct pulsation can be felt throughout the gland. The veins unite to form the superior, middle, and inferior thyroid veins, the two former of which empty into the internal jugular vein, the last into the innominate. They are devoid of valves, and a rich plexus surrounds the gland, often causing much bleeding in operations. Some authors have described collections of a colloid like substance in the veins of the gland, and suggested that this was the method by which the gland disposed of its secretion, *i.e.*, directly into the circulation. However, these appearances are probably due to accidental extravasations occurring in the handling of the gland. It seems most probable that the excretion of the colloid substance occurs through the lymph channels, which are very numerous in the thyroid and lie in direct contact with the basement membrane of the vesicles, sometimes even with the gland cells themselves. In their lumen colloid is usually to be found, distinguished from other substances by its staining with Van Gieson's stain. After free anastomosis the lymph vessels leave the gland and pass through the superior and inferior deep cervical glands. (See description of lymphatics under "Tumors of the Thyroid.")

The nerves of the thyroid come from the middle and inferior cervical sympathetic ganglia, and pass into it with the blood-vessels. The recurrent and external laryngeal, the hypoglossal, and the vagus all send filaments to the gland, but these all seem to be vaso-motor or secretory, that is to say, they are all of sympathetic origin (Kölliker). The branches run to the bases of the epithelial cells, but the actual endings are not exactly determined.

The weight of the thyroid seems to vary greatly in different countries, since most German authors (Virchow, Rauber) place it at from 30 to 60 gm.; Schaefer in England gives it as 30–40 gm.; Poirier and Charpy in France give the average as 22–24 gm. In sixty thyroids removed in this country, I found the average weight but 22 gm. It would seem that in goitrous countries the normal gland is larger than in non-goitrous countries. The thyroid shows the effects of senility sooner and more than any other organ that is not essentially reproductive. In my series in persons over forty-five years of age the average weight was but 16 gm., while in people between twenty and forty-five years it averaged 25 gm. Differing from the other organs, it is larger, as a rule, in women than in men—a fact which, together with its early atrophy, indicates its close relation to the reproductive organs. It is relatively larger in infants than in adults; in the former the proportion to the body weight being 1 to 700 or 1,000, in the latter 1 to 1,500 or 2,200. According to Huschke there is even a decrease in size after birth, followed by a rapid growth at puberty. In the adult the transverse measurement is usually 50–60 mm., antero-posterior thickness of the lateral lobes 18–20 mm., of the isthmus 6–8 mm.; length of the lateral lobes 50 mm.; height of the isthmus, 5–15 mm. The right lobe is slightly larger when a considerable number of cases is averaged, although often in individual glands the opposite is true.

DEVELOPMENT.—Three separate "anlagen" unite to form the human thyroid. 1. A median diverticulum of the pharyngeal hypoblast pushes its way downward, and forms a tube that is connected with the base of the tongue. Subsequently it becomes solid, its upper end forming the foramen cæcum, from its lower end developing the isthmus, part of the lateral lobes, the pyramids (when they are present), and occasionally accessory thyroids. It sometimes happens that this structure remains in the adult as the "*ductus lingualis.*" 2. From the fourth visceral cleft on each side spring pouches which pass in front of the larynx and unite with the lower end of the median diverticulum, ultimately forming the outer part of the lateral lobes. These three masses fuse to form a horseshoe-shaped structure encircling the embryonic larynx, and are separated from their origin in the hypoblast. At first the gland consists merely of rod like columns of epithelial cells, resulting from the division and branching of its original rudiments. The ingrowing connective tissue divides these cords of cells into short

FIG. 4712.—Thyroid of Fœtus at Term. The lobular outlines are more prominent than in the adult; there is no colloid in the acini.

segments, which form the vesicles later, when colloid is secreted. Colloid formation begins in intra-uterine life, but the vesicles are not generally filled until some time after birth, section of the gland of a new-born child showing but few of the acini containing colloid. Because of the method of formation, in the fœtus a lobular structure is distinct, but in the adult this is generally absent or indistinct.

HISTOLOGY.—Fully as great variations are seen microscopically in the thyroids of persons who die of diseases that have no known effect on the thyroid, as have been noted in the gross anatomy. Study of the thyroids from consecutive autopsies shows such a variety of conditions as to suggest that perhaps this organ suffers much more in disease than we have reason to suspect from any clinical evidences. What may be considered the normal structure is described most briefly by saying that it differs from other tubular glands chiefly in having the tubules closed and filled with colloid to varying degrees of distention. The arrangement of capsule, septa, basement membrane, vessels, and nerves is that common to glandular organs in general. By reconstruction methods Streiff has shown that the vesicles are not always spherical sacs, but often are tubular, and frequently are sacculated. The size of the vesicles varies greatly, some being quite without lumen, while others are more than half a millimetre in diameter. As the epithelial cells are modified by the pressure of the colloid in the lumen of the acinus, they vary much in size and shape from those that are distinctly columnar in empty acini to those flattened, in distended sacs, to the nature of an endothelial cell. For the most part they are cuboidal, with a small spherical nucleus that stains more intensely than that of most epithelial cells. They are described as of two kinds—the chief cells and the colloid cells. The chief cells, which form by far the greater part, are clear or with very fine granules and have no distinct membrane, but seem to blend with one another, their outer ends resting on the basement membrane, the inner lying in the colloid substance. The colloid cells are characterized by a more granular and opaque appearance, obscuring the nucleus, and they are lower than the chief cells, from which they seem to be derived. The granules stain like colloid, and they seem to become converted into this substance, to be replaced by new cells from the chief cells. All stages between these forms may be found. Acidophile granules are also described, which are considered analogous to the zymogen granules of other glands. The colloid content of the alveoli stains a clear pink-white eosin, and is usually structureless. Often, however, nuclei or entire cells are present, but the frequently observed total exfoliation of the epithelial cells into the colloid is probably to be interpreted as a post mortem occurrence, quite the same as the desquamation of the endothelium of blood-vessels. Red corpuscles are frequently found, apparently normally, and it is stated that they will retain their form and staining properties for a very long time in the colloid. However, pigment from this source is frequently present. The vacuoles that often fringe the colloid are probably for the most part, if not entirely, the result of shrinkage in the hardening process. Ernest considers the orange, or yellowish brown color assumed by the colloid when stained by Van Gieson's method to be characteristic, but this is by no means constant; sometimes it gives a good red color. Fat is constantly found in the epithelial cells of the thyroid as well as the parathyroids and hypophysis, increasing in amount with age (Erdheim).

The stroma of the gland is scanty in the adult, but more abundant both in infancy and in old age. Larger septa of very dense fibrous tissue separate the original lobules of the gland, while bands that are often extremely thin separate individual acini. In it are the wide, colloid filled lymphatics, the abundant vessels, and the nerve fibres, which are mostly non-medullated. There are no intrathyroid ganglia, but simple ganglion cells of very irregular form, which, as a matter of fact, are not fully distinguished from branched connective-tissue corpuscles (Poirier and Charpy). Between the follicles are often found groups of cells that seem to indicate undeveloped follicles, even to the extent of sometimes containing colloid droplets. What are considered to be embryonal rests are found, especially under the capsule.

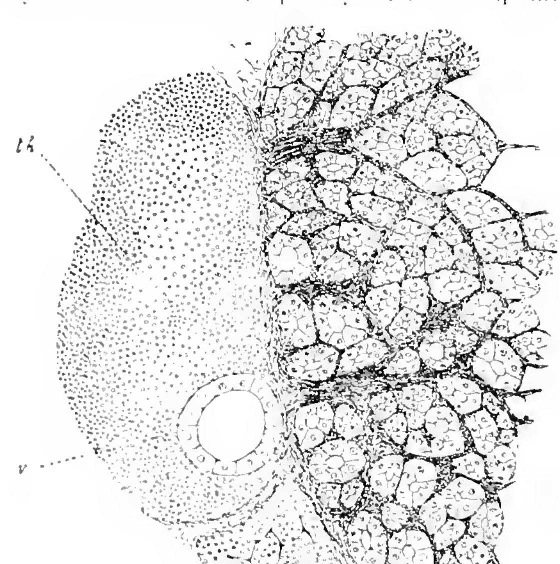

FIG. 4713. Parathyroid, Thymic Vesicle, and Thymic Lobule of New-Born Guinea-pig. (Poirier and Charpy.) *th*, External thymic lobule; *v*, thymic vesicle; *g.l.* external parathyroid.

The cells lie with little order in the stroma, and have large, chromatin rich nuclei and little cytoplasm. Their exact nature is not settled. Bozzi found no alterations in embryonal rests present in small stumps of gland tissue remaining after removing the greater part of the gland, nor did their presence prevent the death of the animal, suggesting that perhaps they are not really embryonal rests.

Parathyroids.—These organs are composed of columns of epithelial cells, with large, deeply staining nuclei, and a rather small amount of cytoplasm. They resemble the carotid glands in structure, but the thyroid not at all, and it is considered by Prenant that they are derived from the fourth inner branchial cleft, from which the thymus and the lateral rudiments of the thyroid are also derived. Gley believed that they represented embryonic rudiments of the thyroid, but, as will be shown later under Physiology, this interpretation is not correct. For further description of these organs see under *Goitre*, Vol. IV., p. 378, and under *Parathyroid*, Vol. VI., p. 506.

Thymic Lobules.—As a rule these little-known bodies are four in number, but sometimes there are but two, and in some animals they are lacking (Nicolas). There are two external lobules, usually on the posterior surface of the lateral lobe; and two internal lobules, in the centre of the lateral lobes, surrounded on all sides by glandular tissue, or sometimes they are near the tracheal face. They possess the structure of the thymus, even to the concentric epithelial corpuscles, but they are often mistaken for lymph nodules. They are ascribed to the common origin of the lateral lobes of the thymus and thyroid in the fourth branchial clefts. They seem to occur infrequently in man (Müller). Besides these normal structures not rarely rests of thymus tissue are found in the thyroid gland, or about it.

Ciliated Vesicles.—Vesicles lined with ciliated epithelium are occasionally found, not only in the thyroid, but in the parathyroid, or thymic lobule (see Fig. 4713), or in the thymus; they may give rise to cysts. Their content is a clear fluid, quite different from the colloid. They are probably derived from the original pharyngeal or branchial diverticulum, and persist as does the thyroglossal duct.

CHEMISTRY.

Until 1896 the thyroid was studied frequently to learn something of its chemistry, because as a gland with internal secretion it seemed possible that this unknown secretion might be found. It was learned that it was rich in the various extractives, indicating metabolic activity, and that it contained a nucleo-proteid and a globulin of some interest. Fraenkel thought he had isolated an active principle in a crystalline, alkaloid-like body, apparently belonging to the guanidin series. Baumann in 1896 succeeded in isolating the real active principle in the iodine compound, *thyroiodin* or *iodothyrein*. This, according to Baumann, is a brownish, amorphous compound, remarkable for its resistance to chemical and physical agencies; it can be boiled for days with ten per cent. sulphuric acid or undergo prolonged digestion with gastric juice without alteration. This explains its successful use per os therapeutically. It is almost insoluble in water; in alcohol it dissolves with difficulty. It manifests no proteid reactions, and in the purest specimen that Baumann was able to obtain, he found 9.3 per cent. of iodine, which is probably below the true proportion. Working with Baumann, Roos subjected it to physiologic and therapeutic tests that showed it to be the active principle of the gland. There seem to be no essential differences in the substance as obtained from either human glands or from the lower animals. However, the variations in the amount of iodine found in the glands of individuals in health is great, but it may be stated that in goitrous districts the amount of iodine is much less than in the places where goitre is rare. This is shown by the accompanying table.

The manner in which the iodine is combined in the thyroiodin is still unknown, although according to the work of Oswald it is preponderatingly, if not entirely, united to aromatic groups. However, it is known that the iodine is combined in a non-proteid body, the thyroiodin, which in turn is combined with a proteid, forming the

Place.	Dry weight of glands.	Iodine per gram in milligrams.	Total milligrams iodine.	Frequency of goitre.
Freiburg	8.20	0.33	2.50	Endemic.
Hamburg	4.60	.83	3.83	Not endemic.
Berlin	7.40	.90	6.60	Not endemic.
Chicago	5.37	2.10	10.79	Not common.
Boston and New York	4.47	2.64	11.80	Not common.
Baltimore	5.41	2.36	12.76	Not common.
Montreal	4.49	2.40	10.77	Not common.

thyroglobulin. This thyroglobulin contains 1.6 per cent. of iodine, and is found entirely in the colloid of the gland, but it is not the sole ingredient of the colloid, which contains a neucleoproteid also. Oswald believes that the iodine is united with the globulin either just as it is excreted from the cells or after it is in the acini; a thyroglobulin devoid of iodine may be found under some conditions. The thyroid of new-born infants, as well as of calves and other young animals, is either devoid of demonstrable quantities of iodine or contains but traces, and in them a colloid containing globulin free from iodine is found. Many experiments have shown that the functional activity of the thyroid, whatever it may be, is due entirely to this iodine compound, acting not as iodine or as an iodide, but specifically as thyroiodin. Whatever effects can be obtained by administration of the entire thyroid can be as well obtained with the pure thyroiodin. There is no evidence of any function on the part of the nucleoproteid. The thyroid, then, differs from ordinary glands simply in having the lymph vessels for its excretory ducts. What becomes of the thyroiodin after it is eliminated from the gland is unknown, but it is thought that the iodine is returned to the gland after it has performed its functions, to be rebuilt into thyroiodin. Iodine cannot be found in the other organs in appreciable quantities, although infinitesimal quantities are said by some observers to be quite widespread. If large quantities are administered to animals iodides appear in the urine (Blum), but according to Oswald physiological doses do not lead to its appearance in quantities that can be detected. Nor is it known in what manner it is taken up by the gland, whether from unknown tissue iodides, or organic iodine compounds, or from minute traces that exist as iodides in the water and air. It is known that when iodides are administered therapeutically the colloid becomes richer than normal in iodine, but it is questionable if the iodides are converted into thyroiodin before exerting their effects. Administration of bromides does not influence the iodine content of the thyroid, and there is no storage of bromide in the gland. Administration of pilocarpine does not increase the thyroiodin.

The colloid seems to vary greatly in its composition, but as a rule the more colloid there is in a gland the less the proportion of iodine, so that the total iodine content is kept nearly constant under normal conditions. This is far from true in the goitres, for some are nearly devoid of iodine, while others contain much greater quantities than normal. In goitres, while in a way the amount of iodine increases with the amount of colloid, yet this is only partly true, for the greater the amount of colloid the less its proportional amount of iodine. Oswald has found that in colloid goitres this is due to the accumulation of a globulin in the colloid that differs from thyroglobulin in not possessing any iodine. In the parenchymatous form of goitre, in which microscopically the enlargement is due to the development of enormous amounts of epithelium with very little colloid, the amount of colloid in each part of gland tissue is much lower than normal, although the total amount will usually approximate that found in the normal gland. The scanty presence of iodine is not due to an inability of the gland to combine it, for in the goitrous thyroids of people who had received iodides before death the amount of iodine has been found to be large. In exophthalmic goitre the proportional amount of iodine has generally been found to be small, although here, too, the gland has been found by Oswald to be capable of utilizing iodine administered therapeutically. The colloid from goitres, so far as it contains iodine, possesses the same physiological properties as the thyroglobulin from normal glands, but in less quantity. If free from iodine it is entirely inactive (Oswald).

According to Gautier the thyroid contains about 0.75 mgm. of arsenic in each 100 gm. of substance, and is the richest in arsenic of any of the tissues of the body. He considers that it is bound to the nucleoproteid of the colloid, perhaps substituting for phosphorus, and that it is of physiological importance, especially in relation to sexual phenomena. The amount of arsenic is too small to cause confusion in medico-legal matters.

Physiology.

Most of our knowledge of the action of the thyroid gland is based upon the changes observed in man and animals when they are under one of two conditions, which are:

1. When the animal is receiving less than the usual amount of secretion from the thyroid, as in extirpation experiments.

2. When the amount of secretion in the body is above normal, as when thyroid extract is being administered.

These observations include not only the results obtained by experiments, but also those obtained from clinical observations, since here the symptoms are due sometimes to hypo activity, *e.g.*, myxœdema and cretinism; or to hyperactivity, as sometimes in therapeutic use of thyroid, or after operations, and possibly in exophthalmic goitre.

In the first case when the subject is receiving less than the full influence of the thyroid gland, we observe symptoms that may be divided into nutritional and nervous.

(*a*) The nutritional changes seem to be of such a nature that the metabolic changes throughout the body do not proceed to their full extent, or are reduced in rate, and the power of cellular reproduction is altered. As a result of the first the connective tissues stop in their metabolic processes just short of completion, leaving them, as Semon suggested, in an embryonic condition, that is, in the form of myxomatous tissue, which is their embryonic representative. From this results the condition of the skin seen in myxœdema. This change seems not to be confined to the subcutaneous tissues, but is a general change, for Halliburton has shown that in the blood of monkeys rendered myxomatous as a result of thyroidectomy, there is demonstrable a considerable quantity of mucin. Because of the failure of complete cell reproduction, or an alteration in the process, we observe a change in young animals, quite analogous to cretinism in children. Besides this, there is a decrease in the gas exchange of the blood, for in thyroidectomized animals the amount of carbon dioxide is increased and the oxygen diminished until the arterial blood may be below the normal venous standard. The urine indicates that all metabolic changes are lessened. Oligocythæmia is usually marked.

(*b*) The nervous system is apparently greatly affected, the most marked symptoms from this source being those due to the excitation of the muscular fibres, viz., twitching, tremors, and spasms. These seem to proceed from the lower centres, for Horsley has observed them in monkeys subjected to ablation of the motor cortex, and Munk found that they were not affected by division of the cord, while Schiff showed that they were not of peripheral origin by finding that section of the motor nerves stopped them. Degenerative changes have been found in the anterior horn ganglion cells of thyroidectomized dogs. Later, these symptoms are followed, if the animal survives, by a lessening of the power of voluntary action, as well as by loss of sensation. The thermotaxic apparatus is also affected, so that the body temperature falls three or four degrees below normal. Lorrain Smith has observed that the reaction of thyroidectomized animals to changes of temperature is abnormally rapid, so that if such an animal is exposed to cold the production of carbonic acid is increased immediately, instead of being delayed for some time as in normal animals. Moreover many of the symptoms of athyreosis are alleviated by artificial heat.

The clinical picture resulting from the above-described changes is referred to as *cachexia strumipriva*, or *thyroid cachexia*.

When the thyroid preparations are administered to animals experimentally, or to man therapeutically, opposite effects are produced.

(*a*) *Nutritional.*—Metabolism throughout the body undergoes an increase, shown best by the urine. This is considerably increased in quantity; it contains a greater amount of urea as well as chlorides and phosphates. At the same time the weight of the patient decreases, particularly if it is above normal on account of fat deposition. This decrease in weight is constant and considerable, and, according to Wendelstadt, but one-sixth can be attributed to destruction of proteid, as indicated by the urinary nitrogen, the rest being due to loss of water and of fat through increased oxidation. In young individuals of stunted growth the height is often increased.

(*b*) *Nervous.*—Of these, palpitation of the heart is often one of the most prominent. With it come headache, nausea, and vomiting, if the dose is very excessive, and the heart may weaken to a dangerous degree. The patient is excitable, irritable, and often sleepless. Diarrhœa often sets in, and in some patients taking thyroid extract continuously in myxœdema and cretinism the condition of the bowels is found a good guide to the amount of the extract to be administered. Sometimes glycosuria is produced, which in a few instances is said to have developed into a true diabetes mellitus. Schaefer has also shown that if thyroid extract is injected into the veins of healthy dogs there follows an immediate fall of blood pressure due to general vascular dilatation.

It is to be noted that the symptoms that are attributed to the thyroid may be due in part to the parathyroids, which according to some experiments seem to be really more essential to the individual than the thyroid itself. There is a tendency to attribute much of the nervous manifestation to the parathyroids, while the metabolic processes are credited to the thyroid. According to Hutchinson, removal of the thyroid alone probably causes myxœdema, while removal of the four parathyroids causes the acute tetanic symptoms. (See article on *Parathyroid*.)

From the facts noted above have been developed two theories to explain the action of the thyroid. One assumes that the thyroiodin that has been excreted by the gland neutralizes a toxic material, either while passing through the thyroid in the blood, or, more probably, while circulating in the blood stream of the body as a whole. This hypothetical toxic substance may come either from alimentary absorption, or from metabolism, as an abnormal or normal intermediary or end-product. The other theory advocates the idea that thyroiodin is essential in normal metabolism. It suggests that thyroiodin may be essential for certain of the normal cell processes, much as calcium salts are involved in the coagulation of the blood. Either of these theories may be applied to most of the known facts, but neither is entirely satisfactory. One of the strongest evidences in support of the antitoxic nature of thyroiodin is furnished by Blum, who found that ninety six per cent. of his thyroidectomized dogs died when fed upon meat, while but sixty per cent. died when they were fed upon milk. Dogs that were getting along well on a milk diet developed symptoms of athyreosis when fed upon meat. Hence it is considered by him that symptoms that follow thyroid extirpation are produced by substances formed by the meat in the gastro intestinal tract, which are produced in less quantity by milk, and which the thyroid normally neutralizes. It is, however, probable that milk contains thyroiodin, for young calves are said by Oswald to have iodine in their thyroids, and he believes that the deficiency is supplied by the mother's milk, for, as is well known, the maternal thyroid is hypertrophied during gestation and lactation. He is inclined to think that if there is a toxin it is one of the normal intermediary products of metabolism which does not undergo its usual transformations because of the general decrease in metabolic activity.

That there is a close relation between the thyroid and the reproductive functions, particularly in the female, is beyond question. This is shown by its enlargement during menstruation and pregnancy, its early atrophy after the menopause, its greater size in the female, its tendency to develop goitre during pregnancy, and the loss of sexual appetite in many of the thyroid diseases. It is stated that from eighty to ninety per cent. of all cases of goitre and eighty six per cent. of the cases of myxœdema are in women, and Graves' disease occurs chiefly in females. Halsted observed that bitches that had lost part of their thyroids, but not enough to give rise to symptoms, when impregnated showed evidences of athyreosis as the time of parturition approached, which disappeared soon after the litter was born. Further, in all of the pups of these litters the thyroid glands were many times the normal size of the glands of pups of the same weight. Just what part the thyroid plays in pregnancy is unknown.

It may be that it hypertrophies to supply the needs of the fœtus, which, as we have noted, does not form thyroiodin in its thyroid, and whose needs must be great if thyroiodin is necessary for cell growth. As to the hypertrophy of menstruation, Gautier claims to have demonstrated both iodine and arsenic in menstrual blood as well as in the thyroid, and he believes that the latter supplies the former. It has been thought by some that the thyroid may play a rôle in the production of puerperal eclampsia. One writer states that hypertrophy of the thyroid is absent in eclampsia, and ascribes this disease to thyroid inefficiency. In this connection the experiments of Blum are of interest. He found that in the dog thyroidectomy was followed by albuminuria almost constantly, sometimes with hæmaturia, and accompanied by marked renal lesions if the animal survived long enough to develop them. Alterations in the central nervous system, affecting chiefly the Nissl bodies, have been described by Blum and other observers.

Lange sums up the relation of the thyroid to pregnancy as follows: A physiological hyperplasia like that observed in the thyroid in pregnancy has never been found in the kidney at this period. Pregnant animals need a larger thyroid than those not pregnant. When a piece of thyroid just sufficient to continue life in a non-pregnant animal, is allowed to remain in a pregnant animal, an insidious kidney disease develops, one that may result in convulsions and coma, which are not relieved by thyroiodin, and which are distinct from the convulsions of tetany.

The marked atrophy of the thyroid in old age has been regarded as indicating some possible influence on senility. More probably it is related to the decline of sexual life. It is interesting to note that the thyroid arteries are prone to show very early sclerosis, often before other vessels are at all affected. The decrease in red corpuscles after thyroidectomy is probably the result of the decreased activity of the blood-making organs, or it is dependent upon an increased destruction by toxic substances. The decrease is not, as was once thought, an indication of hæmatopoietic properties of the thyroid. Another old theory, probably baseless, was that the thyroid was a reservoir into which the carotid blood might be shunted to produce cerebral anæmia and thus favor sleep.

Pathology.

Malformations.—Because of its manner of development the form of the thyroid is very inconstant, and this matter has been in part discussed under the subject of anatomy. The commonest alterations from the usual form are absence of the pyramids, or of the isthmus; the latter may also be of peculiar shapes, and it has been known to pass between the trachea and the œsophagus. Hypoplasia, and even total absence, may be observed in cretinism, and it is usually absent in acephalics. Hektoen has recently reported a case of dwarfism, related to the type of achondroplasia fœtalis, in which the very small gland was nearly devoid of epithelial elements, and contained no demonstrable iodine. Unilateral glands are uncommon. Many abnormalities of form are produced by the formation of colloid cysts, and by the cicatricial contraction of healed cysts.

The *thyrolingual* duct may fail to become obliterated, remaining as a canal which extends for a longer or shorter distance from the foramen cæcum; occasionally residual portions of this duct become dilated into cysts of varying size. These cysts may open and form a median cervical fistula, usually opening below the cricoid cartilage, and lined either with stratified or with columnar epithelium. Lingual dermoids and tumors at the base of the tongue have been traced to this origin.

Accessory thyroids are of a structure identical with that of the thyroid, although they sometimes reproduce rather the fœtal than the adult type. They are far from constant in occurrence, or location, or numbers. In general they are located in an isosceles triangle which has its base at the lower jaw and its apex at the aortic arch. The most frequent location is in the vicinity of the hyoid bone, and they have been found within the bone itself. Many of them are attributable to remnants of the diverticulum that ordinarily forms the pyramids, often replacing this structure. Of particular practical importance are those found within the larynx or trachea, for these may give rise to marked symptoms. Thiesen found in the literature 10 positive and 2 doubtful cases of this sort, 8 of which occurred in Germany. Of 91 benign intratracheal growths which Bruns in 1898 collected from the literature, 7 were of thyroid origin. The structure is usually the same as that of normal thyroid, and, like it, contains colloid. Accessory thyroid may be the result of inclusion of an accessory thyroid lobule in the larynx or trachea in intra-uterine life, or the membrane between the rings of the trachea may be penetrated by adherent thyroid tissue during later life. Usually the growth is located on the posterior or on the lateral wall, being attached by a pedicle to the thyroid. Seven of the 10 cases were in women, and were detected usually between the fifteenth and thirty-third years. In Thiesen's case dyspnœa was increased by pregnancy. In only 2 cases did goitre coexist. One case of thyroid tumor at the base of the tongue is of particular interest, in that its removal was followed by symptoms of myxœdema, which were relieved by thyroid therapy (Shurley). Here it would seem probable that atrophy of the gland proper had resulted in a compensatory hypertrophy of the remnants of the thyrolingual duct.

Circulatory disturbances of the thyroid are prominent because of its great vascularity, but they cause relatively little trouble unless the gland is already enlarged, when the added size may be of importance.

Passive congestion may occur in heart disease and from pressure on the cervical veins, but it is rarely evident, has no apparent effect on the function of the organ, and it seems not to cause structural changes of moment.

Active hyperæmia is frequent, usually physiological, and it is held responsible for the visible enlargement of the gland in menstruation, pregnancy, sexual excitement, and at puberty. However, it is not always easy to determine how much of the enlargement is due to the vascular dilatation, and how much to hypertrophy of the gland elements or to increased production of colloid, since all these may go together. At times it may be so great that a distinct bruit can be heard over the gland; this is particularly the case in Graves' disease. In various forms of goitre (*q.v.*) hyperæmia is present; in fact, a vascular form has often been mentioned in the literature, although it is very doubtful that there is such a thing as a real goitre produced solely by vascular enlargement. Probably the active hyperæmia of sexual origin is the same as that of other glands during physiological activity. Sudden hyperæmia may cause severe, even fatal attacks of dyspnœa when the glands are goitrous. So in pregnancy dyspnœa is always increased if it existed previously, or it may appear first at this time.

Infarction does not seem to occur, the circulation being too free. If emboli lodge there they seldom seem to cause effects, for even in pyæmia, miliary tuberculosis, and vascular dissemination of malignant growths the thyroid escapes more often from secondary lesions than do other organs, particularly if the great amount of blood that it receives is considered.

Hemorrhage is a prominent feature of the goitres, but it also seems to occur even in the normal gland. The red cells are preserved for a long time in the colloid, but eventually give rise to accumulations of pigment and cholesterin crystals, which latter may be very abundant. Any trauma of the thyroid is likely to give rise to hemorrhage, either into the vesicles or into the periglandular tissues. Large intraglandular hemorrhages may soften and lead to cyst formation, or become infected.

Progressive Changes.—Thyroid tissue has great vitality, and there is no other gland that can be transplanted so successfully. As the secretion is removed by the circulation any transplanted portion can functionate, and the treatment of myxœdema w s first successfully accomplished by grafting. An important fact, in view of the study of cytotoxins, is the following: transplantations can be made from one species into another with perfect results For example, sheep thyroid has been implanted into man and has cured myxœdema, showing that the secretion is practically the same in the different species. At first, the graft undergoes considerable necrosis and is partly absorbed, but some cells remain alive, and from these develop thyroid tissue in proportion to the needs of the body, for thyroid tissue has almost unequalled capacity to undergo compensatory hypertrophy. Grafts removed after four and one-half years have been found of the same structure as normal or hyperactive thyroid.

During hyperactivity, whether compensatory or not, the gland shows a decrease in the amount of colloid in the vesicles, as if it were being absorbed as fast as formed. The epithelial cells increase in size, either because of lack of pressure from colloid or because of formative or secretory stimuli, and the walls are thrown into folds so that the secreting surface is increased. Such changes as this were observed by Halsted in remnants of glands left after partial thyroidectomy, and they are seen in many cases of exophthalmic goitre, supporting the theory of the origin of this disease in thyroid hyperfunction. But a small remnant of the gland needs to be left in most cases to enable the demands of the body to be met, and not only normal gland tissue, but accessory thyroids and even tumor metastases, may functionate adequately.

Hypertrophy of a simple nature seems to be the process which causes many goitrous enlargements, and it is undoubtedly physiological in many instances, in response to some unknown demand of the body for increased activity. It is probably in such cases that operation is particularly likely to be disastrous. In acromegaly, associated with disease of the hypophysis, the thyroid is often enlarged, as it also is in many cases of giantism The hypertrophy of pregnancy is undoubtedly physiologic.

Retrogressive Changes.—*Atrophy* occurs prominently in old age, and is accompanied by a relative increase of the connective tissue, and a decrease in the amount of both colloid and epithelial elements This is without evident effect on the individual, and seems to be secondary to decreased needs of the organism. It has been suggested that it may have a relation of primary importance to senility In this connection it is to be noted that sclerosis of the thyroid arteries seems to occur particularly early in life. In youth atrophy sometimes gives rise to cretinism, while in adults it may lead to myxœdema However one may find very small thyroids in individuals who show no evidences of any thyroid deficiency. The gland has been found atrophied in scleroderma (Hektoen), and in various forms of dwarfism that were quite different from cretinism. Katzenstein found section of the nerves of the thyroid to be followed by marked atrophic changes.

Parenchymatous Degeneration.—Studies of the histology of the gland in various intoxications by different observers have been reported as showing many changes in the way of epithelial proliferation or desquamation, increase of stroma, etc., but the results have been so inconstant, and the structure of the thyroid is so variable, that little importance can be attached to them. It may be that in infectious diseases injury to the thyroid leads to detrimental effects to the individual, but if this is so there are no clinical or anatomical evidences to show it. Slight changes have been described in the thyroid following experimental operations in the bile ducts (Wiener, Müller, Hürthle).

Amyloid deposition occurs in either the normal gland or in goitres as a part of general amyloidosis, affecting here as elsewhere the arteries and stroma chiefly. In one hundred and eighteen autopsies in which amyloid disease was found at St. George's Hospital, amyloid was noted in the thyroid but once, but this is probably to be attributed to lack of search for it there. In goitre occasionally local deposits of amyloid may cause wax-like nodes, similar to local amyloid deposits that have been found in the larynx.

Hyaline degeneration is frequent in the stroma of goitres, in senility, and in tumors. It frequently is followed by calcification.

Fatty degeneration is not prominent in the thyroid, but may accompany the same changes in other organs. According to Erdheim, there is normally some fat in the epithelium of the thyroid.

Calcification of the stroma and arteries may occur in senility, and sometimes earlier in life. It is very common in goitres, especially in the walls of old cysts, which may be entirely enclosed in a shell of calcified material. Rarely ossification follows. The finding of areas of calcified materials in goitre is a frequent occurrence in autopsies.

Infections.—*Acute inflammation* of the thyroid is, on the whole, very infrequent. It is much more likely to occur in goitrous glands, which condition is sometimes called *strumitis*, to distinguish it from inflammation of non-goitrous glands, or *thyroiditis*. It would seem that the normal gland possesses in a marked degree the power of resisting infections, a characteristic that is perhaps due in part to its great vascularity, which is lost in the goitres with their frequent areas of degenerated tissue. When acute inflammation does occur it is nearly always suppurative, and the pus may burrow in disastrous ways in the tissues and organs of the neck. Infection may come through the blood stream, which is most frequent, or from extension from surrounding structures, or from direct external injuries, as in attempts at suicide by cutting the throat. Of 20 cases Lancereaux found that 4 occurred in the puerperal state, 3 in typhoid, 2 in nephritis, 2 in pyæmia, 2 in pneumonia, 1 in acute articular rheumatism, and 6 were independent of other diseases. Later observations have shown that of the febrile diseases thyroid infection is particularly frequent in typhoid, Schudmark having collected 13 authentic cases. Termination is most frequent by rupture and cicatrization, when the infection is not a complication of a mortal disease, although gangrene has resulted in several cases. In goitres the pus may accumulate in cystic spaces until large accumulations result. Of particular interest are the few reported cases in which myxœdema, cretinism, and Graves' disease have followed the healing of such destructive inflammations.

Chronic interstitial inflammation with formation of connective tissue may occur; little, however, is known about such a process. Probably certain cases of myxœdema, and perhaps of cretinism, are produced in this way. Often at autopsy thyroids are found that show so much fibrous tissue that the suspicion of an interstitial thyroiditis is warranted, but as no results seem to have been produced by the lesion, and as there is no apparent cause, the condition is of no evident practical interest.

Tuberculosis occurs most frequently in generalized miliary tuberculosis, but naturally is overlooked clinically, and often at autopsy. Chiari found lesions in the thyroid in seven per cent. of his cases of pulmonary tuberculosis, and in twelve per cent. of Fraenkel's fifty cases they were present. Miliary tubercles are much more frequent than the larger caseous nodules. They generally start in the interacinous connective tissue. There are three cases in the literature in which, so far as clinical manifestations showed, the thyroid lesions were primary. Tuberculosis of the cervical glands seems to be transmitted to the thyroid much less often than might be expected. According to Roger and Garnier sclerotic changes are constant in the thyroid in chronic phthisis.

Syphilis might be expected to spare the thyroid in view of the large amount of iodine that the gland contains, but it cannot be said that syphilis is proportionately less frequent than other infections of this organ. Gummata have been occasionally observed, although scar formation of the irregular, deforming type seen in other organs is perhaps as frequent. During the stage of intoxication the thyroid often participates in the general glandular enlargement. In congenital syphilis thyroid gummata are not rare, although a diffuse sclerosis is more frequent, and cases of cretinism have been attributed to the thyroid sclerosis of congenital syphilis. Myxœdematous symptoms have resulted from syphilis of the thyroid in a few instances; they were relieved by antisyphilitic treatment.

Actinomycosis may result from extension by way of the cervical fascia, and a number of such cases have been reported. Metastatic actinomycotic infection does occur, although very infrequently.

Cytotoxins.—In connection with the general study of the formation of toxins for different animals by immunizing them against various tissues from a different species attempts have been made with the thyroid. The only reports published at the time of this writing are by Gontscharukov and Mankovsky, each of whom, after injecting the immune serum into dogs obtained symptoms that were considered comparable to those resulting from thyroidectomy. Their work is, however, limited, and other more extensive work, as yet unpublished, furnishes results which are by no means corroborative.

In this connection may be mentioned the recent trials of the serum and of the milk of goats in the treatment of exophthalmic goitre. These trials have been made on the assumption that this disease is due to hyperactivity of the thyroid, and that the serum and milk of goats contains an excess of the substance that the thyroid should neutralize. Lanz, and also Moebius, have tried this treatment, and both consider it of positive benefit.

Tumors.—*Benign tumors* of the thyroid, if of epithelial nature, are difficult or impossible to differentiate from hypertrophy of compensatory or functional nature; they are all described in the article on *Goitre*. Benign mesoblastic tumors are rare, although fibromas, chondromas, and osteomas have been described. They present no special peculiarities because of their origin in the thyroid.

Years.	Carcinoma.	Sarcoma.
One to ten	..	..
Ten to twenty	3	2
Twenty to thirty	13	9
Thirty to forty	33	12
Forty to fifty	38	28
Fifty to sixty	40	26
Sixty to seventy	19	20
Seventy to eighty	3	2
Eighty to ninety	1	..

Malignant tumors have also been discussed in the article on *Goitre*, but since its publication the elaborate study

Thyroid.

of all available cases by Erhardt has appeared, and a rather full abstract of this in English may be of value. Trustworthy reports were found of about 150 carcinomas and 100 sarcomas. Of the carcinomas 65 occurred in

FIG. 4714.—Primary Carcinoma of the Thyroid.

men and 85 in women; of the sarcomas 40 were in men and 59 in women, these results agreeing with the general prevalence of thyroid diseases in women. The preceding table shows the age status of the malignant tumors.

It will be noted that the usual earlier occurrence of sarcoma is not the rule in thyroid tumors, for which fact there is no evident explanation. Trauma seemed to be the starting-point of the tumors in 3 cases, while in 3 others acute infectious disease preceded the growth, and in 2 it accompanied pregnancy. Out of 200 reports it is expressly stated that goitre preceded the tumor in 104; in but 21 was the absence of goitre specifically noted, while in the remainder this point was not mentioned. In view of the great frequency with which nodules are found in thyroid glands that are not enlarged, it is possible that in even some of the 21 cases in which there was no goitre, some small goitrous nodules existed. A location of the goitre behind the sternum seems favorable to malignant transformation, probably because of irritation. Naturally, thyroid cancer is more frequent in goitrous than in non-goitrous districts.

Anatomical Features.—Carcinoma is not to be distinguished from sarcoma by any clinical features, and anatomically also these two varieties of new growth resemble each other more closely when they are located in this organ than when they develop in almost any other organ in the body. Occasionally the growth is so diffuse from the start that its origin cannot be determined. For some time the capsule seems to offer a barrier to extension, but invasion of both blood and lymph vessels occurs early. Although sometimes of enormous size, especially when the seat of cystic and hemorrhagic dilatations, yet occasionally scirrhous carcinomas are formed of such small size that it may be impossible to palpate them. In such cases as this, careless autopsies may fail to explain, or may explain incorrectly, the origin of the metastases found. The greater part of the growth in the thyroid results from fusion of secondary growths, rather than from a process of infiltration. Histologic diagnosis is particularly difficult, not only between sarcoma, carcinoma, and endothelioma, but especially between carcinoma and benign adenomas. Medullary carcinoma is the most frequent form of carcinoma, although adeno-carcinoma and cylindrical-celled forms are not infrequent. Associated with papilliferous tendencies cyst formation often occurs, resulting in a growth described as *cystadenoma papilliferum malignum seu carcinomatodes.* The cases of scirrhus, in Erhardt's report, number but six, the growth in them being chiefly at the periphery, while the centre had been replaced by a mass of scar tissue. The rare instances of primary squamous-celled carcinoma are probably to be explained as originating from misplaced embryonal remnants rather than as growths due to metaplasia. The sarcomas are composed chiefly of round and of spindle cells. They are rarely encapsulated. Generally they infiltrate the gland diffusely; sometimes they entirely replace its structures. Much less frequent are cavernous and giant-cell sarcomas, while there are a few instances of osteoplastic sarcoma. Tumors of the type of the peritheliomas, with cells radiating about vascular channels, are not uncommon, the simpler endotheliomas being much less frequent. While a case of primary melanosarcoma exists in the literature, the report of this case makes it seem probable that the growth was really secondary. Other malignant tumors described are chondro-osteoid sarcoma and teratoma malignum.

Secondary tumors of the thyroid are but rarely found. Some of these are of vascular implantation, and some owe their origin to an extension from neighboring growths, especially of the larynx and œsophagus.

Extension and Metastasis.—After the growth once penetrates the capsule it usually grows rapidly and involves the surrounding tissues extensively, often fusing with the regional lymph-gland metastases. Often the trachea is infiltrated, twenty-two such cases being reported in the series. In these the growth took place either by direct extension from the thyroid or by transference by way of the tracheal lymphatics. The œsophagus is often also involved, as also is the sternum. While the large veins of the neck are often invaded and plugged by the growth, the arteries seldom are. The vagus and sympathetic usually resist invasion, but the recurrent laryngeal is often involved. Invasion of the muscles and other tissues of the neck is not particularly common. Metastasis usually takes place early in all

FIG. 4715.—Secondary Carcinoma Nodule in Lung, Secondary to Carcinoma of the Thyroid shown in the Preceding Drawing. Illustrates tendency of secondary tumors to approach normal gland in structure.

varieties of sarcoma and carcinoma except the papilliferous cystadenomas. Of 94 bodies thoroughly examined but 14 were devoid of metastases. Of 46 carcinomas 23 had metastases by the blood stream alone, 9 by the lymphatics alone, and in 14 the metastasis was by way of both these channels. Of 34 sarcomas the transmission was by the blood in 24, in 7 by lymph alone, and in 3 by both. This great relative frequency of dissemination of the carcinomas by way of the blood is explained by the great vascularity of the gland, the early invasion of the large veins of the neck, and the resistance to lymphatic transportation that the capsule of the gland seems to offer. Of 131 carcinomas and 107 sarcomas metastases were found in the lymph glands in 49 of the former and 18 of the latter. Erhardt has made an extensive study of the lymphatic system of the thyroid, both in health and in relation to tumor transportation, and as there seems to be no other accessible study of a similar nature, I will give here the main features.

The *lymphatics* of the lateral lobes anastomose to a slight extent, much less so than has been generally supposed. This fact explains the relative infrequency of transportation of carcinoma from lobe to lobe, in contrast to the frequent direct extension of sarcomas. The greater part of the lymphatics are collected into a few large stems on the lateral and posterior sides of the gland, where what appear to be lymph reservoirs containing large quantities of colloid can be found. These vessels pass to the glands about the large vessels in the neck, which are first and almost constantly involved when there is lymphatic dissemination. Then follows infection of the inferior and deep cervical glands below and behind the clavicles These are in turn connected with the axillary and mediastinal glands, which are accordingly next involved. The isthmus is connected chiefly with the glands lying between the œsophagus and the larynx, whose involvement is important because of the serious pressure effects that are certain to result. These glands communicate with a retro-œsophageal plexus. There are some lymph vessels that pass directly from the upper poles of the lateral lobes to the submaxillary and sublingual glands, which are occasionally infected in early stages. Similar direct branches pass from the lower poles to the mediastinal glands. After the usual routes have become plugged with tumor growth the flow may pass in any conceivable way, with corresponding location of the metastases.

In the following table is shown the order of frequency of location of the vascular metastases.

	Carcinoma.	Sarcoma.
Lungs	66	63
Bones	43	23
Liver	21	15
Kidney	13	7
Pleura	10	6
Brain	7	5
Scattering	7	6

The great frequency of osseous metastasis in thyroid tumors, similarly to what occurs in the prostate, is well known. At the same time, no satisfactory explanation seems to be forthcoming. Such metastases are most often located near the epiphyses, and often lead to spontaneous fracture, which differs from that resulting from primary bone tumor in that sometimes the bone reunites because of the formation of abundant osteophytes. Iodine has been found in the bone metastases. A table of the frequency of involvement of the bones is of interest.

Skull	30	Humerus	10
Inferior maxilla	30	Pelvis	8
Sternum	18	Scapula	4
Vertebræ	11	Malar	2
Ribs	11	Palate	1
Femur	10	Clavicle	1

Symptomatology.—The mere fact that a thyroid increases rapidly in size is hardly an indication of the presence of a malignant growth, since such an increase in size so often happens either in goitrous or in non-goitrous glands. The relative frequency of non malignant enlargements, as compared with those which are malignant, is apt to divert suspicion, particularly when goitre previously exists. Probably the most important of the symptoms is immovability of the gland during the act of swallowing, which was noted in forty per cent. of the collected cases. However, this symptom is sometimes present in benign goitre, and, since in cancer it usually is the result of extracapsular extension of the growth, binding it to the neck tissues, it is not, as a rule, a very early symptom. Dyspnœa also is of slight value, because the goitre that commonly precedes it usually causes this symptom to be wrongly attributed, although in the case of a malignant growth the dyspnœa is particularly severe. Deformity of the larynx and trachea may be observed by laryngoscopic examination when the dyspnœa is not too great. Occasionally hæmoptysis results from intratracheal extension. Obstruction of the œsophagus is sometimes severe, with symptoms much the same as in stricture from other causes; the obstruction is usually located about 20 cm. below the teeth, and phlegmon may result from the tissues becoming infected. The superficial veins are prone to be more distended than in simple goitre, and sometimes they may be palpated when filled by tumor growth, from which metastases with their resulting symptoms may develop. Occlusion of the carotid, with the consequent loss of pulsation, is of significance as regards malignancy, but still more so is the direct entrance of the vessel into the tumor mass, a condition which can be made out without difficulty. Paralysis of the recurrent laryngeal is of great importance, for although it may occur in goitre, it does so rarely. Of twenty cases of this complication, in seventeen the involvement was unilateral, in three bilateral. The vagus usually escapes and the instances of tachycardia and arrhythmia from this cause are rare. The sympathetic is involved a little more often than the vagus; it is indicated by a pin-point pupil, a narrowed palpebral opening, and local vascular dilatation with local sweating and local heat. Only in the latest stages does involvement of the hypoglossal and spinal accessory occur, with paralysis of the tongue and dropping of the shoulder. Neuralgic pains, that radiate to the ear, shoulder, and occiput, often develop in the growth, and sometimes at quite an early stage. Fever of mild grade, independent of complications, is not rare. It is important to note that cachexia is not a common accompaniment of the disease; it was observed in only twenty out of one hundred and fifty cases. The destruction of the gland does not lead to manifestations of cachexia strumipriva, partly because of the slowness of the process, but probably more because the tumor is able to form colloid itself. In six reported cases the features of exophthalmic goitre were present, and in three of these they were relieved by operation.

The average duration is about two years, with no great differences between carcinoma and sarcoma, although the most acute growths are usually sarcomas, the most chronic being the scirrhous carcinomas. Death rarely results from cachexia because of the location of the growth, which most often kills by involvement of the air passages, (either from asphyxia or from pneumonia). The asphyxia may result from œdema of the glottis, from kinking of the trachea, or from sudden swelling of the tumor through hemorrhage or congestion. Fatal hemorrhage is rare; the blood may escape into the air passages or even into the tissues.

Operative treatment is difficult, first because suspicion of malignancy in the goitrous neck comes late, and also because of the respiratory complications that are usually present at the time operation is sought. Narcosis is usually extremely dangerous, and Erhardt advises that operation be begun under local anæsthesia, and that chloroform be given if the operation becomes too painful. In the early stages it may be possible to enucleate the entire gland with success, but this is probably done oftenest when the growth is in a goitre that has not shown its malignant change clinically. Of course, thorough clearing out of the neck is the only operation possible when the capsule has been penetrated and the glands are involved. The cachexia strumipriva is to be combated by thyroid medication as the lesser of the two evils. Of 68 partial thyroidectomies (unilateral) performed during the past ten years 6 were fatal immediately after the operation—10 per cent. against 2.88 per cent. in benign goitre. Of 17 thyroidectomies involving resection of surrounding structures, including trachea or œsophagus, 5 were fatal. The results are much better now than in the previous decade. In several instances the patients remained free from a recurrence of the growth for a period of several years. In one case, according to the report, the recurrence took place as late as eight years after the removal of the original growth. Recurring growths are usually diffusely infiltrating and inoperable, frequently requiring tracheotomy.

Mixed Malignant Tumors of the Thyroid.—In reporting a case of a malignant tumor in the thyroid of a dog in 1901, which was remarkable in that the primary growth

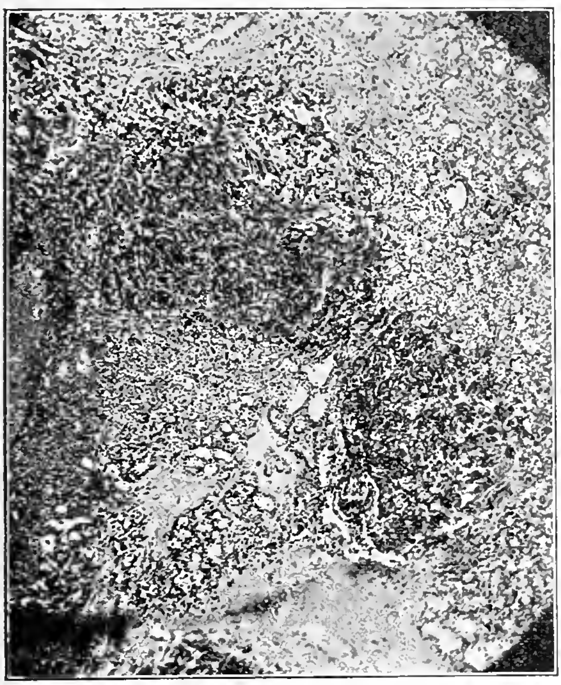

Fig. 4716.—Primary Mixed Tumor (sarcoma and carcinoma) of the Thyroid. The sarcomatous tissue is seen extending obliquely across the section.

consisted of a mixture of sarcomatous and carcinomatous elements, and had produced metastases of each kind of tumor tissue, as well as of the mixed variety, I searched the literature for other instances of mixed malignant tumors. I was able to find only two such instances, both of which were in the thyroid. Since that time a similar case has been reported by Woolley, and another by Leo Loeb, in each case in the thyroid. That all the existing instances in which a primary tumor presented a mixture of carcinoma and sarcoma were thyroid tumors, in the face of the infrequency of malignant tumors of the thyroid, is certainly of some significance, but it has not yet been determined what the significance is.

Metastasis of normal thyroid tissue and of benign thyroid neoplasms has been reported in a number of instances. This apparent exception to the rules of tumor- and tissue-growth would seem to be best explained, in the light of the latest studies, as due entirely to misinterpretation of histological pictures or to inaccurately studied cases. An example is the report of Oderfeld and Steinhaus published as recently as in 1901. This report concerned an instance in which a growth had developed in the left frontal bone, having the structure of normal thyroid gland, and it did not recur after removal. In the absence of any evidence of disease in the thyroid itself this growth was believed by the writers to be the result of metastasis of normal thyroid tissue which had proliferated in its new location as does a thyroid graft. A similar case had been reported by Riedel. In less than two years the authors named above were obliged to report an entirely different explanation. The patient had died in the mean time with multiple metastases, all of which had a structure that resembled normal thyroid. The thyroid itself showed no growth except a small encapsulated nodule, which also was of the structure of normal thyroid. They were obliged to conclude that, after all, their case was one of carcinoma of the thyroid with metastases, remarkable chiefly for the resemblance of the structure of the tumor to that of the gland. A study of many cases of thyroid carcinoma shows that the metastases have a decided tendency—which is particularly true of adenocarcinoma—to reproduce the structure of normal thyroid-gland follicles. It is highly probable that the above-mentioned facts are sufficient to explain the supposed instances of transportation of normal gland tissue or adenomas, and that it is safe to assume that when any structure of the thyroid produces metastases it is to be considered *prima facie* evidence of the malignancy of that structure.

Tumors of the thyroid in lower animals are by no means infrequent, especially in dogs, in which goitre is common. They have also been described in horses. They seem to differ not at all from those observed in man. Of the five sarcocarcinomas reported, one was in a dog, and another, that of Loeb, was in a white rat. It may be recalled that Loeb's work on the transplantation of tumors was done with a thyroid sarcoma from a rat.

H. Gideon Wells.

REFERENCES.

Many of the matters pertaining to the pathology of the thyroid have been discussed in previous volumes, under the topics of *Goitre*, *Cretinism*, *Myxœdema*, and *Organotherapy*, to which the reader is referred.

General.

Hektoen: American Textbook of Pathology, 1901, 890.
Wells: Physiology and Therapeutics of the Thyroid Gland and its Congeners. Journ. Amer. Med. Assn., 1897, October 30th, November 6th and 13th.
Murray: Gulstonian Lecture on the Pathology of the Thyroid. Lancet, 1899, March 11th, 667.
Hutchinson: Practitioner, April, 1901.

Anatomy.

Poirier et Charpy: Traité d'anatomie humaine, 1901, iv., 566.
Marshall: Variations in the Form of the Thyroid. Journ. of Anat. and Physiol., 1895, xxix., 234.
Perrando: Anatomy of the Thyroid in the New-born. Studi Sassaresi, vol. ii., sec. 11, 1902.
Reinbach: The Secretion of Colloid. Ziegler's Beiträge, 1894, xviii., 596.
Bozzi: Histology of Secretion and Excretion of Colloid. Ziegler's Beiträge, 1895, xviii., 125.
Streiff: Reconstruction of Thyroid Structure. Arch. f. mikr. Anatomie, 1897, xlviii., 579
Erdheim: Fat Granules in Thyroid Cells. Ziegler's Beitr., 1903, xxxiii., 158.
Kashiwamura: Relations of Age to Structure. Virchow's Arch., 1901, clxvi., 377.

Physiology.

Roos: Properties of Thyroiodine. Zeit. f. physiol. Chemie, 1895, xxi., 19, and xxii., 16.
Cristiani: Implantation Experiments. Journ. d. Physiol. et Path. gén., 1901, iii., 124 and 298.
Lange: Thyroid in Pregnancy. Zeit. f. Geburtsh. u. Gynäk., xl., 34
Halsted: Regeneration and Hypertrophy. Johns Hopkins Hospital Report, 1896, i., 373.
Blum: Antitoxic Function of Thyroid. Virchow's Arch., 1900, clxii., 375.

Chemistry.

Oswald, A.: Beschaffenheit und Funktion der Schilddrüse, Strassburg, 1901. Zeit. f. physiol. Chem., 1901, xxxii., 121. Virchow's Archiv, 1902, clxix., 444.
Baumann: Original Papers on Thyroiodine. Zeit. f. physiol. Chem., 1896, xxi., 381 and 481, 1896, xxii., 1.
Hutchinson: On the Composition of Colloid. Journ. of Physiol., 1896, xx., 474.
Gautier: Arsenic in the Thyroid. Compt. rend. Acad. des sciences, 1899, cxxix., 929.

Pathology.

Erhardt: Review of Subject of Malignant Tumors of the Thyroid. Beitr. zur klin. Chir., 1902, xxxv., 343. *Ibid.*, The Lymph Vessels and Glands of the Thyroid in Relation to Malignant Tumors. Cent. f. Path., 1902, xiii., 379.

Oderfeld and Steinhaus: Metastasis of "Normal" Thyroid Tissue. Cent. f. Pathol., 1901, xii., 209, and 1903, xiv., 84.
Shurley: Thyroid Tumors at Base of Tongue. Phil. Med. Journ., September 13th, 1902, 362.
Loeb, Leo: Transplantation of Thyroid Tumors in Rats. Journ. of Med. Research, 1902, viii., 44.
Wells: Mixed Malignant Tumors, "Sarcocarcinoma," of the Thyroid. Journ. of Path. and Bact., 1901, vii., 357.
Thiesen: Intratracheal Colloid Struma. Amer. Journ. Med. Sci., 1902, cxxiii., 1051.
Blum: Renal Alterations Following Thyroidectomy. Arch. Path. u. Physiol., 1901, clxvi., 403.
Schudmark: Post-typhoid Suppuration. Wien. klin. Wochenschr., July 19th, 1900.
Roger and Garnier: Tuberculosis of Thyroid. Arch. gen. de Med., April, 1900.
Lanz: Treatment of Exophthalmic Goitre with the Milk of Thyroid-ectomized Goats. Münch. med. Woch., 1903, No. 4, 146.
Moebius: *Ibid.*, 149.
Gontscharukov: Thyroid Cytotoxin. Cent. f. Pathol., 1902, xiii., 121.
Wiener: Influence of Bile on Thyroid. Cent. f. Physiol., 1899, xiii., 142. See also Muller, in Ziegler's Beiträge, 1896, xix., 152.

THYROID CACHEXIA.—See *Thyroid.*

THYROIDECTOMY. See *Goitre.* (*Surgical.*)

THYROID EXTRACT. See *Organotherapy.*

TINEAS, THE.—There are included under the general term of *Tinea* several diseases of the skin, both of the hairy and the non-hairy parts, caused by the parasitic action of various kinds of fungi belonging to the order of *Hyphomycetes* or mould fungi. These fungi have an affinity for the keratinized portions of the skin and its appendages—hair, nails, and epidermis. They attack these structures in man and some of the lower animals (horses, dogs, cats, birds), and infection in the former can often be traced to the latter source.

Although these moulds thrive best upon the surface of the skin, certain varieties sometimes penetrate beyond the superficial horny structures into the corium or subcutaneous tissues, causing the so-called *kerion* and *hyphomycetic granulomata.*

In all of the various diseases caused by these fungi they may be readily detected by the following procedure: A small piece of crust, scales, hair, or pus is placed in a

FIG. 4717.—Section of Favus scutulum, showing Spores and Mycelium of the Fungus, Achorion Schönleinii. (Bausch and Lomb one-eighth inch objective, one inch eyepiece.)

few drops of liquor potassii or a week solution of caustic soda upon a glass slide and allowed to remain for a few moments; a cover glass is then pressed gently over it. A one-seventh objective and low eyepiece will disclose the conidium or spores and the mycelium or threads, which vary in their size, shape, and arrangement according to the variety of the fungus to which they may belong. The spores are small, round or oval, bodies; and the mycelia long, sharply defined, narrow tubes which fork or branch in various directions

TINEA FAVOSA, or favus, is a contagious and very chronic disease of the hairy and non-hairy parts, due to

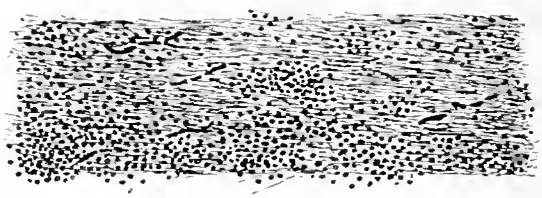

FIG. 4718.—Microsporon Audouini (small-spore fungus) in Hair. (Engman.)

the action of the fungus, Achorion Schönleinii, which causes the formation of cup-shaped yellow crusts about the hairs, and subsequent atrophy and baldness of the part.

The most common location for favus is upon the scalp, but any portion of the integument may be attacked. The nails especially are not infrequently involved by secondary inoculation from the scalp. The disease is rarely contracted after childhood, and is said to be more frequent in males. It is usually seen in this country (United States of America) among the poorer classes of foreigners, especially in Polish, Russian, German, and Italian children.

The fungus gains access to the scalp generally through direct contagion from another child, or from one of the pet, domestic animals, and shows its presence there by causing a superficial, slightly red, scaly patch, which slowly changes its aspect until it presents, at several of the follicular openings, a small yellow point pierced in its centre by a hair. These points gradually increase in size and develop into the "cups," crusts, or scutula, characteristic of the disease. They vary in size, but at an early stage show the scooped-out or cup-shape, which is produced by the luxuriant growth of the fungus at the mouth of the follicle and the rapid increase and piling up of its elements and tissue débris at the peripheral portion in a uniformly concentric manner. The convex or under surface of the scutula is rather firmly attached to the skin, at the mouths of the follicles, and when removed discloses an oozing, slightly excavated and reddened surface. If the crusts are allowed to remain for a sufficient length of time the surface upon which they rest becomes atrophic, white, and permanently bald. The yellow color of the crusts may, from the admixture of foreign material, become correspondingly modified. As the disease progresses new foci of infection may appear or the initial patch may spread peripherally, and as the scutula increase in size and numbers, they join each other, producing diffuse, "mortar-like masses," often extending over a large surface. When this occurs a peculiar mouse-nest odor is apparent.

The hairs are involved very early in the disease; their nutrition is interfered with by the mechanical influence of the mass in the follicle, and by the direct parasitic action of the fungus which grows upon the shaft and in the medulla, with the result that the hairs become lustreless, friable, brittle, and break off or fall out. When the stumps are of sufficient length a frosted or peculiar powdered effect is often seen in a reflected light, due to the access of air into the split up shaft.

The disease is generally slow in its progress, and varies in different climates and different individuals in the rapidity of its extension and growth The fungus, having gained access to the follicle, increases proportionately to the fertility of the soil, and produces the favus scutulum, varying in size from a pea to a silver dime, the presence of which by its pressure and probably by the toxicity of the organism causes a mild inflammation. This inflammation and the mechanical pressure of the scutulum, if long continued, produce an atrophy of the tissues, the contraction of which loosens the crust and it is then either knocked or cast off, leaving a pinkish-white atrophic surface, free from hair. As this process of recent infection of new and atrophy of old infected follicles is continuously going on, a patch may present crusts in various stages of evolution, with atrophy between them.

Favus of the non-hairy parts presents the same essential characteristics, in the lanugo hair follicles, as upon the scalp, except in certain cases in which a special variety of the fungus or a peculiar condition of the soil causes alterations similar in appearance to those of tinea circinata (favus à lésions trichophytoïdes). In neglected cases great yellow masses may be scattered generally over the surface of the body.

Favus of the nails (Onychomycosis favosa) may occur in two forms: in one a scutulum is formed in the deep cells of the nail, and is distinguished as a small yellow mass through the clear nail substance above it; in the other variety the nail plate is lustreless, fissured, split, and raised from its bed, but the microscope is necessary to confirm the diagnosis.

If the characteristics of favus are kept in mind the diagnosis is not difficult, except in atypical forms, when it is necessary to demonstrate the fungus in the scales in order to differentiate the condition from certain types of eczema.

The distinguishing microscopical characteristics of the favus fungus are the predominance and great variety as to the size of the spores, the short and jointed appearance of the mycelia, and the ease with which they break up into single cells (Kaposi).

Prognosis.—Favus is one of the most difficult of scalp diseases to cure, and consequently a very guarded prognosis must be given; months and often years are necessary to effect a cure.

Treatment.—The indications for treatment are to remove the crusts with a sulphur salve or carbolized oil, to resort next to epilation, and then immediately afterward to apply some parasiticide, which should be rubbed vigorously into the parts. The methods of treatment and

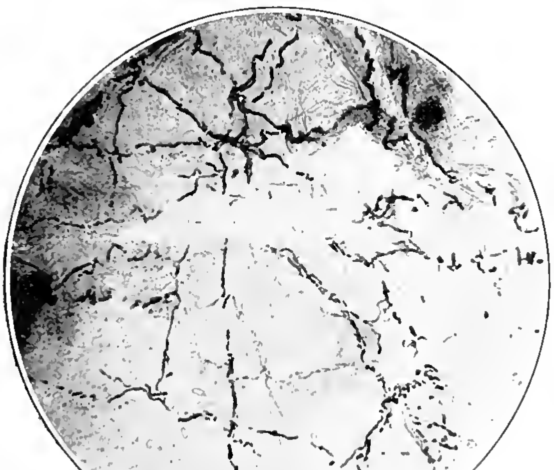

FIG. 4719.—Microsporon Audouini (small-spore fungus) in Horny Layer. (Eyepiece, three-fourth inch; objective, one-twelfth inch; oil immersion.)

agents recommended are innumerable. The hairs should be epilated well beyond the diseased area, and, whatever remedy be selected, it should be applied immediately. George T. Jackson has had good results in both ringworm and favus with iodine (one drachm of the crystals rubbed up in an ounce of goose grease). The writer has been encouraged by the results obtained from the thor-

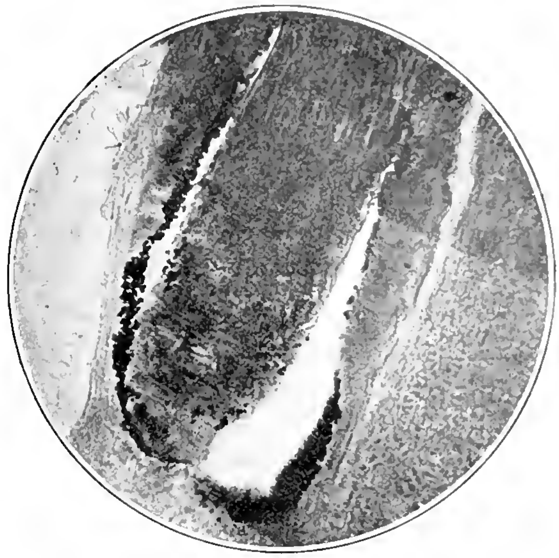

FIG. 4720. Microsporon Audouini (small-spore fungus) in the Follicle and Hair. (Eyepiece, two inches; objective, one-eighth inch.)

ough application of equal parts of trikresol and alcohol after epilation. Sulphur, chrysarobin, pyrogallic acid, tar, and numerous other parasiticides have their advocates, however. Many of them will prove efficacious in conjunction with epilation, patience, and perseverance. The most encouraging remedy of all is probably that of radiotherapy. The patch or patches should be exposed to a tube of low vacuum for from ten to twenty minutes two or three times a week, until the hairs fall out. This procedure often effects a cure. The healthy scalp should be protected by lead foil. Upon the glabrous skin favus should be treated as ringworm (Tinea circinata).

TINEA TRICHOPHYTINA OR RINGWORM.—The presence of the ringworm fungi excites upon the skin several clinical types of disease, which vary in their symptoms according to the locality attacked and the variety of the fungus concerned.

Formerly the ringworm fungi were thought to be identical until Sabouraud demonstrated (and his observations have in the main been confirmed) that they should be divided into two groups—a small-spore (*Microsporon Audouini*) and a large-spore fungus (*Megalosporon*). The latter he subdivides into *Megalosporon ectothrix* and *Megalosporon endothrix*, according to whether its elements lie outside (*ectothrix*) or in the shaft of the hair (*endothrix*), which is believed by many to be a fanciful division, as these two forms seem to be "a question of soil rather than of origin" (Crocker).

The small-spore form chiefly attacks the scalp of children, and is responsible for the majority of the resistant cases of ringworm in them. Upon microscopical examination the spores are seen to have a lack of any particular arrangement, being in irregular groups or swarms, which is characteristic. Each spore is separate from the other, and they are located outside the shaft of the hair, with a few thin, curved, branching mycelia in the medulla.

The large-spore form causes a small percentage of scalp ringworm, but is the one most commonly found in that of the beard, glabrous skin, and nails. The spores in this variety are arranged in chains with short-jointed mycelium here and there; these elements being in more or less profusion either in or outside the shaft or they may occupy both localites—an endo ectothrix.

Wherever the large-spore fungus is found, especially the ectothrix variety, there are more objective signs of inflammation. Sabouraud affirms that the ectothrix is

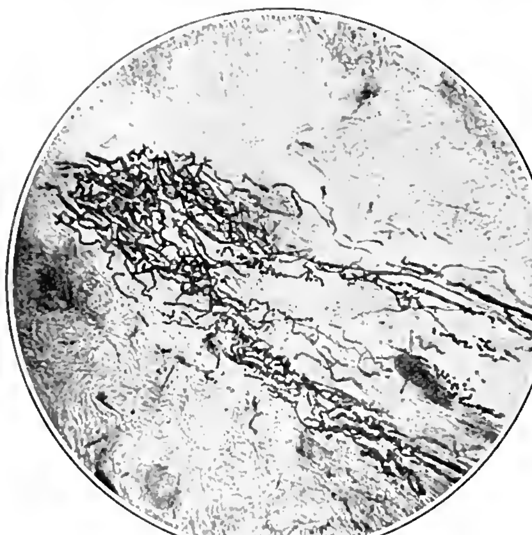

FIG. 4721. Microsporon Audouini (small-spore fungus) in Tissue about Follicle. (Eyepiece, one inch; objective, one-twelfth inch; oil immersion.)

always of animal origin, and is the cause of all pustular ringworms; others, however, have found the microsporon in similar conditions.

If the arrangement and location of the spores in the different forms be remembered, one can upon microscopical examination readily determine the variety to which they belong.

Trichophytosis is contagious, the fungus being conveyed by direct contact or through the media of toilet articles, wearing apparel, bed linen, etc. It is less frequent after the age of fifty, and some individuals are probably more susceptible than others. In children the scalp and in adults the glabrous skin and beard are the regions most frequently involved.

TINEA TONSURANS OR RINGWORM OF THE SCALP occurs almost exclusively before the age of fifteen years.

Since the investigations of Sabouraud and others it is necessary to treat the clinical aspects of scalp ringworm especially from a pathological standpoint, according to the variety of the invading fungus.

Microsporon Ringworm of the Scalp.—The small-spore fungus is accountable for from eighty-five to ninety per cent. of all scalp ringworms, and occurs exclusively in children. It is generally seen as one or several round or oval bald-looking patches of a slaty, dull gray color, their size dependent upon the length of time they have existed, as they begin from small points and spread peripherally. Various bizarre or gyrate outlines may be described if several patches coalesce. The infected surface, which may be more or less thickened, is covered by fine whitish scales, and the hairs are found upon close inspection to be twisted, bent, or broken off close to the scalp. This circumstance, coupled with the fact that a fine white sheath extends a short distance upon the shaft, gives the patch the appearance of being bald. When a hair is pulled it readily breaks, showing the disorganizing effect of the fungus upon it. Under the microscope the hair is seen to be frayed at the ends, and the white sheath to be composed of the fungus elements. In but few cases are there any symptoms of active inflammation.

Megalosporon Endothrix of the Scalp.—The endothrix fungus is divided by Sabouraud into two subdivisions: one with mycelium which breaks easily ("fragile") and the other with a more resistant mycelium ("resistant"). These varieties cause an alopecia, which is often quite similar in appearance to alopecia areata. There may be one or several smooth bald patches disseminated over the scalp, with a few illy-nourished hairs scattered over it, and numerous "black dots" here and there, which upon extraction prove to be broken and disorganized hairs. The patches are irregular in shape, and in some cases are pityriasic. In this form of ringworm there may be scattered groups of a few broken hairs upon a scaly, scurfy scalp.

"Black-dot ringworm," "disseminated ringworm," "bald Tinea tonsurans" are terms formerly used by English writers to designate this form.

Megalosporon Ectothrix of the Scalp.—The ectothrix always causes more inflammatory symptoms than do the other types. The infection begins as a red, scaly ring with a distinct border composed of papules, vesicles, or, later, pustules, the hairs becoming disorganized and broken as the disease progresses. In many cases the fungus penetrates deeply into the follicle and produces marked inflammation with suppuration, forming a fluctuating mass, from which pus oozes at the openings of the follicles. The condition thus caused is known as *Kerion.* Several English observers have seen the microsporon cause the same process.

Granuloma trichophyticum of Majocchi is analogous to kerion; so also is *hyphomycetic granuloma* (Schamberg), which may simulate a malignant growth. *Conglomerate pustular folliculitis* or *agminate folliculitis* consists of a circumscribed, highly inflamed patch, occurring generally upon the hand or arm, at the follicular openings of which is a pustule or an oozing point from which pus can be expressed—a pus which contains double-contoured spheres, the spores of the Trichophyton ectothrix.

The diagnosis of scalp ringworm is made by the broken hairs and the microscopical demonstration of the fungus elements.

The prognosis as to ultimate cure is good, but from three months to a year is a conservative estimate as to the time necessary for the cure, especially in the microsporon type. Permanent baldness often remains at the site of kerion.

TINEA CIRCINATA, TINEA CORPORIS, OR RINGWORM OF THE BODY are the terms applied to the invasion of the non-hairy skin by the trichophyton fungus, all varieties

FIG. 4722.—Megalosporon ectothrix (large-spore fungus) in Hair. (Eyepiece, three-quarter inch; objective, one-twelfth inch; oil immersion.)

of which cause at the beginning of infection a circular scaly pink patch that spreads peripherally with a pinkish border, and clears up or involutes in the central portion.

leaving a faintly yellowish tinge in its wake, thus forming a ring. The border of the ring may be minutely papular or vesicular.

The rings caused by *microsporon* are small, seldom larger than a silver quarter, and are generally seen upon the exposed parts in children with ringworm of the scalp.

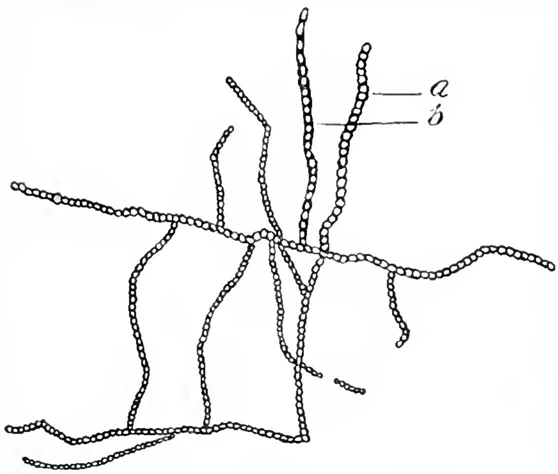

FIG. 4723.—Megalosporon Ectothrix (large-spore fungus) from Nail Scrapings. *a* and *b*, Filaments of very large spores. (Engman.)

Not infrequently in this variety small scaly, reddish plaques are seen which do not undergo central involution to form rings.

The rings caused by *megalosporon* are large, often attaining several inches in diameter; they are scaly; the border may be papular, vesicular, or crusted; all the symptoms are more inflammatory than in the former type. If several points of infection occur close together, the rings may meet by peripheral extension, forming various gyrate figures.

When the infection occurs in the genito-crural or axillary regions, where the heat and moisture of the part favor the growth of the organism and a more inflammatory reaction, there ensues a condition which was formerly called "eczema marginatum," and can often be differentiated from certain forms of eczema only by the demonstration of the fungi.

The diagnosis of ringworm of the body is difficult only when there are numerous foci scattered over the body, and when the patches fail to form rings, in which event microscopical aid is necessary to differentiate it from eczema seborrhoicum of Unna and from certain analogous forms of that disease.

The disease in all its various phases is readily amenable to treatment.

TINEA BARBÆ, TINEA SYCOSIS, BARBER'S ITCH, is a folliculitis of the hairy portion of the face caused by the *Trichophyton Megalosporon Ectothrix*. The disease is generally contracted in barber shops, the fungus being most probably conveyed by the shaving brush or "pinchers" used by barbers for extracting "ingrowing hairs."

The earliest symptoms consist of one or more scaly spots or rings of a rather inflammatory nature. Scattered on or about the border of the patch are several hard, raised papules or pustules, pierced by a hair. The subsequent increase of symptoms depends upon the soil, and upon neglect or improper treatment; more papules and pustules develop, the hairs are loosened and may easily be plucked out. The part burns and itches, and is inflamed and swollen in appearance. By the massing together of a number of infected follicles, pea- to nut-sized nodules form, the surface of which becomes crusted. When the crust is removed a raw, excoriated surface is exposed, dotted by oozing points. This appearance has been compared to the cut surface of a fig; hence the term sycosis (σῦκον, a fig). There is only moderate tenderness or pain about these lesions.

The diagnosis of Tinea barbæ is readily made by the ring, by the nodules, and by painless extraction of the hairs; in mild and atypical cases it may be easily confounded with coccogenic sycosis ("non-parasitic"). The latter has not the deep lesions or lumpiness, is not so rapid in its progress, and the hairs are not loose and are painful to extract.

TINEA UNGUIUM, ONYCHOMYCOSIS TRICHOPHYTINA, RINGWORM OF THE NAILS, is due to the Megalosporon ectothrix. It is usually a secondary auto-inoculation from ringworm elsewhere, causing a splitting up of the nail plate, rendering it brittle, dull, yellowish, ridged or striated transversely or longitudinally; finally, the separation of the nail plate from the bed may occur. One or more nails may be involved, but seldom symmetrically.

A diagnosis from various other nail diseases which present similar symptoms can be made only by microscopical examination of the nail scrapings (Fig. 4723).

The condition is exceedingly difficult to treat successfully, and may last for years.

TINEA IMBRICATA or TOKELAU RINGWORM is a form of ringworm which occurs in the tropics; it is characterized by the formation of large concentric rings of scales, involving a large part of the body surface, but rarely attacking the hair or follicles. It is probably due to a special variety of the large-spore trichophyton fungus.

TINEA VERSICOLOR, PITYRIASIS VERSICOLOR, CHROMOPHYTOSIS is a parasitic disease caused by the *Microsporon furfur*, a fungus, and characterized by variously sized and shaped pityriasic patches of a yellowish, fawn color, which occur most frequently upon the trunk. The disease may be said to be confined to the trunk, but it at times is seen upon the neck, arms, thighs, or other parts. Allen claims that the hairs of the pubic region often conceal a patch that may remain as a focus for subsequent reinfection. The patches begin as small, roundish, yellow, or light-brownish points, which increase in size very slowly by peripheral extension or by the coalescence of several points of infection, thus forming variously sized patches; sometimes one patch may involve a large area of skin, possibly more or less of the whole trunk. The borders of the patches are sharply defined, almost imperceptibly raised, and the surface, especially near the periphery, is slightly scaly, the scales being fine and of a dirty white color. In the dark-skinned races the diseased areas are darker than the surrounding skin. In very fair individuals it is not uncommon to find a tinge of red added to the fawn color of the patches, showing through the yellow, especially in hot sultry weather.

The infection progresses very slowly, and shows no tendency to self-limitation. The fungus, the Microsporon furfur, is the sole cause of the condition, and is

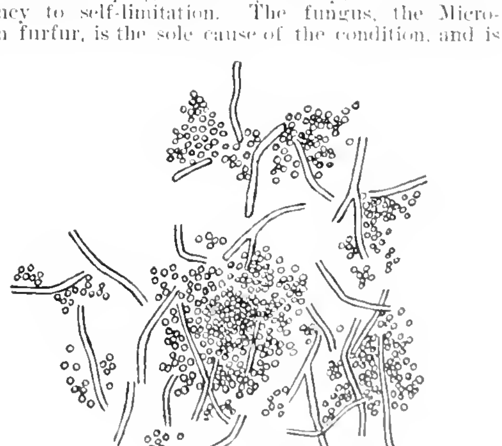

FIG. 4724. Microsporon furfur, Fungus of Tinea versicolor. Spores and mycelium. (Diagrammatic.)

easily detected by scraping off a few of the scales and examining them in liquor potassii as before described. It is readily differentiated from the other fungi by the large size of the conidia or spores and by their tendency to occur in groups or masses over the field; the mycelia are fine and interlace between these groups. The Microsporon furfur grows luxuriantly in the upper layers of the epidermis, causing no appreciable irritation, and produces by its strongly refractile spores the yellowish color of the infected regions. It is supposed to have greater affinity for a moist skin; it is therefore found most frequently in those who perspire freely. Perfectly healthy adults are attacked as well as the delicate. It is exceedingly rare in children. The disease is contagious, but mildly so, as some special condition of the epidermis besides moisture is necessary for the growth of the organism.

In all suspected cases the scales should be examined for the fungus. Mild parasitic applications cure an attack. Of these the most elegant and cleanly is a saturated aqueous solution of hyposulphite of soda, applied night and morning after a soap and water bath. A cream of ten-per-cent. sulphur precipitate in Unguentum aquæ rosarum is equally efficacious. Various other parasitic ointments and lotions are used. The attack is easily cured, but when once a person has become susceptible recurrence is the rule; therefore each relapsing spot should at once be destroyed, with any of the agents mentioned; care also being given to the sterilization of wearing apparel and articles of the bath.

Treatment of the Various Forms of Tinea.—The cure of all the types of ringworm depends upon the efficacy with which the parasiticides are brought into contact with the offending organism. This is easily enough accomplished upon the glabrous skin but is quite difficult when the hair follicles are infected. In the latter event it is recommended to extract the hair by epilation, which often proves useless, as the hairs are frequently so badly disorganized that the least traction breaks them off close to the scalp, or just within the follicle. This, however, is not true in ringworm of the beard, where the disease is due to the ectothrix variety, with the formation of pus and the subsequent loosening of the hair. In the infection of the scalp in children, by the microsporon fungus, which disorganizes but does not loosen the hair, it is probably better to "shingle the head than to spend useless time and trouble breaking the hairs by epilation. Epilation by means of the *x*-rays is not indicated here as in favus, for fear that permanent baldness may ensue. The latter disease (favus) frequently produces permanent baldness independently of epilation, while it never occurs in ringworm except in kerion.

Chrysarobin, pyrogallic acid, oleate of mercury, iodine, salicylic acid, sulphur—in fact, all antiparasitic agents, have been used in ringworm of the scalp with more or less success. Whatever remedy be selected it is necessary that it be applied thoroughly and often, and in a medium which is capable of being manipulated into the follicle. It is also necessary to employ the agent in sufficient strength to kill the parasite and cause a not too violent reaction of the skin. Of all these agents chrysarobin, in the following combination of Unna's, has, in the writer's hands, proved the most efficacious: Chrysarobin, 2 parts; ichthyol, 5 parts; salicylic acid, 5 parts; and vaseline, 88 parts. This is applied to the whole scalp (after the hair has been cut as short as possible) twice daily, with a soft tooth brush. A cloth cap is then fastened to the head by a bandage passed along the hair line; this prevents the chrysarobin from getting upon the smooth skin or in the eyes. The latter accident should be carefully avoided. The scalp will show irritation from this treatment in from two to four days. Then the chrysarobin salve should be washed off and a soothing cream or ointment applied until all irritation has subsided and the reduced or hardened epidermis scales off. This procedure should be repeated for several courses, until the hair again grows to sufficient length to show whether or not the fungus has been entirely destroyed. Frequent microscopical examinations are a great assistance in watching the effects of the treatment. The chrysarobin discolors the skin and hair and is an heroic procedure. In young girls, and when the patient cannot be carefully observed, less heroic measures are advisable. In all cases in which the sacrifice of the hair is not too great it should be closely cut, and some weak parasiticide applied to the whole scalp, while the patches themselves may be treated more vigorously. A very good procedure is to apply to the entire scalp a weak sulphur cream and attack the patches with one of the stronger parasiticides previously mentioned. Trikresol, lately introduced by MacGowan, is a most valuable remedy. The patches should be first rendered free of fat and débris by washing with ether or benzin. A mixture of equal parts of trikresol and alcohol is then well rubbed, with a cotton swab, into and beyond the patch. This applicaion will cause some desquamation, which will last for several days, when the remedy may be again applied; some mild antiseptic cream being used in the mean time. Precipitated or sublimed sulphur, in the proportion of from twelve to fifteen per cent. in lard or vaseline, is slow but efficacious. It is well to remember that it is useless to continue applying a remedy after it has caused thickening of the epidermis, and therefore more obstruction in the mouths of the follicles, thus protecting the fungus. It is better to wait and assist the desquamation of the epidermis by the use of a mildly antiparasitic salve before proceeding.

Ringworm of the body is best treated by means of pastes, to which is added a parasiticide. The pastes adhere to the skin, and are not easily rubbed off. The best of these is one made of equal parts of oxide of zinc, starch, vaseline, and lanolin. To this may be added either sulphur (from six to twelve per cent.) or ammoniated mercury (four to six per cent.). Taylor recommends one to three grains of mercuric bichloride to an ounce of the compound tincture of benzoin. Resorcin, salicylic acid, ichthyol, and preparations of tar are all efficacious in salves, pastes, or lotions.

"Eczema marginatum" is, for the reasons already given, the most difficult of the so-called body ringworms to cure. In this affection pastes often prove irritating; the application of salves, dusted over with talcum powder, is more agreeable. The itching and consequent rubbing and excoriation are elements to be dealt with in this locality; therefore the use of an antipruritic, like carbolic acid, is necessary. The writer has been pleased with the following: Carbolic acid, gtt. v.; precipitated sulphur, gr. xx.; balsam of Peru, gtt. xx.; vaseline, ℥ v.; lanolin, ℥ iij. Lotions, unless the case is very mild, do not act well in this locality.

Tinea barbæ in the mild form is readily cured by the application of any of the parasiticides mentioned. In severe cases the crusts should be removed with carbolized or salicylated oil or vaseline; the diseased hairs should be epilated and the beard shaved, immediately after which the remedy is rubbed in. Sulphur, five to ten per cent. in vaseline, or in equal parts of lanolin and vaseline, is generally useful. Xeroform, five per cent. in olive oil, has proved valuable in the writer's experience.

In Tinea unguium the nail, after being scraped, should be soaked in a hot alkaline solution, and the parasitic salve rubbed in; then some of the salve should be spread upon cloth and bandaged on, or held in place by a finger cot. Unna applies, after the scraping, a solution of bichloride of mercury, in flexible collodion thinned with ether (bichloride of mercury, gr. i.–iv.; ether, ℥ ij.; flexible collodion, ℥ vi.). *Martin F. Engman.*

TINNITUS AURIUM.—DEFINITION.—Any subjective noise, heard in one or both ears, as the result of some abnormal condition somewhere in the body.

CAUSES.—Anything which irritates the nervous mechanism of hearing, in any part, from the cortex of the brain to the cochlear hair cells. Tinnitus has been noted as an *aura epileptica* (cerebral irritation); at the onset of an attack of *syncope* (cerebral anæmia); and at the time of an attack of cerebral hemorrhage (general cranial hyperæmia). It also occurs as the result of poisoning by certain drugs (quinine, salicylic acid). The precise physiology of this action is not clear, but it is probably due to cerebral irritation, since it can be readily controlled by the administration of bromides. Tinnitus is also observed in meningitis. This may depend upon irritation of the auditory nerve in its course.

As commonly seen, however, tinnitus is due to some form of ear disease, and some of these cases present perhaps the most perplexing problems which the whole range of otology can offer. For it is a matter of common observation that a moderate degree of deafness may pass unnoticed for years, and finally be discovered, as it were by accident, by a patient's friends. Tinnitus, however, never fails to be a matter for complaint, causing as it does a degree of discomfort always considerable, and being often of grave danger to the patient's bodily and mental health. It has been claimed that some suicides have been caused by loud and persistent tinnitus, but the writer has not been able to find any reported cases. It is, however, almost certain that in persons predisposed to mental disease, tinnitus has led to auditory hallucinations, and thus has acted as the determining cause of an attack of insanity.

According to Sexton, fifty per cent. of all ear patients have more or less tinnitus. In the writer's experience a greater or less degree of it is so common in chronic deafness that its absence in any case is worthy of comment. It is seen in diseases of all parts of the ear. It is often a prominent symptom in cases of impacted cerumen, also in furunculosis of the meatus externus. It may also be found in cases of tubal catarrh, of stricture of the Eustachian tube, of acute otitis media, catarrhal or purulent; it is a common symptom in all forms of chronic otitis media, and in the lighter forms of otitis interna, where the auditory nerve is not completely destroyed. The worst and most obstinate cases are those of otosclerosis. This disease, which has been only of late differentiated from chronic aural catarrh, is one of the most frequent causes of tinnitus, which is usually an early, and may be during months or years the only, symptom.

Tinnitus presents itself under various forms, both as to quantity and as to quality of noise, and also as to constancy or intermittency of its occurrence. As to quantity, the noise may vary from a soft, barely noticeable rustle, as of the leaves on a tree, to an excessively loud screaming sound, like a steam whistle. The latter extreme is, of course, rare. All intermediate degrees, however, are constantly seen. The quality of the sound varies greatly. It may be high-pitched or low-pitched, blowing like the wind, whistling like the escape of steam, crackling like a wood fire, or occasionally detonating like an exploding firecracker. More serious are those rare cases in which the noise takes the form of music, or of human speech. It is always possible that in such a case we are dealing with a psychopathic patient, and we must therefore be on the watch for the development of genuine auditory hallucinations. Many patients have two or more kinds of tinnitus at once. The writer has at present two such cases under observation.

Panse (*Zeit. für Ohrenheilkunde*, 1898, p. 244) attempted to show that low-pitched sounds occur chiefly in diseases of the sound-conducting apparatus, and those of high pitch in conditions affecting the labyrinth. His conclusions are denied by Politzer, with whom the writer is inclined to agree, never having been able to satisfy himself that there was any necessary relation between the kind of noise and the anatomical condition causing it.

Constancy or intermittence of the noise is a more important feature, because it seems to have a bearing upon prognosis. In certain cases tinnitus occurs in waves, synchronous with the beat of the pulse. In these cases it is always possible that the underlying lesion is of the type of a simple congestion, which may be curable, partly or wholly. In other cases the wave of sound comes with inspiration or expiration (respiratory tinnitus). These cases are sometimes due to the rushing of the inspired air through an abnormally patulous Eustachian tube, as in a case reported by Kerrison (*Med. Record*, April 19th, 1902). In this particular case treatment was wholly successful, and the patient, a man over seventy years of age, was completely cured.

Some patients say that they hear the noise only when lying down, and especially at night. These are usually cases of the milder type. This may depend upon the recumbent position, or more probably perhaps upon the fact that during the hours of rest one has fewer distractions than at other times. To interfere seriously with sleep, tinnitus must be very severe. There are other cases in which the tinnitus is made worse by bending forward, or by or during heavy exercise.

It must also be noted that some persons have the knack of causing at will certain sounds in the ear. These are usually clicking sounds, probably caused by opening and shutting the pharyngeal orifice of the Eustachian tube, by action of the tensor palati muscle. This action sometimes takes place involuntarily, and the noise thus produced is one of the class known as *entotic*. These noises are actual, as opposed to those which are strictly subjective, and in many cases may be heard by the examiner. Apart from the clicking caused by action of the tensor palati, there may be clonic contractions of the intrinsic muscles of the ear (tensor tympani and stapedius) which cause ticking or humming sounds. There are also the so-called vascular entotic noises, caused by anomalies of the blood-vessels. According to Politzer ("Diseases of the Ear," 1902, p. 777) they may be due to the following pathological conditions: dilatation of the arterial branches within the tympanum, changes in the carotid canal, cardiovalvular lesions, goitre, cranial aneurisms, or chlorosis (*bruit du diable*). They are synchronous with the pulse, and may, in some instances, be heard by auscultation all over the head. Attempts which have been made to relieve these cases by ligating the carotid artery have given unsatisfactory results. In a case operated upon in this manner by Linsmayer, and reported by Politzer (*loc. cit.*), the operation was followed by death from softening of the corresponding cerebral hemisphere.

Prognosis.—It goes without saying that the prognosis as to recovery in any given case depends upon the nature of the underlying anatomical cause. In a general way, however, it may be said that the hope of recovery from tinnitus is much less than the hope of relief from deafness. Many patients who complain of both deafness and tinnitus gain a very fair degree of hearing, while their annoying ear noise continues about the same. Cases of intermittent tinnitus offer a somewhat better prognosis than where the noise is constant, as the causative lesion is apt to be of a less permanent character. Slighter degrees of tinnitus, and those in which the noise has existed only for a short time, are more favorable than those of severer character and longer standing.

Treatment.—The successful treatment of tinnitus depends entirely upon the possibility of discovering and removing its cause. Therefore it may be said that the treatment of tinnitus is the treatment of diseases of the ear. Accuracy in diagnosis is essential. Every patient is entitled to the most careful and painstaking examination of which the aurist is capable. A complete history of the case must first be taken, and all possible causes, apart from the ear, must be considered. Next comes a detailed physical examination of the auricle, the external meatus, the drum membrane, and the mastoid region, followed by examination of the nose and throat. By means of the auscultation tube we should listen to the sounds that are generated while air is being forced through the Eustachian tube into the middle ear. Finally, all known means of functional testing of the hearing should be employed—voice, watch, acoumeter, the various tuning-fork tests (Rinné, Weber, Gellé); also the Galton-whistle test for the upper tone limit should be tried in order to acquire as complete a knowledge as is possible of the anatomical condition. Treatment then is directed to rectifying what is wrong, so far as this can be done. Impacted cerumen must be removed. Furunculosis or other disease of the canal calls for appropriate treatment. A retracted drum membrane or a chain of ankylosed ossicles must be restored to the normal condition by inflation, pneumo-massage, or the Lucae pressure probe. A contracted Eustachian tube calls for dilatation by the use of bougies. The ordinary filiform urethral bougie serves this purpose well. Of intratympanic conditions suppurative cases call for measures which tend to dry up the discharge, thorough cleansing, the removal of granulations, polyps, or cholesteatomatous masses, and perhaps for ossiculectomy or the Schwartze-Stacke operation (see Vol. VI., p. 706).

Of the non-suppurative cases it is very important to differentiate between chronic aural catarrh and otosclerosis. The former disease is best treated by attention to the nose and throat, with such local treatment for the middle ear as has been mentioned above. The latter disease has only lately been recognized, and, as it is a frequent cause of obstinate tinnitus, calls for special mention. It is of the nature of an hyperostosis, and usually affects the region about the oval window, on either the tympanic or the vestibular side, so that it may give symptoms of ankylosis of the stapes, or of labyrinthine involvement, or both. It is a chronic progressive disease with intermissions. During the active periods there is usually a reddish tinge to the drum membrane, due to the shining through of the congested promontory. At other times the membrane may appear normal, in both character and position. The disease is due to injury, or to extra-aural causes, usually auto-intoxications, from gout and allied conditions, or to disease elsewhere in the body, acting reflexly from a distance, as certain uterine and ovarian conditions. Hartz (*Ann. Otol., Rhinol., and Laryngol.*, vol. xi., p. 637) says the disease is very frequent at the puerperium. The treatment is to be directed to the cause. In the acute stage active local treatment aggravates the condition. Probably in the future, when the physiology of nutrition shall be better understood, some dietetic and hygienic régime will be discovered which will help these patients. At present no treatment does much good.

Tinnitus, due to labyrinthine disease, is often syphilitic. Such cases call for iodides in large doses, and show better results with mercurial inunctions than without them. Pilocarpine also sometimes helps these cases. It is best given at bedtime, beginning with one-tenth of a grain and increasing until the dose is sufficient to cause profuse sweating.

Palliative local and general treatment usually gives only temporary relief. Politzer ("Diseases of the Ear," 1902, p. 778) recommends sodium bromide internally, five to fifteen grains three times a day. He also recommends a small blister over the mastoid region, followed by applications to the vesicated area of antimonial ointment or bisulphate of quinine. He also speaks of instillations into the meatus of about five drops of a mixture of tincture of valerian, 4 parts, and acetic ether, 3 parts, in glycerin, 40 parts. These measures at least tend to satisfy the patient that his distressing malady is not being neglected by his physician. *Donald M. Barstow.*

TIN, POISONING BY.—Metallic tin, if pure, has no injurious action on the system. The soluble salts of tin, especially the chlorides, are violent irritants; but cases of poisoning by them have rarely come under observation. Two grams (ʒ ss.) of a solution of the chloride has caused death in three days. In the treatment of cases of poisoning by these compounds, milk or albumen, alkaline carbonates, and emetics are indicated first. The after-treatment should be symptomatic.

The compounds of tin owe their toxicological importance chiefly to the fact of their frequent occurrence in various articles of food; but whether this occurrence of tin is attended with any danger to health is still a disputed question. A non-fatal case of acute poisoning has been attributed to the use of salt which had been dried on a tin dish on the stove. It has been suggested, however, that the symptoms described might more reasonably be attributed, in the absence of a chemical analysis, to lead poisoning; since much of the tin plate formerly used was not pure tin, but an alloy of tin with lead.

Many cases of acute poisoning have followed the use of canned foods, and in some of these cases the symptoms have been attributed to tin; but rarely, if ever, has the theory of tin poisoning been substantiated by an analysis of the suspected food. It is a well-recognized fact that many cases of acute sickness have been caused by the ingestion of food which was entirely free from injurious metals. It is considered, therefore, more reasonable, by some authorities, in the absence of any chemical analysis, to attribute the symptoms which frequently follow the ingestion of canned foods to some cause other than metallic poisoning, such as putrefactive changes taking place in the food; or, in a certain number of cases, to idiosyncrasy. Some, while denying the probability of tin poisoning, admit the possibility of poisoning by other metals, as lead or zinc, the former derived from the tin plate or from the solder, the latter from the soldering fluids used in sealing the cans.

It is not disputed that canned foods frequently contain tin, which has been dissolved from the tin plate by the action of acids or other constituents of the food, or which has been introduced by the careless use of stannous chloride, which is a constituent of some of the soldering fluids used in sealing the cans. But the quantity of tin is usually small, varying from a few one-hundredths of a grain to one grain per pound, rarely approaching, however, the higher figure. These amounts are not likely to give rise to symptoms of acute poisoning. Winter Blyth states that he found in some samples of canned fruits as much as 14.3 grains of stannous hydrate per pound, and that the average amount in all examined was 5.2 grains per pound. In some cases the juice had a metallic taste. With such quantities of tin, in a form easily absorbed by the system, the possibility of acute poisoning must be admitted. But the facts at present known to us do not seem to warrant the conclusion that acute tin poisoning, as a result of the use of canned foods, is an occurrence to be greatly feared. A quantity of tin salt sufficient to cause poisoning would probably be recognized by the taste, and the food thus contaminated be rejected as unpalatable.

Stannous chloride is sometimes added to the cheaper grades of molasses to lighten the color and give the sample the appearance of a higher grade of molasses; and sugar crystals are said to be washed with a similar solution, the greater part of which afterward passes into the molasses. Whether this use of the tin salt is attended with any danger to the consumer has not been determined. The chloride is immediately decomposed by some of the constituents of the molasses and converted into an insoluble compound, which is deposited with the sugar, the clear molasses usually not retaining any of the tin. The composition and physiological action of the resulting insoluble compounds have not been investigated.

The question of chronic poisoning, as a result of the habitual or frequent use of foods containing traces of tin compounds, is an important one, which has not yet been thoroughly investigated, and concerning which opinions differ.

In order to determine how far absorption into the circulation may produce disturbances of health, T. P. White has investigated the action of the double tartrate of tin and sodium, and of stanno-triethyl acetate on animals. He places tin near lead in its toxic power. The administration of the acetate is followed by two series of symptoms—one referable to the digestive tract, namely, loss of appetite, nausea, vomiting, abdominal pains, and diarrhœa; the second referable to the central nervous system, manifested by weakness of the extremities and paralysis, diminution of the power of the heart, severe respiratory disturbances, and convulsions. The urine is scanty, has a high specific gravity, and frequently contains albumin. According to White, tin acts directly on the intestinal tract, whatever the channel by which it is introduced. Post-mortem examination showed: Mucous membrane of the stomach and intestines soft, covered with mucus, and hyperæmic; heart in diastole; blood thin and dark; lungs collapsed and hyperæmic; liver pale and somewhat enlarged.

Similar results were obtained with the double tartrate, but larger doses were required. After the administration of these salts tin was found in the muscles, liver, kidneys, brain, heart, and urine. The blood in most cases contained no tin. White concludes, however, as a result of many experiments, that there is no danger of tin poisoning resulting from the contact of fruits and vegetables with the metal, and that cases of poisoning which have been attributed to tin were due to solder or to metallic impurities in the tin.

Ungar and Bodländer have also investigated the action of the two tin salts studied by White, and with similar results; concluding that the question of the poisonous action of the tin compounds, aside from any local effects, must be answered in the affirmative. To determine whether foods containing tin are likely to produce any local or general effects, they fed dogs and rabbits on fruits, etc., containing small quantities of tin, but failed to observe any irritant action on the mucous membrane of the stomach and intestines. The absorption of tin under such conditions was proven by its detection in the liver, spleen, kidneys, brain, heart, muscles, and urine. None was detected in the blood. The authors also detected tin in the urine of man in two cases.

William B. Hills.

TOBACCO (*Tabacum*, U. S. P.; *Tabaci Folia*, B. P.; *Folia Nicotianæ*, P. G.; *Nicotiane, Tabac*, Fr. Cod.) consists of the dried leaves of *Nicotiana Tabacum* Linn., of the order *Solanaceæ*. It is a rank, viscidly hairy plant, four to six feet high, with coarse, entire, alternate leaves, having a disagreeable odor and taste and turning brown on drying. The simple stems terminate in panicles of rose-purple flowers. The calyx and corolla are five-toothed, the former tubular, the latter funnel-shaped and conspicuous, about two inches long. There are five stamens and a single two-celled ovary. The fruit is a two celled capsule an inch long, opening by two or four valves. The seeds are small and numerous.

Tobacco is a native of America, but is now grown in many parts of the world. The seeds are sown in beds and in early spring are transplanted. The flowering tops are cut off to encourage the growth of the leaves. In August or September the leaves are gathered, dried under cover, then piled up and allowed to ferment or "sweat." The details differ in different tobacco-raising regions, and the further process depends upon the kind of tobacco to be made.

Nicotiana Persica and *Nicotiana rustica* are also used in making Turkish tobacco, from which Egyptian and Turkish cigarettes are made.

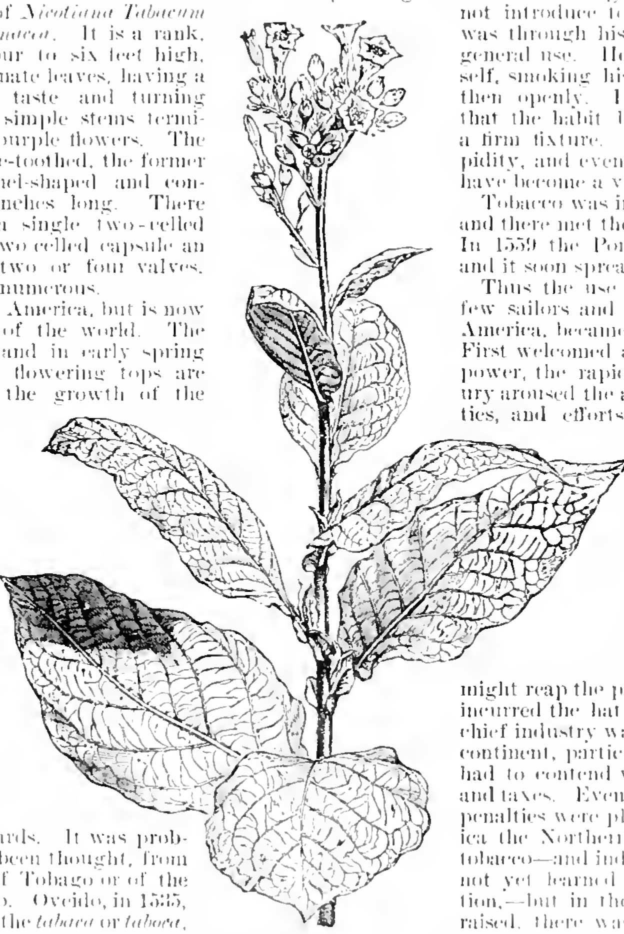

Fig. 4625.—Nicotiana Tabacum Linn. (Baillon.)

The word *tobacco* was introduced by the Spaniards. It was probably not derived, as has been thought, from the name of the island of Tobago or of the Mexican state of Tobasco. Oveido, in 1535, described an instrument, the *tabaca* or *taboca*, used for smoking or inhaling various substances. It was a hollow stick, shaped like the letter **Y**. The small ends were placed in the nostrils and the powdered drug was put in the other end. Ernst believes that the term was derived from a Guarani word meaning "to eat, sucking." Las Casas applied it to rolls of tobacco like cigars. The words *uppowoc* and *pætun* were used in Europe at first, but *tobacco* soon displaced them.

Tobacco was introduced into Europe from the American Indians. Smoking was first observed during the first voyage of Columbus. In November, 1492, he sent an expedition into the interior of Cuba, and members of the party noticed the Indians smoking rolls of the dried leaves, the prototypes (shall we say?) of our Havana cigars. Cartier and other followers of Columbus also observed the practice, and the sailors returning from these early expeditions carried it back to Europe.

The introduction of the habit into other European countries and its spread through the whole world is a most remarkable chapter, and one which can only be touched upon here. In 1559 Jean Nicot, ambassador from France to Lisbon, whose name is perpetuated in that of the genus Nicotiana, sent some seeds to Catherine de Medici, who powdered them and used them as medicine. Thus tobacco was introduced into France.

In England tobacco was known as early as 1564, when Hawkins described its use in Florida. The habit was not introduced till 1586, when Sir Walter Raleigh's unsuccessful Virginian colony, under Ralph Lane as governor, returned to England in the vessels of Francis Drake. Many of the colonists had learned to smoke from the Indians and they brought the habit home with them. Raleigh himself, not being a member of the party, did not introduce tobacco into England, but it was through his influence that it came into general use. He was a famous smoker himself, smoking his pipe at first secretly and then openly. His social position was such that the habit became first a fad and then a firm fixture. It spread with amazing rapidity, and even Queen Elizabeth is said to have become a victim.

Tobacco was introduced into Italy in 1589, and there met the same enthusiastic approval. In 1559 the Portuguese carried it to India, and it soon spread all over the East.

Thus the use of tobacco, starting with a few sailors and adventurers returning from America, became general all over the world. First welcomed as a drug of rare medicinal power, the rapid spread of its use as a luxury aroused the apprehensions of the authorities, and efforts were everywhere made to stamp it out. In England James I. wrote his "Counterblast to Tobacco" in 1603, and followed it with many restrictive laws, as ineffectual as they were severe. Both James I. and Charles I. imposed the severest restrictions and taxes on tobacco, ostensibly to control its use, but really to so regulate the trade that they might reap the profits therefrom. Thus they incurred the hatred of the Virginians, whose chief industry was tobacco-growing. On the continent, particularly in Italy, the smokers had to contend with papal bulls, civil laws, and taxes. Even in Persia and Turkey severe penalties were placed on smokers. In America the Northern colonies legislated against tobacco—and indeed some of our States have not yet learned the futility of such legislation,—but in the South, where tobacco was raised, there was naturally no such opposition. The extent to which tobacco is used to-day may be judged from the fact that in England in the years 1899 and 1900 the consumption amounted to about two pounds per head of the population.

Tobacco needs no description. Its only important active principle is nicotine, which is present to the extent of from one to eight per cent., in combination with citric and malic acids. It is a volatile, oily fluid, soluble in water, and, when fresh, nearly odorless and tasteless. On standing it turns brown and develops the familiar odor of tobacco. The exact structure of the nicotine molecule ($C_{10}H_{14}N_2$) is not yet known with certainty. It surely contains two organic groups, one of which is pyridine. The other has been thought to be piperidine and, more recently, a hydrated pyrrhol ring. Moore and Row believe that the molecule contains a reduced pyridine ring. Besides nicotine dried tobacco contains pyridine and other decomposition products and an oil which is of importance in determining the flavor.

As a medicine tobacco is obsolete. Among its former uses were the reduction of strangulated hernia and intestinal obstruction by tobacco enemata; the resuscitation of the apparently drowned by blowing smoke from a reversed pipe into the rectum; the relief of baldness and other skin diseases by its external application. Lumbermen and other ignorant persons sometimes treat wounds by the disgusting use of tobacco sputum. Though still retaining its place in the Pharmacopœia, it is too dangerous to be of practical value. Its importance depends wholly upon the prevalence of its use as a luxury.

Physiological Actions.—Nicotine is classed by Schmiedeberg with pilocarpine. Its most notable effects are increased glandular activity (salivation, sweating, and lachrymation), contraction of the non-striated muscles of the alimentary tract (vomiting and catharsis), of the bladder (micturition), of the iris (myosis), and of the arteries (increase of blood pressure). These effects are due to stimulation of the sympathetic nerve ganglia. They are for the most part but temporary, stimulation giving way to paralysis. They are just the reverse of those due to atropine. But the latter acts on nerve terminations in glands or muscle cells, so that, while the effects of nicotine are prevented by the previous administration of atropine, those of atropine are uninfluenced by nicotine.

Moderate doses of nicotine cause slowing of the pulse followed by a return to normal or to a rate slightly above normal. Large doses cause no slowing at all. It must be remembered that the heart is slowed by depressor or inhibitory influences coming through the vagus and accelerated through the sympathetic. Both sets of nerve impulses must pass through ganglia before reaching the heart muscle. Nicotine at first stimulates the ganglia on the vagus, thus causing slowing of the heart, while it afterward paralyzes them and so produces the opposite effect. The action is further complicated by the fact that the accelerator ganglia are probably also affected, and still further by a direct action on the cardiac muscle fibres or the nerve terminations in them, for, after removal of the ganglia, nicotine first slows and then quickens the heart.

The blood pressure is markedly though temporarily increased by nicotine, owing to stimulation of the vasoconstrictor ganglion cells. The pressure may rise to two and a half times the normal. The subsequent fall is due to paralysis of the same ganglia. Brunton and Tunnicliffe show that pyridine causes a fall, and Moore and Row therefore attribute the rise to the reduced portion of the nicotine molecule. This effect on the blood pressure is important. Obviously its frequent repetition might produce the most widespread results—results having to do not only with the vessels themselves, but also with all the organs whose supply of blood is affected. Accordingly Huchard and others attribute to this action many of the evils resulting from the abuse of tobacco.

As to the effects on the coronary circulation, though of great clinical importance, little is known. Beyer perfused nicotinized blood through the excised mammalian heart and found a short period of increase followed by a decided and permanent decrease of the volume of the coronary circulation. This appeared to be independent of any change in the action of the heart itself. His results, however, are not altogether conclusive, and it would be unsafe to infer that in man the use of tobacco causes such changes.

The respirations are first quickened and deepened, and hence there is the appearance of dyspnœa. Larger doses cause decreased respiratory activity and the breathing becomes progressively slower and shallower. In lethal doses it is the arrest of respiration that causes death. These results are due to stimulation of the respiratory centre in the medulla, followed by paralysis of this centre.

The stimulation and subsequent paralysis of glandular secretions by nicotine has been especially studied in the salivaries. As the nicotine acts only on the ganglion cells, when secretion has been stopped by it activity may again be brought about by the injection of muscarin or pilocarpine as these act on the nerve endings, or by mechanically stimulating the nerves between the ganglia and the gland. The same facts have been established in regard to sweating by Langley. There is no evidence that the secretion of urine is increased by nicotine, though micturition results from contraction of the bladder wall.

The contraction of the involuntary muscles of the alimentary canal is probably due to stimulation of the sympathetic ganglia in the walls of the organs. The result is the vomiting and purging, so prominent in cases of acute poisoning, and perhaps the mild catharsis which is one of the ways in which an old smoker is prone to excuse his habit.

The action on the central nervous system is first one of stimulation, as shown by the increased respiratory activity and heightened reflexes and in larger doses by convulsions. The spinal cord, and particularly the lower brain centres, are chiefly involved. The stimulation is followed by marked depression of the whole central nervous system, so that when the animal does not die in the convulsions, there are slow, shallow breathing, lost reflexes, and unconsciousness.

The actions of nicotine are rapid in onset and of brief duration. They are not cumulative. It is a matter of common observation, as well as one capable of experimental demonstration, that tolerance is easily established. In some this appears to be almost absolute, while others cannot "learn to smoke" at all.

Acute Tobacco Poisoning.—Mild cases of poisoning by tobacco are common among smokers who have not yet thoroughly established a tolerance, and they have occurred in others from breathing air containing the smoke. Yet in spite of the extensive use of tobacco and its extremely poisonous nature, serious cases of acute poisoning are extremely rare. Death has resulted from the internal use of infusions and decoctions, from enemata, and even from external application. Tobacco is used by ignorant persons as a household remedy and thus serious poisoning has resulted from the administration of water saturated with smoke to children. Chewers have been poisoned by swallowing tobacco juice and children from sucking old pipes. Taylor describes the case of a child of three who died as a result of blowing soap bubbles with its father's disused pipe.

The use of nicotine for suicidal purposes is rare. A few homicides are recorded, of which the most famous are those of the poet Santeul and of the Count Bocarmé. The former was killed by drinking wine with which snuff had been mixed. In the other case Bocarmé killed his brother-in-law by forcibly giving him nicotine, which he had himself prepared after several months' study of the process.

The symptoms of mild poisoning, such as occur in inexperienced smokers, are nausea, vertigo, vomiting, tremor, salivation, clammy sweating, and prostration. Severer symptoms rarely result from smoking as the terrible nausea deters the smoker from carrying his indulgence to the danger point. Where nicotine or tobacco is introduced in greater quantities there is violent purging, often with abdominal pain and involuntary micturition. Clonic convulsions are always seen in severe cases provided the person affected lives long enough.

They are followed in fatal cases by mental confusion, unconsciousness, and death from respiratory failure. The pupils are generally contracted, or at a later stage dilated. The pulse is small and weak. Where still larger doses are taken, convulsions may begin almost immediately and end in death from arrest of respiration. Enormous doses of nicotine kill almost instantaneously. The Bocarmé case was fatal in about five minutes. In other cases death may be delayed for several hours or several days.

The lethal dose of nicotine is not known. According to Witthaus it is probable that two or three drops of pure nicotine might prove fatal. An infusion of thirty grains of dried tobacco leaves has caused death.

For treatment the unabsorbed drug should be removed from the stomach or rectum with the tube. Tannin is recommended as a chemical antidote to render the nicotine insoluble, and atropine in full doses to counteract its physiological actions. Stimulants and heaters should be freely used. As death results from respiratory failure, this should be met by artificial respiration.

Chronic Tobacco Poisoning.—Tobacco is used as a luxury by chewing, snuffing, dipping, and smoking. In chewing the poisonous substances come into close contact with the mucous membrane, but will produce little local effect beyond the mouth. Salivation is marked, since to the action of the absorbed nicotine on the glands is added the reflex action due to irritation of the buccal mucous membranes. Snuff takers suffer particularly from local irritation of the upper respiratory passages. The effects of snuff have in certain cases been modified by the presence of lead. "Dipping" is a habit, formerly seen in the South, of taking snuff by dipping into the powder a stick, which is then rubbed on the teeth or gums.

Smoking is the commonest method of using tobacco. Its effect on the upper respiratory passages is especially marked, and is due to heat as well as to the presence of chemical irritants. The nicotine and other active principles are more or less modified by partial combustion. The composition of tobacco smoke was studied in 1872 by Vohl and Eulenberg, who claimed that it contained no nicotine. They demonstrated a long list of substances, including a series of pyridine and picoline bases, to which they ascribed the effects usually attributed to nicotine. Since then the subject has been repeatedly investigated, chemically and physiologically, and the nicotine in the smoke has been estimated at amounts varying from nothing to fifty per cent. of that in the tobacco. Heubel, Vas, and others have proven that nicotine is present, the latter finding no other poisonous substance. For practical purposes it would appear to be of little moment whether the effects of smoke are due to nicotine or to decomposition products having essentially the same actions.

Tobacco is smoked in pipes, cigars, and cigarettes. The first mentioned method is probably the most deleterious because very strong tobacco is thus used. The black, oily juice, which collects in the stems of foul pipes, and which has been shown by Heubel to be extremely poisonous, is partly taken in when the pipe is again smoked. In cigars, on the other hand, the nicotine, which is partly evaporated and partly broken up in the burning end, is to some extent recondensed and deposited in the region near the mouth. It is then thrown away with the stub. In spite of the strong lay opinion to the contrary, it is altogether probable that, used in moderation, cigarettes are the least harmful method of smoking, though they have some dangers peculiarly their own. They are so mild that the smoker is tempted to use a large number of them and thus he constantly, though slowly, absorbs a great amount of poison. The same mildness leads to their use by minors and women, and causes the smoke to be inhaled. It is said to be especially dangerous for a pipe-smoker to use cigarettes, as he thus learns to inhale the smoke, a practice which is objectionable with the pipe. The belief that cigarette tobacco contains opium, or that the paper contains deleterious substances, has little or no foundation. Neither has the especial prejudice against Turkish and Egyptian cigarettes.

Operatives in tobacco factories are sometimes affected by the fine particles of tobacco dust in the air. In a case of the writer's, a girl of fifteen, predisposed by bad habits, late hours, and the excessive use of tea, worked for a week as "stripper" in a small room full of tobacco dust. She vomited on the first two days and fainted four times in the week. When seen, she complained of throbbing sensations in the head, violent cardiac pain, dyspnœa, and palpitations, and presented a rapid and irregular heart and marked anæmia. Such symptoms are not uncommon in beginners, but tolerance is soon acquired, permitting them to work with impunity in the dust. Dowling, studying chiefly the ocular symptoms, found that forty-five out of a hundred and fifty men working in the tobacco factories of Cincinnati showed evidences of chronic tobacco poisoning. But all of these men smoked or chewed. Apart from anæmia—a common symptom among girls working in factories of any sort—there was little evidence of harmful results in women or men who did not use tobacco. Workers sometimes show conjunctivitis and irritation of the upper respiratory passages; but these effects are rare, and it does not appear that the manufacture of tobacco is especially dangerous.

Before considering the effects of the continuous use of tobacco on the various organs, it should be said that harmful results are, considering its almost universal use, rare. In most cases tobacco is not the only source of the trouble, morphine, tea, coffee, alcohol, or other injurious habits being present.

The effects of tobacco on the mouth, throat, and upper respiratory passages are due to local irritation rather than to the action of nicotine after absorption. They are more marked from smoking than from chewing. And every pipe smoker knows that mild tobacco "bites the tongue" more than strong. These facts suggest that the irritation is due rather to products of combustion than to nicotine. Catarrhal inflammation of the nasopharynx with marked hypersensitiveness of the throat is common in smokers. It may extend through the Eustachian tubes to the middle ear. It is possible that the ear may be injured in another way, viz., by the production of a neuritis of the auditory nerve similar to that seen in the eye, an action of course taking place after absorption. However, this rarely, if ever, results. Excessive chewers sometimes show inflammatory conditions of the mouth and throat and extreme discoloration of the teeth, which are sometimes worn down to a level with the gums. Snuff-takers suffer from various inflammatory conditions of the nose. Inspissated masses of snuff have formed nasal calculi. It has been said that smoking predisposes to cancer of the lip. If there is any truth in this the disease is due to local irritation.

The effects of tobacco on the alimentary system have been a subject for experimental study as well as for clinical observation. They are partly due to the swallowing of sputum containing toxic substances from the smoke or bits of tobacco from cigars held long in the mouth and chewed. The stomach may also be injured indirectly through the circulatory system. The symptoms are those of chronic gastric indigestion, hyperacidity, or flatulence. These symptoms are so common and so many excessive smokers are also excessive drinkers that the importance of tobacco as a factor is difficult to estimate. In rabbits fed for months on cabbage soaked in tobacco infusion, Adler found no gastric symptoms after the first few days, and the appetite continued unimpaired. On the other hand, it has been noticed by military writers (Korloff) that where food is lacking tobacco markedly decreases the sensation of hunger.

In Adler's experiments the liver became enlarged, and on microscopic examination showed marked proliferation of the interlobular connective tissue with new formation of bile ducts, but without any involvement of the hepatic cells. These experiments were incomplete and not altogether conclusive. Adler does not draw any comparison between the processes observed and human cirrhosis, and indeed tobacco has never been noted as one of the causes of the latter. As a result of somewhat similar experiments Kohos found small, hard livers.

The effects on the blood have been studied experimentally by Vas on puppies. After eight weeks he noted marked anæmia, the hæmoglobin and red corpuscles decreasing over a half. The solid residue and the alkalinity decreased a little while the white corpuscles were decidedly augmented.

Of all the effects of chronic tobacco poisoning the most important, both from their frequency and from their severity, are those which have to do with the circulatory system. Though sometimes seen in boys, they generally result from long-continued abuse. They are said to be most frequently caused by Havana cigars. Many if not most of the cases, like the writer's patient previously referred to, are predisposed by other conditions, such as alcoholic excess, emotional strain, over-exercise, nervous disease, convalescence from acute diseases, bad habits, or indigestion. Epidemics of tobacco angina, like those described by Kleefeldt and Gélineau, may depend largely on such predisposing influences. In the latter instance a series of cases appeared on a French man-of-war, where the men, debilitated by scurvy and poor food, smoked to excess in a small close apartment.

Although the clinically observed effects of tobacco have not been fully explained, the following facts are of importance: 1. The work of the heart is increased by the vaso-motor contraction and consequent increase of the peripheral resistance, *i.e.*, the blood pressure. That this results from the administration of nicotine has been amply demonstrated by experiments. But, so far as the writer is aware, it has not been shown to result in habitual smokers from each indulgence. Such proof is all the more needed since smoke contains pyridine as well as nicotine, and the effect of the former is to reduce, and not to raise, the blood pressure. 2. Any such additional work has to be done by a heart hampered by the disturbing action of the drug on the nerve centres and muscle fibres. 3 The heart is at the same time further embarrassed by decrease of its blood supply through contraction of the coronaries. That this takes place has not been conclusively demonstrated by experiments, though the work of Beyer points in this direction, but it is accepted clinically by Huchard, Farvarger, and others.

It is probable that in far the greater number of cases the cardiac symptoms of chronic nicotine poisoning are due to functional disturbances without gross pathological lesions. Occasionally, however, after long continued abuse, hypertrophy may result from the above-mentioned factors, especially the first. Fatty degeneration and other forms of myocarditis have been attributed to the myocardial ischæmia Huchard believes that the constantly repeated vascular contractions and rises of blood pressure may result in arteriosclerosis. Tobacco is not ordinarily considered to be one of the causes of this common condition. There is, however, just a suggestion in some recent experimental work that such may be the case. If, as Huchard believes, the sclerosis may involve the coronaries, myocarditis and true angina might result as from the same conditions due to any other cause.

The symptoms most commonly seen are those of "irritable heart." They are often associated with digestive disturbances Palpitations are commonly complained of, with dyspnœa, ordinarily mild. Asthmatic symptoms may be present Heart pain is common; it is usually slight and transient, but every gradation exists from the mildest to the terribly severe attacks justly described as anginal. Pallor, cold extremities, cold sweating, tremor and muscular weakness, small and feeble pulse, vertigo, headache, amnesia, psychical irritation, and even aphasia or transitory hemiplegia (spinal or cerebral anæmia) are considered by Huchard to result from the contraction of the vessels of the organs involved. To say the least, many of these symptoms are extremely uncommon.

Physical examination of the heart may show absolutely nothing abnormal. Generally there is irregularity or intermittence, which may be very marked. Rapidity is common, and is especially shown in the undue degree and permanence of the increase in pulse rate on suddenly sitting up or after slight exertion. The symptoms and signs of hypertrophy, fatty degeneration, and arteriosclerosis need not be described here, since they are at best rare and doubtful results of tobacco, and do not differ from the same conditions produced in other ways.

Attacks of heart pain, severe enough to be classed as true angina pectoris, are extremely rare. Osler states (1897) that he has seen but two cases as results of tobacco. Huchard describes three forms: (1) Functional (*angine spasmo-tabagique*), due to spasm of the coronaries. (2) Organic cases (*angine scléro-tabagique*), due to organic stenosis of the coronaries. (3) A benign form (*angine gastro-tabagique*), precipitated by gastric disorder. The first of these, though the symptoms may be very severe, almost always recovers in a fortnight after the withdrawal of tobacco; the second is always fatal; the third is the most benign of all, and disappears on withdrawal of the tobacco or curing the indigestion.

The following are among the peculiarities of the angina due to tobacco mentioned by Huchard: Vaso-motor symptoms are common—pallor, vertigo, small pulse, syncope. Other evidences of nicotine poisoning, like amblyopia, may be seen. Irregularity and rapidity of the pulse are more common than in angina due to other causes. The attacks are more apt to be slight or abortive, and are usually spontaneous.

Various effects on the central nervous system have been ascribed to tobacco. Vertigo, headache, muscular tremor, and debility are not uncommon. Tobacco as a rule favors sleep, but an unusually strong cigar may have the opposite effect. Huchard attributes all these things to ischæmia of the nerve centres, as he does the rare cases of aphasia and transient hemiplegia. In the experiments of Vas, already alluded to, degenerative changes were noted in the cells of the spinal and sympathetic ganglia similar to those caused by certain other poisons. Peripheral neuritis and neuralgia are described, but it is probable that serious nervous diseases of an organic nature, such as locomotor ataxia or general paralysis, are never caused. Insanity has been attributed to tobacco and a peculiar psychosis is mentioned. Its rarity may be judged by the fact that Kraepelin says he has never seen anything of the kind. Any influence that tobacco has in this respect is probably an indirect one, due to the general physical depression, or to the marked injury of some particular organ.

The effect of tobacco on the eyes is universally recognized. An amblyopia of a specific type may certainly result from the abuse of tobacco, though alcohol is often an auxiliary factor. It is commonest in men beyond the age of thirty-five, and is said to be more common in smokers than in chewers. Dowling found some evidence of amblyopia in 45 out of 150 tobacco workers, all of whom smoked or chewed. Hirschberg found 7 cases in an ophthalmic clinic of 18,000; Galezowski, from 5 to 15 in 1,000; Landolt, 12 in 2,771. Pathologically the amblyopia is considered by some to be a retrobulbar interstitial neuritis, involving the papillo-macular bundle. Recently several investigators have attributed the cause to retinal changes taking place in the macular region, the degenerative changes in the papillo-macular bundle being secondary.

There is dimness of vision, not improved by glasses. The patient may see best at night or in a dim light. The most characteristic finding is the central scotoma for color, a condition which is almost pathognomonic of toxic amblyopia. The ability to distinguish green is usually lost first, then red, and finally blue. The scotoma may later exist for form as well as for color. The periphery of the visual field remains normal. With the ophthalmoscope the papilla is normal at first or slightly congested, then evidences of atrophy appear on the temporal side of the disc and finally become general.

Certain French writers have claimed that tobacco may cause sexual impotence, and have found experimental evidence of degenerative processes in the testicles. Symptoms of this sort are certainly not common, and again there is difficulty in establishing the fact that tobacco is the cause.

As to the effects of tobacco on the general development, the puppies to whom Vas continuously administered nicotine lost weight very decidedly, while the rabbits, to whom Adler administered tobacco, retained perfect health for months. The statistics for one of the Yale classes is said to have shown that the men who did not use tobacco gained much more rapidly in weight, height, chest girth, and lung capacity than the moderate smokers, while the latter exceeded the excessive smokers. Thus the popular belief that tobacco "stunts the growth" appears to have some support.

In some diseased conditions the use of tobacco is undoubtedly injurious, though here, if a patient has always used tobacco, the hardship entailed by giving it up may be more deleterious than its continuance in moderation. In mental diseases Bucelli considers that its use is inadvisable, particularly in convalescents. As regards tuberculosis the views of different writers have varied from those of Melier and Ruef, who considered that tobacco was beneficial, to that of Benjamin Waterhouse, who, in 1805, thought that tobacco was the cause of the prevailing ill health of Harvard students, and especially of the increase in phthisis. Recently Stern has shown that the use of tobacco may aggravate an existing glycosuria, and even, though infrequently, cause it.

Tazzinari has subjected various pathogenic organisms to the action of cigar smoke, and shown that it very decidedly retards the development of some pathogenic bacteria, and wholly prevents that of certain others. The effect was most marked on the organisms of Asiatic cholera, typhoid, and pneumonia. Some have inferred that smoking is of value in the prophylaxis and treatment of such diseases as diphtheria.

Arguments in favor of the use of tobacco on this or similar grounds have little weight. Its great value, after all, is the pleasure and mental satisfaction it affords. That tobacco is of great service to humanity in this way there can be no doubt. Most military writers admit that it is of value to soldiers, helping to pass the time in monotonous camps and acting as a nervous sedative in times of hardship and anxiety, as well as preventing the sense of hunger when food is scarce. Socially it has objections on account of its odor and in the habit of promiscuous spitting. It need not be expensive. Used in moderation by healthy adults it will seldom do serious harm. Surely it should not be classed with alcohol and morphine, but more properly with tea and coffee. The commonest of the more serious injuries are those having to do with the heart and the eyes.

The *prognosis* of the functional disorders resulting from over-indulgence in tobacco is good. They usually disappear promptly on ceasing the habit. If organic changes have taken place the prognosis is more grave. Thus the general or coronary arteriosclerosis, if such a lesion does result from tobacco, will not improve. The amblyopia usually recovers completely if proper treatment is instituted early enough; but, if the habit is persisted in, a high grade of ocular deficiency may become permanent.

Treatment.—Physicians should do all in their power to prevent the excessive use of tobacco, especially by women and young persons. Moderation, or better abstinence, should be observed by persons convalescing from acute diseases, those suffering from anæmia, gastric disorders, cardiac abnormalities, especially myocarditis, and other depressed states, even though they may have previously smoked with impunity. The combination of alcohol and tobacco is especially dangerous. Smokers will decrease the dangers if they will use pipes with long stems and keep them well cleaned. Notoriously strong tobacco should be avoided. The smoke should not be inhaled. Cigars should not be smoked too close to the end, nor held too long in the mouth. "Cold smoking" and chewing the ends of cigars are to be avoided. Athletes in training should avoid tobacco. Farvarger advises smoking only after meals. This decreases the quantity of tobacco smoked, and any irritating saliva which is swallowed comes into less intimate contact with the mucous membrane of the stomach.

When any of the symptoms of chronic tobacco poisoning appear, especially if the heart, nervous system, or eyes are affected, the habit should be given up entirely. This is difficult, but there is no particular danger in sudden withdrawal as "abstinence symptoms" do not occur in the same sense as they do after sudden withdrawal of alcohol or morphine. Abstinence must be prolonged, since, when symptoms have once begun, they are prone to recur. Alcohol must also be absolutely forbidden. Other predisposing conditions should receive attention. An abundant supply of easily digested food should be given and fresh air and general tonic treatment instituted.

For drugs strychnine is of value in full doses. Iodide of potassium is also recommended for the amblyopia. Tobacco angina and the other cardiac manifestations are to be treated by rest, small doses of digitalis and other heart stimulants, iodide of potassium, nitroglycerin or inhalations of amyl nitrite as in the same conditions from other causes.

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REFERENCES.

Adler: Journal of Medical Research, November, 1902.
Beyer: Johns Hopkins Hospital Reports, vol. ix.
Blatin: Recherches physiologiques et cliniques sur la nicotine et le tabac, Paris, 1870.
Bragge: Bibliotheca Nicotiana, Birmingham, 1880.
Brunton and Tunicliffe: Journal of Physiology, vol. xvii., p. 275.
Bucelli: American Journal of Insanity, January, 1897.
Cushny: Pharmacology and Therapeutics, 1899.
Dowling: Cincinnati Lancet-Clinic, 1892, vol. xxix., p. 585.
Ernst: American Anthropologist, 1889, vol. ii., p. 133.
Farvarger: Wien. med. Woch., 1887, No. 11.
Heubel: Centralbl. d. med. Wiss., 1872, No. 41.
Holden: Archives of Ophthalmology, xxviii., 125.
Huchard: Bull. Méd., Paris, 1889, iii., 643.—Maladies du Cœur, Paris, 1889.
Kerr: Twentieth Century Practice of Medicine, iii., 106.
Kissling: Zeitschr. f. analyt. Chemie, 1882, xxi., 64.
Kohos: Bull. Méd., Paris, 1897, xi., 384.
Knapp: Archives of Ophthalmology, January, 1891.
Kraepelin: Psychiatrie, 1899, vol. i., p. 50.
Lancet Com. Report: Lancet, 1888, ii., 638 and 785.
Langley: Journal of Physiology, xii., 359.
Langley and Dickenson: Journal of Physiology, xi., 272 (with bibliography).
Lloyd: Twentieth Century Practice of Medicine, iii., 431.
Love: Journ. Am. Med. Assn., March 2d, 1902.
Masoin: Bull. de l'Acad. de Méd. de Belgique, 1900, No. 8.
Moore and Row: Journ. of Physiol., xxii., 273.
Munson: Military Hygiene, 1901.
Osler: Angina Pectoris and Allied States, N. Y., 1897.
Poisson: Annales d'Hygiène, vi., 385, 1881.
Polkinhorn: Ophthal. Record, July, 1900.
Schmiedeberg: Grundriss der Pharmakologie, 1902.
De Schweinitz: Morris and Olliver's System of Diseases of the Eye, 1900, vol. iv.
Sée: Maladies du Cœur, 1883.
Stern: New York Medical Record, April 27th, 1901.
Tabor: Boston Med. and Surg. Journ., vols. xxx., xxxi., xxxii., xxxiii., xxxvii., xliv., and xlv. (A series of papers on the history of tobacco, with bibliography.)
Taylor: Medical Jurisprudence, 1892.
Tazzinari: Centralbl. f. Bakteriol. u. Parasitenkunde, iv., 149, 1888.
Vas: Arch. f. exp. Path., xxxiii., 141.
Vohl and Eulenberg: Arch. Pharm., cxlvii.. Abstr. in Pharm. Journ. and Trans., 1872, 567.
Waterhouse: Cautions to Young Persons Concerning Health, Cambridge, 1805.
Wertheimer and Colas: Arch. de Physiol., iii., 341, 1891.
Wharton and Stillé: Medical Jurisprudence.
Witthaus and Becker: Medical Jurisprudence, iv., 770.

TOLENAS SPRINGS.—Solano County, California

These well known springs are located about five miles north of the town of Suisun in Solano County, adjoining the famous Tolenas onyx quarries. They are reached by rail from San Francisco or Sacramento to Suisun, and thence by stage over a good level road. The resort is 1,253 feet above the sea, and is pleasantly located. On a clear day the State Capitol, Suisun Bay and Valley, and many other points of interest are easily seen. There are nineteen springs in all at Tolenas, flowing between six hundred and seven hundred gallons per hour. The temperature of the water varies from 60° to

65° F. The springs have had a local reputation for over thirty years, and of late the water has been bottled and sold extensively all over the State. The resort is at this time in a very flourishing condition. Two analyses have been made, one by J. Hewston, Jr., and the other by Dr. Winslow Anderson. They show no important difference in their results. Following is Anderson's analysis:

One United States gallon contains (solids). Sodium chloride, gr. 194.16; sodium carbonate, gr. 46.93; sodium bicarbonate, gr. 6.45; sodium biborate, gr. 19.13; potassium chloride, gr. 6.47; potassium iodide, gr. 1.75; magnesium carbonate, gr. 11.58; calcium carbonate, gr. 49.80; ferrous carbonate, gr. 0.89; alumina, gr. 1.10; silicates, gr. 1.92; organic matter, a trace. Total solids, 340.18 grains. Free carbonic acid gas, 31.27 cubic inches. Temperature of water, 61.5° F.

Hewston's analysis shows 360 grains of solid matter to the gallon. The water is warmly indorsed by many who have used it. In chronic skin affections, eczema, scrofula, and syphilitic infections it seems to act well. Chronic gastric disturbances, kidney and bladder diseases also improve under its use. The water is gently aperient and strongly diuretic. *James K. Crook.*

TOLIPYRINE.—This substance differs from antipyrin only in the substitution of the methyl group, CH_3, for one atom of hydrogen in the phenyl group. It is a white crystalline powder very similar to antipyrin in its physical as well as its therapeutic qualities. The indications for its use are the same as those for antipyrin, the dose being somewhat less—one part being equal to one and a half parts of the older drug. Its dose is given as from eight to thirty grains.

A salicylate of tolipyrine has been prepared to which the name of *tolysal* has been given. It bears the same relation to tolipyrine that salipyrine does to antipyrin. It is a crystalline, almost colorless (faintly pinkish) substance, lustreless, and with a bitter taste. In doses of fifteen grains every two hours it is said to be of much value in acute rheumatic attacks. *Beaumont Small.*

TONGUE, DISEASES OF.—In health the tongue varies greatly in appearance, but usually it is of a rosy-red color, moist, covered with minute papillæ (thread-like papillæ and larger round papillæ), free in its movements, and almost constantly changing in form. Very many persons, especially smokers and those engaged in such occupations as tea-tasting, have a more or less coated tongue even when apparently in perfect health. The volume of the tongue also varies greatly within normal limits. In some the organ is narrow and pointed at its tip, while in others it is large and flabby, with thick and rounded tip and margins which often show indentations made by the teeth. In nervous individuals the tongue is protruded quickly and as quickly withdrawn; in others of a more phlegmatic temperament the motions of the tongue, like those of the other voluntary muscles, are sluggish. In old age the tongue is almost always coated and is less moist than in youth, becoming often very dry and glazed upon the advent of even the slightest ailment. This is a point of some importance, for the physician called to see an aged person may be led to exaggerate the gravity of the condition if he take into consideration the evidence furnished by the state of the tongue alone.

The appearance of the tongue is not modified in every abnormal state, and it frequently presents no change in cancer of the stomach, or in gastralgia or enteralgia. It also often presents a normal appearance in simple jaundice, nasal catarrh, and many other slight ailments unaccompanied by fever.

Movements.—The movements of the tongue are sluggish in all adynamic conditions, in mental hebetude, and when the organ is dry. In paralyses of various kinds the muscles of the tongue are often affected and then the organ lies like an inert mass in the mouth, and cannot be protruded. In paraplegia one side of the tongue may be paralyzed, and then, when protruded, it deviates toward the paralyzed side, being pushed that way by the sound muscles. A trembling of the tongue is seen in adynamic conditions, in alcoholism, lead poisoning, and paralysis agitans, and when the individual is under the influence of various emotions, such as fear, anger, etc. Fibrillary contractions are sometimes observed in progressive muscular atrophy, in general paralysis of the insane, and in locomotor ataxia. Convulsions involving the lingual muscles have been observed in hysteria, epilepsy, and chorea, and in tuberculous meningitis in infants.

Coating.—A furred tongue is usually the condition which attracts the most attention. This occurs in many conditions, and the presence of a fur is almost always indicative of some abnormal state. In perfect health the tongue is clean, as a rule, although some seemingly healthy individuals have an habitually furred tongue. A thin whitish coating is almost always seen also in smokers. The fur is ordinarily composed of mucus, epithelium, particles of food and micro-organisms. It is due to increased production of the epithelium, owing possibly to reflex hyperæmia, or to any cause which prevents the removal of the cells normally cast off. When normal secretion is interfered with, as in fevers or in adynamic conditions, there is less chance for the detached epithelia to be washed away, and the coating is further increased by the collection of the inspissated mucus. A dry tongue is almost always coated, and when the mouth is open the dust collects from the atmosphere and helps impart a brownish tinge to the fur. Sometimes, when the fur is light or when the papillæ are enlarged, the latter project above the surface of the coating as little red points, presenting the appearance known as "strawberry tongue." This is seen in its most typical form in scarlet fever, and is recognized as one of the diagnostic points of that affection; it is also commonly present in Rötheln.

In dyspepsia the red fungiform papillæ will be seen to slope toward the tip, while in scarlatina they stand erect, their rounded summits suggesting the nodular surface of the fruit.

The fur is variously colored in different conditions, and these various colors often furnish valuable diagnostic indications. Thus, a thin white coating indicates febrile disturbance, or slight indigestion; a yellowish tinge points to hepatic disturbance; and a dry, brown fur, except in mouth-breathers, is usually a sign of profound dyscrasia. The fur may be moist or dry, the former condition prevailing in apyretic gastric disturbances, the latter in marked febrile conditions which have persisted for a long time and in which the vital forces of the patient are greatly depressed. In such states the tongue becomes covered with a thick, dry, brown or blackish coating, which is often furrowed and cracked, being perhaps partially detached in places, and showing a deep red color beneath. In disordered digestion the coating is thick, moist, and often brownish in color. A sign of some importance in the diagnosis of gastric ulcer from cancer of the stomach is the presence of a coated tongue in the first-named affection, and its absence in the second, unless there is fever. A clean tongue in the early stages of a continued fever should cause the physician to hesitate in making a diagnosis of typhoid fever. A hemorrhagic coating results from the imbibition of the coloring matter of the blood. It is usually accompanied by great dryness of the tongue, and the blood escapes from the fissures in the mucous membrane which result from the contraction of its epithelial covering. In diphtheria a false membrane occasionally, though rarely, forms on the tongue. As the coating is often the result of hyperæmia of the tongue, it may be seen in local diseases of the organ, and frequently a yellowish fur forms on one side in consequence of the irritation caused by a carious or broken tooth. In certain cerebral affections, especially in apoplexy, the tongue is covered with a thick sticky fur, and it is also coated and foul in chronic alcoholism.

Color.—In anæmia and allied conditions the tongue is pale, as it is also after profuse hemorrhages and in wasting diseases. In various diseases, such as icterus, Addison's disease, etc., the tongue participates in the general pigmentation and approaches the skin in color. The tongue is abnormally red in scarlatina, in inflammatory fevers, and often in the beginning of smallpox. A red, moist tongue indicates debility, such as occurs in consequence of long-continued exhausting discharges. In chronic conditions affecting permanently, in a measure, the digestive organs, the tongue is often intensely red, more or less dry, and sometimes presents a glazed appearance, as if varnished. In gastritis and in inflammation involving the other organs of digestion, the tongue is ordinarily redder than normal, dryish, narrowed, and pointed; sometimes it is furrowed and becomes of a brownish-red color. It presents a more or less purplish venous hue in all cases in which there exists an impediment to the circulation, or in which there is interference with hæmatosis. Thus we see this color in many cases of heart disease, in cholera, in croup, in pulmonary affections causing asphyxia, and when large effusions are present in the pleural or abdominal cavities. In malarial fevers the tongue is often purple at its margins, and in plethoric conditions the same venous hue is generally present.

SURFACE.—Normally the upper surface of the tongue is somewhat convex, and is slightly rough from the projection of its papillæ. When moderately dry it is smooth and presents a glazed appearance from the presence of inspissated mucus. When very dry the epithelium contracts and the surface is marked by rhagades of greater or less depth. Fissures of the tongue, without any furring, dryness, or change in color, are sometimes observed to occur in gastric disturbances. In some individuals, however, the organ is normally fissured even when moist. In syphilis the tongue is often ulcerated and fissured, and after healing there remain persistent whitish cicatrices. Wounds of the tongue caused by the teeth are seen in epilepsy, and may be of considerable diagnostic value in cases in which the convulsions are nocturnal.

An *impetiginous stomatitis*, in which the tongue, along with the buccal surface of the cheeks and lips, is covered with a tenacious exudation, and at times fissured, has been described by Sevestre and Gaston.[1] It occurs in debilitated infants with gastro-intestinal diseases, measles, pertussis, and impetigo. The Staphylococcus aureus was found in eight cases.

MOISTURE.—The tongue is moistened by the secretion of its glands and by the saliva. In ptyalism there is an increase in the secretion of the lingual as well as of the salivary glands. A return of moisture is a favorable sign in adynamic conditions. Dryness of the tongue is constantly present in a slight degree in some individuals, in whom it seems to be a normal condition. It is noticed in obstruction of the nasal passages, and in dyspnœa (phthisis, pneumonia, heart disease, etc.), when the patient is compelled to breathe rapidly and through the mouth. Certain drugs, such as belladonna, cause dryness of the tongue as well as of the other mucous membranes of the head. Long-continued speaking also induces dryness of the tongue, and the same condition occurs as a result of fasting. In prolonged febrile conditions, especially when the temperature remains constantly at a high elevation, the secretions of the tongue become diminished. In acute inflammation of the abdominal viscera, in intestinal obstruction, etc., and in typhoid conditions, the tongue becomes very dry, and often fissured. Such a condition indicates that the vital forces are ebbing.

VOLUME AND FORM.—The tongue is swollen oftentimes when there is interference with the return circulation of the head in consequence of heart disease, pulmonary affections, or compression of the veins of the neck from any cause. In chronic diseases of the chylopoietic system the organ is often considerably enlarged and indented. In idiots and in those suffering from certain mental affections the tongue is often large and flabby. In general paralysis, in paraplegia, and sometimes even in hemiplegia, the organ is large, soft, and flabby, its dimensions being such as sometimes to prevent closure of the mouth. In anæmia the tongue is broad and flabby, and shows the marks of the teeth. A similar condition is seen in smallpox, typhus fever, scurvy, and various blood dyscrasiæ and in mercurial poisoning. Inflammation with turgescence of the organ occurs as a result of the local action of certain irritant and corrosive poisons.

A broad, flat, square tongue, nearly filling the mouth, points to myxœdema. In acromegaly, too, the organ may become so enlarged as to prove of serious inconvenience. Abnormally long tongues have been described as malformations.

Enlargement occurs, too, from œdema, which, among other conditions, is seen in *stomatitis epidemica*, an affection in which the excessive swelling may be followed by necrosis. Enlargement is encountered also in urticaria, and occasionally it is due to quinine.

Changes in the shape of the tongue are owing, in many cases, to the absence of moisture, the organ becoming frequently concave on its upper surface from contraction of the dried epithelial layer. According to Gubler, there is a contraction of the transverse muscular fibres in fevers, so that the organ is less broad than normal. In hemiplegia the shape of the tongue is altered in consequence of the unilateral paralysis. The affected side is soft and flat, and after a time may become reduced in volume.

ARTIFICIAL DISCOLORATIONS may have diagnostic significance.

Rigal gives a table showing that black discoloration may be produced by ink, iron, mulberries, and some kinds of cherries; yellow by saffron, laudanum, rhubarb, nitric and chromic acids; red by rhatany, quinquina, and citrate of mercury, etc.; grayish-white by sulphuric, carbolic, and oxalic acids; white or pearl-gray by nitrate of silver and corrosive sublimate.

Corrosive acids, blackberries, tobacco, and rhubarb must also be mentioned as common discoloring agents. Caustic potash produces a gray and gelatinous appearance.

Tea-tasters are said to acquire a smooth, orange-tinted coating.

DEFORMITIES of the tongue may be either congenital or acquired, and consist principally in a complete absence of the organ, a split or bifid condition, a chronic state of prolapsus, hypertrophy, atrophy, adhesions, etc.

Aglossia.—Absence of the tongue has been recorded as a congenital condition in a case seen by Jussieu,[2] and in one mentioned by Förster[3] and as the result of disease in a number of recorded cases.

Atrophy of one-half the tongue, with nodules near the root, was observed by Lewin. The tongue deviated toward the affected side, and could scarcely be projected or elevated to the palatine vault. There was great difficulty in chewing, swallowing, and in pronouncing the letters *d, t, l, n,* and *r*. At the autopsy two gummata were found in the cranial cavity; one situated directly upon the hypoglossal nerve. Such cases may also, but more rarely, be due to peripheral causes.

Hemiatrophy has also been described by Ballet,[4] who says it may be the first evidence of central disease.

Atrophy of the whole organ is very rare compared with that of one side. The affected side in hemiatrophy is noticeably decreased in size, shrivelled up, and the mucous membrane covering it is thrown into folds. Atrophy of the whole tongue may follow a bilateral paralysis of the organ.

Hemiatrophy can be produced in the dog by cutting the sensory portion of the trigeminus. It may follow lesions of the intramedullary and intra- and extracranial hypoglossus. As a progressive condition it has been observed in facial hemiatrophy, possibly depending upon a low type of degenerative neuritis. It has been noted in a number of patients having locomotor ataxia, and the drawn up ridges on one side may be among the earliest signs of that disease.

Adhesions of the tongue, causing the common tongue-tie or bridled tongue of infancy, are not very rare. Ankyloglossus is another term which has been applied to this congenital condition when due to an abnormal development in breadth of the mucous fold beneath the tongue, called the frænum, or to its too high attachment.

All movements are restricted and suction is almost impossible.

Adhesions causing more or less complete immobility can also be due to accident.

Lateral adhesions have been noted as a congenital condition, and also as a consequence of mercurial gingivo-glossitis, noma, scurvy, etc. In all of these cases section with scissors is advised.

Children may be born with the dorsum of the tongue attached to the roof of the mouth, but such instances are exceedingly rare.

Bifid, or *split tongue*, a normal condition in some animals and birds (the seal and raven), has occasionally been seen. Barling reports a case of congenital division of the tongue with a median lobe.

HYPERTROPHY.—Though a predisposition to hypertrophy probably exists in many cases, it seems to be determined by some acute process, such as abscess or ranula, or one of the exanthemata. When of large size the organ protrudes from the mouth, the saliva constantly flows, the gums swell, and the teeth become loose. It must not be confounded with acute glossitis, with mercurial stomatitis, nor with tumor in the substance of the tongue.

Virchow describes the hypertrophied tissue as forming a lymphatic cavernous tumor, and it is now the accepted theory that the lymph vessels are dilated and the connective tissue is increased, but the muscular tissue is not hypertrophied. There appears, however, to be a form of muscular hypertrophy which constitutes a separate disease. Billroth says there is a fibrous form. In some cases the blood-vessels as well as the lymphatics are enlarged.

As regards treatment, Freteau has had good results from the application of a bandage in such a manner as to make even pressure from the tip backward. A cure may be effected, so long as the organ does not protrude, by applying pressure in the manner recommended by Butlin, *i.e.*, by inducing the patient to keep the mouth constantly and firmly closed upon the tongue. The application of a bandage to the mouth aids in the accomplishment of this purpose.

Hypertrophic Cicatrix.—False keloid is almost as rare as true keloid upon the tongue. Gevert [5] has presented an instance following a burn.

Hypertrophy of follicular glands in the posterior portion of the dorsum near the papillæ vallatæ, and in the sinus epiglotticus, is often attended with some inflammation, causing the sensation of a foreign body in the throat, with its attendant symptoms of "hacking," attempts to clear the throat, irritative or pertussis-like cough, painful or discomforting deglutition, dyspnœa, asthmatic attacks, and voice tire.

The finger may detect the swelling, and the laryngoscope shows the reddened and swollen follicles lying over the epiglottis and in the glosso-epiglottic fossa.

Hypertrophy of the lingual tonsil in the adult may reach such a degree as to suggest a new growth or polypus. To remove the adenoid vegetations a snare, linear écraseur, sharp spoon, or caustics may be used. Repeated applications of iodine often give good results.

Hypertrophy of Papillæ.—Because of the papillary nature of the surface of the organ hypertrophic enlargement of papillæ is not uncommon. This may, in rare instances, implicate a single papilla, more commonly, however, a small group of papillæ is involved, a wart-like tumor, or *papilloma*, resulting. Such a growth sometimes represents a congenital condition.

When a papilloma of the tongue has existed for some time it may become firm, verrucous, and even horny. At times the whole dorsum is studded with hypertrophic papillæ, giving an open, fig-like appearance.

In the same way hypertrophied filiform papillæ, when kept erect by the action of the teeth, may stand out like small porcupine quills. The *x* ray has a decided effect on the reduction of papillary hyperplasia and overgrowth and I have removed a large-sized papillary tumor by its exclusive use.

Hypertrophy of Pigment.—In Addison's disease dark or black colored areas are found near the tip of the tongue. The pigment lies in the deep cells of the epidermis. In jaundice the tongue is yellow. I have observed that the fungiform papillæ, which in the white races are pale or red, have naturally a brown, bluish, and sometimes black color in negroes, Indians, and dark-skinned Cubans. Maynard found that thirty-two per cent. of coolies had pigmented tongues. At times each fungiform papilla will be found surrounded by a bluish or brownish rim. Dark spots are found at times in melanosis and in malarial cachexia.

Prolapsus Linguæ.—In a few rare cases the tongue has been found too long, so that it constantly protruded from the mouth. This condition is also found as a result of hypertrophy and inflammatory action, and must not be confounded with the rarer congenital increase in length.

FUNCTIONAL DISTURBANCES.—The tongue is protruded with difficulty in low fevers, apoplexy, and sometimes in paralysis; in the latter condition the sound muscles force the tongue over toward the paralyzed side, and there may be loss of tactile sense. In chorea there may be a positive inability to protrude the tongue; it may be constantly thrust far out of the mouth. Here, as in epilepsy, the tongue is often bitten by the patient, and deforming scars may result.

Abnormal mobility of the tongue.—When at birth the frænum is too long, it has happened that the infant has swallowed the tongue or drawn it so far back as to cause suffocation and death. This may also happen after dividing the frænum. Treatment consists in replacing the tongue with the finger, and exercising care in feeding. There has been reported a case in which the patient, who experienced much inconvenience from the accumulations of mucus on the posterior wall of the pharynx, succeeded in cleansing the naso-pharyngeal cavity with his tongue. The frænum, in this case, was found ruptured in several places.

Ageusia and *parageusia* are derangements of the special sense of taste, which is lost for such substances as sugar, salt, acids, etc., in the first, and perverted in the second. Ageusia of an incomplete character is seen in some facial paralyses and in hysteria. It may also result from injury of the trigeminus or the glosso-pharyngeal. Both conditions may arise from irritation of the nerves of taste, and be a symptom in catarrhal diseases. Perverted taste is also seen in hysteria.

Treatment. Antiseptic and stimulating mouth washes and electricity. If the cause can be found and removed, the taste will speedily return.

Anæsthesia of the tongue may interfere with its functions. There may be gustatory anæsthesia or a loss of ordinary sensation in the tongue. This, like paralysis, may be due to a central or a peripheral cause. Loss of taste may depend, according to Butlin, upon failure of conduction in the nerves of taste.

Glossoplegia.—Paralysis may affect the muscles of one or of both sides of the tongue. That of one side alone has been observed by Lewin and others. One case, accompanied by symptoms almost identical with those of a bulbar paralysis, recovered promptly under corrosive sublimate injections. If due to cerebral lesion, glossoplegia will be apt to be attended by the same symptoms of headache, dizziness, etc. In hemiplegia of the body, the tongue is protruded, as I have already said, toward the affected side, and this is also true of monoplegia. I have seen a woman paralyzed on both sides, whose tongue lay as an inert body in the floor of the mouth, the ragged borders quivering when an ineffectual effort was made to protrude the organ, which had become atrophied from disuse. Speech was wholly impossible, and mastication very difficult.

Glossoplegia is the initial symptom in progressive bulbar paralysis, with indistinct speech and feeble protrusion of the tongue. Later on, the dorsum becomes furrowed and wrinkled. Galvanism to the neck may benefit. When the condition is due to intracranial disease, and also when it is perhaps associated with hemicrania, even though there may be no evidence of lues, iodide of potassium freely given may be of great benefit.

Hyperæsthesia of taste is seldom met with, but pain located in the tongue alone is quite common. Aside from the pain attending many diseases, elsewhere considered, we have some rare neuralgias limited to this organ, and, as a rule, to one side only.

Spasm of the Tongue.—*Clonic spasm* is a rare affection observed by Erb and others. The tongue may be protruded involuntarily, being pushed forward against the dental arch, or it may show involuntary muscular contractions on one or both sides. Clonic spasm is seen in hysteria and in the epileptic seizure. Bromide of potassium and electricity are recommended. The condition may be looked upon as a neurosis of the hypoglossus.

Chorea-like movements, limited to the tongue, have been reported as occurring in hemiplegia to the extent of interfering with speech. The movements grow less as the paralysis improves.

Tonic spasm is seen in hysteria, and in other conditions, probably due to reflex irritation.

Unilateral spasm of the tongue has been observed by Wendt. The attacks would last for several minutes at a time, the right half of the organ becoming suddenly hard and contracted by repeated twitchings. The patient recovered under galvanism.

INFLAMMATORY CONDITIONS.—The causes which may be active in producing inflammations of the tongue are multiple. Thus it may follow a great variety of injuries, bites and stings of insects, and the application of irritant substances, and it may be found in eruptive and other fevers. It may be acute or chronic. When deep-seated, inflammation of the tongue may endanger life through suffocation, and in the acute form its onset is often sudden and may end in pus formation, and the subsequent abscess may press upon the epiglottis and thus also threaten life.

In two instances I have seen glossitis result from the accidental taking of ammonia. The tongue, under these circumstances, is first made white, becomes much enlarged and painful, and then subsequently casts off its coating of epithelium. In one of the cases referred to, the patient, who was a sufferer from asthma, mistook the hartshorn for the whiskey bottle at night, and by the time I reached him the thickened tongue filled and protruded from the mouth, causing difficulty of breathing, which, added to that of the asthma, was distressing in the extreme.

Abscess of the tongue may be the result of acute inflammation of the tongue; in such cases it is deeply seated, and has been mistaken for cancer, the tongue having been removed on account of it. The more chronic forms are usually circumscribed and deep-seated, and may occur without preceding glossitis or herpes. The swelling is firm and elastic, and there is no superficial discoloration, so that it may readily be mistaken for a cyst. The abscess is generally situated toward the anterior portion of the tongue, near the edge, and is usually very chronic. An exploratory puncture quickly clears up the diagnosis when fluctuation is not clear or "pointing" is delayed. Treatment by longitudinal incision rapidly brings the case to a favorable conclusion.

Early operation to prevent suffocation is sometimes indicated, though spontaneous cure after rupture occurs in most cases; and if the patient is seen early the application of ice and cooling lotions or emollient washes prevents the more serious condition.

Actinomycosis now and again occurs as a primary disease in the tongue, developing as a deep-seated inflammation of the base, with a wood-like hardness of the entire suprahyoid region. The occupation of the patient may lead to suspicion, and confirmation will be found in the discovery of the characteristic yellow granules. As is well known the tongue, in actinomycosis in herbivorous animals, is frequently affected with nodular swellings of various sizes; and as the affection is becoming more and more frequent in man, and as infection usually takes place by way of the mouth, it will not be surprising if tongue cases become more numerous.

Anthrax.—Malignant pustule occurs in connection with lesions upon the external surface, or, in the œdematous form, upon the tongue with formation of pustules. It occurs also in rare cases as a primary lesion, as reported by Rammstedt.[9]

Chancroid may begin as a reddened tissure, to be followed by ulceration and attended with submaxillary adenopathy.

Syphilis.—The most common form in which the syphilitic poison manifests itself upon the tongue is that of the mucous patch. The primary sore may occur upon the tongue, and in the later stages we have the gummy tumor and ulceration, fissures, plaques, and tertiary ulcerations. Men are more prone to suffer relapses than women, probably owing to their greater use of tobacco and alcohol.[10]

Chancre of the tongue is commonly located at or near the tip. It may run its course before a diagnosis is made. Chancre is apt to be hollowed out, bowl- or crater-shaped, with sides gently sloping to the centre, while a tuberculous ulcer has irregular borders and base, and shows granulations which make it uneven, while here and there at the periphery are little yellow points somewhat suggesting miliary abscesses. From chancroid it is recognized by its red or rosy color, while the latter has a yellow base.

Condylomata as well as papillomata are found in syphilis; the distinction between the two being that the former are more flattened and, besides the hypertrophy of papillæ, there is a tumefaction of the intervening tissue making a more firm or solid as well as a more flattened tumor.

Gummata, which may be confounded with primary sclerosis, occurs upon the surface or within the substance of the tongue. They are rather late manifestations. Nodules the size of a pea or smaller occur upon the posterior part of the dorsum, and might escape notice if they remained unirritated. When single and laterally situated, beginning cancer is simulated. Those located within the parenchyma are not so easy of diagnosis. They may reach the size of a large hickory nut and are not very sensitive. For some reason they occur most often in men. Carcinoma is single and situated at the border, while a gummy tumor is apt to be multiple and more centrally located. Chronic abscess of the tongue is more clearly defined than gumma.

Treatment by large doses of iodide of potassium almost invariably brings about speedy resolution and cure, and this may at times prove of value as a diagnostic test. Locally, nitrate of silver stick, lightly applied, will in most cases soon cause them to disappear. If this does not act well, a solution of chromic acid (strength of from ten to fifty per cent.) will almost always bring about a rapid cure.

Cysticercus cyst of the tongue is more frequent than the echinococcus. The diagnosis is established only on incision or after suppuration. Though the occurrence of this parasite in the tongue is common in animals it is certainly rare in man. In one case the larva of the Tænia solium was found upon incision of a painful tumor of the tongue.

Echinococcus disease involves the tongue in rare instances. The diagnosis can be made only after incision or by the coincident involvement of other parts.

Diphtheria at times presents patches upon the tongue; never, however, unless the throat is coincidently affected.

Erysipelas involves the tongue by extension from neighboring parts. Primary erysipelas of the tongue has been reported by a number of observers, but while some maintain that the organ does not become tumefied, others describe the swelling to be of such a size as to render it impossible to close the mouth.

Erythema Exudativum Multiforme.—Lesions of the exudative form of erythema occur at times upon the tongue, but the quickly rupturing bullæ would be difficult of recognition were no lesions present on the skin

Since this affection likewise is apt to recur, it has been confounded with recurrent herpes of the tongue.

Herpes, in connection with the same disease, upon the face, lips, etc., is a not very uncommon condition. Actual vesicles are naturally present for only a very short time, and when the patient is seen a red, inflamed, tender, and somewhat indurated area shows where the primary lesions were situated. It is found almost wholly upon the tip and edges of the tongue.

For treatment, the application of powders containing acacia, bismuth, prepared chalk, etc., frequently repeated, or of borax in honey by means of a camel's hair pencil, acts beneficially, and when the parts are less tender, borax, alum, or tannin washes may be used.

Aphthous sore mouth often begins as a vesicular eruption.

Keloid is among the great rarities. Sedgewick[7] describes an instance seen in a young girl who had, besides the tumor on one side of the tongue, true keloid on various parts of the body. There was slow extension toward the tip of the organ.

Lepra may produce lesions upon the tongue quite similar to those which occur upon the integument. Campana saw in a leper boy a group of small papilliform tumors, that formed an oval plaque as large as a twenty-five-cent piece, slightly elevated, and with a rough surface. Some of the separate tumors were conical in form and some rounded. They had a rose color and were painless. Characteristic bacilli were found in one which was removed and examined microscopically.

A microscopical section through a leprous tongue showed bacilli collected in groups and in ball-like masses.

Lichen planus, it would appear, not infrequently causes tongue lesions which would present difficulties of diagnosis were the skin lesions absent. Erasmus Wilson first pointed out the possibility that lichen may develop upon the tongue, with roughness and the formation of round whitish patches. Jonathan Hutchinson subsequently observed lesions consisting of small papules. Neumann reports papules similar to those of psoriasis of the mucous membrane, being flattened and lentil-sized. Touton mentions a case in which the tongue was covered with flat, round, grayish-white plaques. Pospelow saw lichen planus papules which were flat and without central atrophy.

The lesions of the tongue may be more or less extensive at the time when the cutaneous eruption is first observed, or the tongue lesions may precede or follow those of the skin. In most cases the lesions occupy the mucous membrane of the cheeks and of the lips at the same time, though I have observed one patient in whom the lichen lesions were limited to the tongue and the glans penis. They occur as sharply defined white spots, rounded or slightly irregular, without marked projection above the surface, isolated or joined in groups, or as parallel lines along the borders of the tongue. Thibierge[8] thinks we must look upon these as lesions of lichen planus, although they do not itch.

According to Unna, the lichen ruber of Hebra is also accompanied by mouth lesions. In a case observed by him, there were lesions upon the tongue in the form of multiple erosions, which were altogether different from the plaques of lichen planus.

Lupus is rarely found on the tongue without having previously existed on the face, larynx, soft palate, or nose. It occurs mostly upon the back part, near the epiglottis, more rarely upon the tip, as small isolated nodules, with soft granular surface; star-shaped cicatrices result. Leloir, Clarke, and others have observed primary lesions here located, and Spires[8] records fourteen observations in connection with lupus elsewhere. The tip in one case was completely destroyed. It was probably inoculated from lupus upon the lips. In distinguishing the disease from tuberculous ulcer we have, as characteristics of the former, much less pain or entire absence of pain, and a much slower evolution.

Neuralgia of the tongue is a most distressing affection, and one difficult to eradicate without operation. Fortunately it is not common. I have observed one instance of it in a lady with arthritis deformans. The paroxysms are of short duration but of frequent repetition, and the attacks may come on at intervals of a few months. The pain is usually located along one border of the organ.

Papilloma of the tongue is an occasional cause of neuralgia, but more often the lingual nerve is affected. Daily scraping of the tongue has been accused of favoring its development. A rheumatic or other diathesis may be found as a predisposing cause.

Dubreuil reports a case in which he performed resection of the lingual nerve in a woman forty-five years of age, whose neuralgia had lasted for four years.

Nigrities Linguæ.—In black tongue the discolored area, is limited to the middle of the dorsum, as a rule, and the edges are not so black as the middle portion. The elongated oval area is limited at first, but slowly spreads. Desquamation usually follows. The affection may last weeks, months, or even years. The papillæ seem much longer and thicker than normal, and the color makes them appear still more prominent. Subjective symptoms are usually wanting. Many cases of so-called black tongue are undoubtedly accidentally or intentionally made black by iron, ink, or dyes. It has been observed under widely varying conditions. The blackness is marked and persistent, and invariably spreads from a small beginning; the color toning down from black to brown, and from the centre to the sides. Raynaud speaks of its resemblance to "a field of corn laid down by wind and rain."

Dessois[9] has described, under the name of glossophyton, a fungus found in the epithelial deposits and débris making up the black deposit upon the elongated papillæ. A black fungus of the class of Hyphomycetes, found by Schmiegelow, has been thought to be the cause.

The treatment consists in frequent applications of peroxide of hydrogen on absorbent cotton. Friction with Hebra's spiritus saponis, followed by mild salicylic ointment, or a five-per-cent. salicylic solution in ether, with the addition of five-per-cent. collodion to form a thin coating when painted on the affected areas, has been found the most efficacious by Brosin.

Pemphigus has been known to occur upon the tongue, and well-marked bullæ distended with fluid have even preceded the eruption upon the skin in the acute form. The pain is here greater than in the lesions of pemphigus vulgaris. The diagnosis must usually be made from the coincident eruption upon the skin, since the bleb almost at once is transformed into an erosion. Menzel believes that pemphigus can exist upon the tongue in the form of reddened plaques without actual bullæ.

Periglossitis sublingualis, or inflammatory œdema of the cellular tissues about the tongue, is an exceedingly rare condition, of which Henoch has recorded one instance. There is pain and difficulty in speaking and eating. The cause is unknown.

This list of affections of the tongue comprises most of those which possess some importance, but the limited amount of space which has been alloted to this topic compels me to omit a number of less important diseases. For information regarding them the reader will have to consult one of the larger monographs on the subject.

Charles Warrenne Allen.

[1] Bul. de la Soc. Méd. des Hôp., 1891.
[2] Hist. de l'Acad. R. des Scien., 1718.
[3] Die Missbildungen des Menschen, Jena, 1861.
[4] Le Progrès médical, October 27th, 1883.
[5] Trans. Belgian Surg. Soc., January 22d, 1898.
[6] Münch. med. Woch., No. 19, 1899.
[7] Pathological Transactions, 1861, vol. xv.
[8] Archives cliniques de Bordeaux, 1895.
[9] Gaz. des Hôp., No. 28, 1879.
[10] Allen: Syphilis of the Mucous Membranes of the Mouth and Tongue. Morrow's System, vol. ii., p. 223.

TONGUE, SURGERY OF THE.—INJURIES OF THE TONGUE.—*Burns and Scalds.*—The tongue is not uncommonly the subject of injury from burns and scalds. Slight burns or scalds are of but little consequence, the superficial portion of the covering of the tongue only being destroyed; in a few hours, or, at most, at the end of a day or two, the tenderness disappears without treatment. To relieve the pain, applications of sweet oil, borax and honey, bicarbonate of soda, or astringent lotions, are useful. The most severe burns are those caused by chemical agents, such as mineral acids, caustic alkalies, corrosive sublimate. When these substances have been accidentally or intentionally swallowed, the tongue is not the only part that suffers, for the whole of the interior of the mouth, the fauces, and the throat are also affected. It is often possible to recognize the poison taken by the appearance of the tongue. In poisoning by corrosive sublimate the tongue is white and shrivelled. Carbolic acid renders the mucous membrane white and hard. Vegetable poisons, as a rule, produce no alteration in the appearance of the tongue in cases of acute poisoning (Butlin).

Scalds of the tongue are not uncommon in young children, and are often produced by sucking the spout of a tea kettle. This accident is more common in England than in this country. The injury to the tongue in such cases is of small importance compared with the grave complications which arise from injury to the larynx and air passages. The tongue swells, becomes red, and is soon covered with blisters; it is of course tender and painful, and food in any form is difficult to take. This difficulty, however, soon subsides, and is of little moment compared with the grievous results which follow injury to the air passages.

Effects of Cold.—In winter, in this country, one occasionally sees an injury to the tongue in children produced by cold, and this, although it is not dangerous, is sufficiently painful. It is generally caused by the child licking with the tongue iron or other metal at a low temperature. In such cases the tongue adheres to the metal, and the child, pulling the tongue quickly away, leaves behind a considerable portion of the mucous membrane. The writer has frequently seen this accident happen to children playing out of doors when the thermometer registers a temperature considerably below the freezing point. On one occasion several children were induced by a mischief-loving companion to place their tongues on an old iron pot, the result being that each one was deprived of a large amount of the covering of the tongue and suffered considerably, especially during meals, for several days afterward. The treatment of such cases is the same, of course, as that of burns.

Stings of Insects.—In England it is not uncommon for insects, such as wasps and bees, to be taken into the mouth, concealed in fruit, and serious inflammation has resulted from their stings. In such cases Fairlie Clark [1] recommends that the mouth be frequently washed with an alkaline solution to neutralize the formic acid. A weak solution of ammonia is very efficacious.

Wounds.—Usually wounds of the tongue are not serious, but Bryant,[2] of London, mentions a case in which death followed a wound of the tongue, in a small child, from trickling of blood down the larynx, the child dying asphyxiated. Wickham Legg[3] relates cases of death following bites of the tongue in persons the subjects of hæmophilia.

Wounds of the tongue may be produced in various ways, but most commonly the wound is caused by the teeth. Epileptics not infrequently bite the tongue severely during a fit. The tongue may be severely wounded by a fall on the chin, or by a violent blow on the jaw when the tongue is protruded. The protruded portion of the tongue may be completely bitten off, or one side only be injured. Injuries to the tongue may be caused by dentists' forceps while the patient is under the influence of an anæsthetic.

The hemorrhage resulting from injury to the tongue is seldom dangerous, and is usually easily controlled by ice or exposure to air. Should the hemorrhage be profuse, its source should be sought for and the bleeding vessel, usually the ranine artery, tied. Oozing from the wound is generally arrested by bringing the edges of the wound together with sutures. In certain cases in which the wound is far back, it may be necessary to pass a ligature through the tip of the tongue to draw it out, and to examine the wound thoroughly; if it be small, then it should be enlarged and the bleeding vessel secured. In some cases it may be necessary to use the cautery to arrest the hemorrhage, its use, however, interferes with primary union. Sutures are not necessary if the wound be small, but if it be large and a portion of the tongue is hanging loose, then the edges of the wound should be carefully brought together with deeply placed silk or catgut sutures. A case is related by Mr. Gant in which the tongue was severed by an incised wound extending nearly through the substance of the organ, and dividing the lingual and hypoglossal nerves on both sides. The detached portion, which hung by a mere shred on the left side, was replaced promptly and secured, complete union took place, and the tongue slowly recovered power of motion and the sense of taste. The after treatment of wounds of the tongue is similar to that of other wounds of the mouth. The mouth should be washed out frequently with weak Condy's fluid, or a paint of iodoform and alcohol may be used.

Wounds of the tongue may be caused by foreign bodies, such as the stem of a tobacco-pipe, crochet needles, splinters of wood, etc. Foreign bodies are occasionally driven into the tongue in cases of gunshot wounds; these consist of teeth, portions of the jaw, etc.

Foreign bodies have been found embedded in the tongue months and years after the accident. A case is related of a soldier who was shot in the face at the battle of Gross Goerschen, in 1813; the bullet passed through the cheek and tongue, carrying away some of the molar teeth; the wound in the tongue quickly healed; in 1845, thirty-two years after, the tongue became swollen and discharged the second molar tooth which had been carried into it by the bullet in 1813.[4] Manget relates the case of a patient in whose tongue a ball had been lodged for six years. During this time the man stammered excessively, but when the ball was extracted, the stammering ceased.[5]

When a wound of the tongue does not readily heal, or when there is secondary hemorrhage, then a foreign body may be suspected; or again, if a sinus exists and an indolent swelling remains, it is very probable that a foreign body is present. When the foreign body is removed, the wound usually heals up. According to Butlin,[6] the removal of the foreign body does not always bring about such a happy result; in more than one case this procedure has been followed by hemorrhage which has caused death.

A case is related of a sailor, aged thirty, who was keeping watch on deck, and at the same time smoking; he either fell or struck against some object by which the pipe in his mouth was driven into his tongue and broken. There was at first but little apparent injury and only slight hemorrhage, but subsequently the tongue began to swell, and on the fourth day he was taken to the London Hospital. His mouth was closed, and he had swallowed little or nothing since the accident. There was swelling at the upper and back parts of the neck; the tongue was enormously enlarged and fluctuating. An incision was made, and an ounce of purulent fluid, mixed with blood, escaped. This gave some relief, but the symptoms soon returned with greater intensity than before. A probe was then passed into the tongue by the opening made with the lancet, and something hard was felt in the deep substance of the organ. This was grasped with forceps and extracted; it proved to be a piece of pipe stem four inches long. Immediately after its removal a frightful torrent of blood gushed from the mouth and nostrils, and the man was dead in little more than a minute. At the autopsy it was found that the pipe stem had entered the right side of the tongue near the tip, passed just below the left tonsil, and completely transfixed the left carotid artery and internal jugular vein.[7]

TONGUE-TIE, or shortness of the frænum linguæ. The tongue is bound down and cannot be protruded beyond the incisors. This is a congenital defect which is not uncommon, and when it exists to a high degree it prevents the child from suckling, and later may interfere with articulation. In such cases it is necessary to divide the tightened band; this should be done with a pair of scissors with blunt points. The points should be directed to the floor of the mouth to avoid wounding the ranine arteries. Cases are on record of fatal hemorrhage occurring from accidentally cutting these vessels. In dividing the frænum only a small cut is necessary, and then the rest may be torn through with the fingers. This even is generally unnecessary, for the child, in crying, still further frees the tongue. Petit[8] draws attention to another danger of cutting too freely. He relates three cases in which vigorous sucking in strong and hungry children tore the wound in these tissues still further open, so that the tongue, losing its anterior attachment, turned back and was embraced by the muscles of deglutition, and pressed the epiglottis firmly over the larynx until suffocation was produced. Two of the cases ended fatally before help could be afforded.

The frænum may be congenitally too long, and cases of death from suffocation have been recorded owing to this condition, the patient swallowing the tongue. A number of cases are reported in which by constant practice the patient has acquired the habit of tongue swallowing.

MACROGLOSSIA.—This is a congenital hypertrophy of the tongue analogous to elephantiasis. It is of slow development, and as the tongue enlarges it causes great trouble, the mere size interfering with deglutition and speech. The tongue may protrude over the chin and reach even as far as the sternum. The subjects of this affection frequently suffer from epilepsy. The great enlargement causes deformity of the teeth and jaws, especially the lower. The teeth frequently become carious and fall out, and the lower jaw has been known to have been dislocated by the pressure.[9] There is constant dribbling of saliva, and the protruded tongue is much altered in appearance, indurated, swollen, and purplish in color; later, nodes, irregularities, and fissures appear on its surface, and occasionally the tongue ulcerates. On puncturing it there is not much bleeding, but there is oozing of large quantities of serum. The disease is not, as a rule, noticed for the first two years, as sucking appears to stop the growth of the organ by continuous pressure. The pathology of this disease was first elucidated by Virchow; he found that there was an overgrowth of interstitial connective tissue, with a remarkable infiltration of the whole organ with white cells collected here and there in a delicate network, and forming true lymphoid tissue. The disease, no doubt, is due to congenital defect aggravated by frequent attacks of glossitis.

Treatment consists in removal of the protruded portion of tongue. In some cases the removal of a V-shaped portion will give the best results. Strapping with plaster has occasionally been successful, but excision is the best method of treatment. A few years ago a German surgeon reported a case in which great improvement occurred in a child aged thirteen months, treated by Pirogoff's method, viz., ligature of the lingual arteries.[10] This is an old method of treatment which years ago was tried and found wanting.[11] Ligature of the portion of tongue protruded has been successfully practised, but nothing is so safe or simple as excision with knife, galvano cautery, or écraseur. The hemorrhage usually is not great, and the result is almost invariably satisfactory. When bleeding is feared in young children, the removal by écraseur should be preferred, but in adults the knife or scissors is better, as their use is not followed by sloughing. The tongue should be drawn forward by means of ligatures passed through its substance behind the line of incision, and the incision should be made in such a manner that the tongue will be left somewhat pointed; the bleeding vessels should be tied as cut. The after-treatment is the same as that used for partial removal of the tongue for any other cause.

In a case of this kind in which I removed a large portion of the tongue a number of years ago, the result has been excellent, the patient now having an almost normal tongue, and speaking with great distinctness and facility.

TUMORS OF THE TONGUE.—*Vascular Tumors.*—Nævi are occasionally found in the tongue; if superficial, they may be treated by nitric acid or by puncture with thermo-cautery needles. When the growth is prominent and can be isolated, it may be excised with scissors or treated by ligature. When a nævus growth is treated by excision, the healthy tissue should be cut all around, the hemorrhage then being inconsiderable. If there is much danger of hemorrhage, the thermo cautery knife may be used. When the growth is large and more diffuse, excision by means of the wire écraseur is a valuable method of treatment; the écraseur should cut through healthy tissue. Ligature is seldom necessary in such cases, but when used it should be passed deeply into the substance of the tongue and tied very tightly.

Sir Joseph Fayrer has described[14] an affection called *cirsoid aneurism* of the lingual vessels. It simulated ranula.

Cystic tumors of the tongue are not uncommon. They may be due to dilatation of the mucous follicles, and contain a gelatinous mucus.

Sebaceous cysts occur in the tongue but very rarely; they should be treated by excision.

Fatty tumors are sometimes met with, and are usually of small size and easily removed.

Enchondromata have been described by Weber.[15]

Sarcomata of the tongue are almost unknown as primary growths.

Keloid has been noticed by Sedgwick.[16]

Fibrocellular tumors of the tongue have been described by Mason,[17] Clarke,[18] and others. They occur mostly in adults and may be congenital; these tumors are situated on the dorsum of the tongue and are quite painless and innocent. Treatment should be by excision.

Papillomata or *warty tumors* occur on the dorsum of the tongue, and consist merely of hypertrophied papillæ. Butlin[19] describes a case in which there was warty enlargement of all the fungiform papillæ. The diagnosis is easy when the affection occurs in early life, but when it exists in old people it is sometimes difficult to diagnose from epithelioma.

Treatment.—Removal by scissors is the simplest and best mode of treatment when the growths are small; when they are large, ligature is more satisfactory. If there be any induration at the base or the slightest suspicion of the growth being malignant, then, to insure its complete removal, the healthy tissue around should be excised as well as the growth. Butlin[20] states "that the treatment of the larger and doubtful warts, in persons over forty years of age, by caustics and other similar measures, cannot be too strongly deprecated." The writer has frequently seen commencing epitheliomas in middle-aged persons treated for several months by caustics, under the supposition that the case was one of warty growth; such treatment increases the rapidity of the growth if cancerous, and lessens the chance of a cutting operation being successful.

Ulceration of the Tongue.—Ulceration of the tongue may be simple, syphilitic, tuberculous, cancerous, or mercurial.

Simple ulcers may be due to irritation from a sharp tooth or to traumatism of any kind. We may have a simple ulcer as the result of long-standing superficial glossitis. Dyspeptic ulcers of a superficial character are not infrequently met with, also aphthous ulcers. These are more common in children than in adults, and general treatment by salines, combined with astringent lotions of alum or tannin, is often of great benefit. Borax and chlorate of potash washes are also useful. In treating simple ulcers the removal of the cause is generally sufficient to cure the disease. If the ulcer does not heal readily, Butlin[20] recommends the frequent painting of the surface of the sore with a solution of chromic acid (gr. x. to ℥ i. of water), or with a lotion of borax (ʒ ss.), glycerin (♏ xx.), and water (℥ i.). Burning these ulcers with nitrate of silver, especially in the old, is not to be recommended, as the irritation caused may induce a cancerous condition in those predisposed. Should the ulcer not heal rapidly under simple treatment in a man over forty years, then cancer is to be suspected, and the ulcer should be cut out. A simple operation of this kind may save the patient much future trouble.

Tuberculous ulcers usually occur on the tip of the tongue. When extensive, they are difficult to diagnose from cancer. The ulcer is irregular, with sharp-cut edges or pale flabby granulations at the base. There is very little induration of the surrounding tissue. The ulcer in its advanced stages may eat deeply into the tongue. It is generally acutely painful, so much so that the lingual nerve has been divided to ease the sufferings of the patient. In the late stages there is considerable salivation. A tuberculous ulcer of the tongue may be the primary manifestation of tubercle, or it may occur secondarily. *Primary* ulcers are rare, *secondary* more common. The writer has seen several cases which were secondary to ulceration in the larynx and tuberculous disease of the lung. When the ulcer is primary the diagnosis is difficult. From syphilitic ulcer it may be distinguished by the history; syphilitic ulcers are usually on the central part of the tongue, and if due to gummata they are preceded by local swelling. With tertiary ulcers the glands are never affected, with tuberculous ulcers they are frequently enlarged. A tuberculous family history and the existence of tubercle bacilli will help one to a correct diagnosis.

The *diagnosis* between carcinoma and tubercle is more difficult still, for in both affections the lymphatic glands are involved. The age of the patient and the existence of extensive induration would point to cancer. Cancer does not usually occur under the age of thirty. A difficult case presented itself to the writer quite recently: a young girl, aged twenty-two, with a decidedly tuberculous family history, had extensive ulceration of the right side of the tongue with slight induration, and with involvement of the lymphatic glands of that side; the ulcer was painful to the touch and there was considerable salivation. A portion was excised and under the microscope it presented the typical characters of epithelioma; no bacilli were found in this case. The patient declined operative interference.

The *prognosis* of tuberculous ulcer is quite as unfavorable as that of cancer, and the patient succumbs to the disease in from a few months to two years.

Treatment.—An endeavor should be made to relieve the pain by soothing lotions, etc. Papaitine often relieves pain, and according to some it is curative, but this the writer cannot indorse. Scraping with a sharp spoon and then painting with tincture of iodine has been advised.

Butlin[22] strongly recommends excision when possible, even if the ulcer be secondary, as both a painful disease and a focus of further infection are thereby removed. Great relief has followed the application of the following: finely powdered iodoform, gr. i.; morphine, gr. $\frac{1}{6}$; borax, gr. iij. The surface of the ulcer should be cleansed and dried before application, and the powder should be applied three or four times a day. Should the pain be intense and confined to one side, division of the lingual nerve must be thought of. General treatment by cod-liver oil and tonics should not be omitted.

Syphilitic ulceration commonly occurs during the secondary stage of syphilis, along the edges of the tongue. The ulceration is superficial, and a white patch on the mucous membrane of the cheek, corresponding to the ulcer of the tongue, will nearly always be found. Fissures or cracks which plough up the dorsum of the tongue in every direction are peculiar to syphilis; these are usually the result of tertiary syphilitic ulceration, single cracks or fissures are sometimes seen in the secondary variety. Superficial syphilitic ulcers have no induration at the base. Mucous tubercles or patches may also appear on the tip and borders of the tongue during the secondary stage, but at the same time they exist on the lips, vulva, and anus; they are oval or round in shape, grayish in color, and covered with partly macerated epithelium.

The *deep syphilitic ulcer* is caused by the breaking down of a gumma, and is usually situated on the dorsum of the tongue. It has sharp-cut edges which may be undermined, the base is sloughy and ragged, and there are always some induration and swelling of the neighboring parts.

Diagnosis.—These cases are difficult to diagnose from cancer; however, the history of the case and the situation of the ulcer will help one to form an opinion. If syphilitic, such ulcers are preceded by a lump; in cancer the induration follows the ulcer and does not precede it. There may be two or more gummata on the tongue, but a cancerous ulcer is always single. Cancerous ulcerations occur more commonly on the side of the tongue, syphilitic on the dorsum. In tertiary syphilis the glands are rarely enlarged; in cancer which has existed for some time the lymphatic glands are always enlarged. Syphilitic ulceration yields to antisyphilitic treatment. Many cases, however, occur in which the diagnosis is very difficult and can be settled only by the microscope.

It must be borne in mind that the primary lesion of syphilis may occur on the tongue, the infection being usually due to inoculation from secondary sores. The occurrence of a primary sore on the tongue is rare, and presents the appearance of primary sores in other parts. The submaxillary lymphatic glands are usually enlarged from the first. In the superficial forms of secondary syphilitic ulceration the treatment should be constitutional as well as local, viz., mercury internally, in the form of gray powder, with local application of half a grain of bichloride of mercury to one ounce of water. Butlin speaks highly of chromic acid as a local application (ten grains to one ounce of water), applied three or four times a day.

In the tertiary syphilitic ulcer, iodide of potassium in doses of from ten to twenty grains three times a day, largely diluted, combined with tonics, will effect a rapid cure; local applications other than those of a soothing character are rarely necessary. Syphilitic ulcers always leave scars; the puckered and furrowed scar left behind by a deep ulcer is characteristic.

Cancerous Ulceration.—This form of ulceration of the tongue is always of one variety, viz., epithelioma. It generally commences as a small ulcer on the side of the tongue, though no part of the tongue is exempt. The posterior half is, however, much less commonly affected than the anterior half. In eighty cases collected by Butlin,[23] cancer affected the sides and borders of the tongue in seventy-one. It occurs more frequently in men than in women; according to Barker,[24] in the proportion of two hundred and forty-seven to forty-six. It will be found, on examining the various statistics, that cancer of the tongue occurs more frequently between the ages of forty-five and fifty-five. Billroth[25] states that it is more common between the ages of fifty and sixty, and such has been the writer's experience. It very rarely occurs in young adults. Barker mentions a case at twenty-six years of age. The writer has seen one case in a woman, twenty-two years of age, in which the diagnosis was verified by the microscope.

There is no doubt that smoking predisposes to cancer of the tongue, as many cases are preceded by leucoma or the so-called psoriasis of the tongue. This condition may be produced by dram drinking, smoking, and also by syphilis. In eighty cases collected by Butlin,[26] sixteen were preceded by leucoma. The psoriasis and scars produced by syphilis, injury, or any other cause, will predispose to cancer; any irritation such as a sharp tooth, the stem of a tobacco-pipe, a bad-fitting tooth plate, etc., will in some persons excite ulceration which may take on a cancerous action. The writer saw one case of epithelioma of the hard palate in an old man, produced by the irritation of the stem of a clay pipe, which continually rested at that point owing to the toothless condition of the gums. There is no doubt, however, that cancer of the tongue may originate without any pre-existing disease or irritation, but in the majority of cases some form of irritation is the exciting cause of the disease. Many practitioners who are consulted by elderly people for ulcers of the tongue are in the habit of cauterizing the sore freely with nitrate of silver or other caustic; this is a most pernicious custom, and one which, while it does no good, may do infinite harm; for, should the ulcer be cancerous, it only aggravates it, and it may excite cancer in an ulcer which is of a simple, non malignant character, by the continued irritation. Again, it does harm in cancerous ulcers by putting off operative measures until a period when operation can be of but little use, by soothing the patient with the idea that something is being done for him. Ulceration of the tongue in people over forty years of age should always be regarded with suspicion, and if there be any doubt as to its nature, the ulcer and a portion of healthy tissue around it should be excised. When the cancerous ulcer is well developed, or the induration at its base is marked, the diagnosis is not so difficult, but if there be any doubt a portion should be excised, and the microscope will usually establish the character of the disease.

Pain is an early and characteristic symptom, not always in the tongue, but in the lower jaw, gums, ear, and sometimes the back of the head. Salivation is also often an early symptom. When the ulcer commences on the border of the tongue it rapidly infiltrates not only the tongue, but the floor of the mouth and the gums, and finally the bone of the jaw itself is affected. The tongue becomes fixed and its motion is so limited that it cannot be protruded. Should the disease begin farther back, the ulceration or infiltration extends to the pillars of the fauces, soft palate, and tonsils. These cases have proved fatal from hemorrhage caused by ulceration into the internal carotid or tonsillar arteries. When the disease has advanced thus far the glands in the neighborhood become enlarged. First, there is tenderness in the submaxillary region, with pain which shoots up to the ear; later, the glands may be felt small and hard but movable; as they increase in size they become fixed. In some cases, in the early stages of the disease, the glands may be affected, yet the fact may not be recognized by external manipulation. The first glands to become affected are the submental in the floor of the mouth, then the submaxillary, afterward the carotid at the bifurcation of the arteries, and finally the parotid. Of course the glands are involved on the same side as the cancerous disease. When the tip of the tongue is the part involved the submaxillary glands and suprahyoid glands are first affected. There are several lymphatic glands embedded in the submaxillary salivary gland. If the root of the tongue be ulcerated, then usually the parotid lymphatic glands near the angle of the lower jaw and the carotid glands are first affected, making the case a much more serious one. The lymphatic channels between the disease and the glands are usually free, a condition, according to Heidenhain, common to epitheliomata. As the disease progresses deglutition and speech become difficult, there are profuse salivation and a horrible fœtor of the breath. Patients may die from hemorrhage due to the growth ulcerating into some large vessel, or there may be frequent hemorrhages from smaller vessels which may hasten the end. The usual mode of death, however, is from exhaustion due to pain, sleeplessness, starvation, sloughing, etc. The average duration of the disease in patients who have had no operation is from a year to eighteen months. Many cases succumb in less than a year, and few live longer than two years.

Diagnosis.—In the advanced stages of cancerous disease of the tongue the diagnosis is not difficult; the foul, deeply excavated ulcer with everted ragged edges and widely infiltrated base, with large granulations protruding from it, the pain, the fixation of the organ, and the induration of the submaxillary glands, stamp the affection unmistakably as carcinoma. At this stage operation is not very hopeful.

The diseases with which carcinoma of the tongue are most likely to be confounded are: (1) Syphilitic ulceration, primary and tertiary; (2) tuberculous ulcer.; and (3) simple ulcer. The differential points of diagnosis between these diseases and cancer have been sufficiently dwelt on above. The writer would strongly urge that when the diagnosis is doubtful, the disease should be treated as cancer and removed; for, should the surgeon wait until all doubt is dispelled by the involvement of the glands and the infiltration of the surrounding tissues, then he has committed a grave fault, and one which cannot be repaired. Butlin[27] truly says: "Medical men are coming to the belief that, to 'give the patient a chance,' means usually to give the carcinoma a chance of obtaining a firm and irresistible hold, and to take all chance of complete recovery from the patient." It is much better to remove a suspicious wart or ulcer by a simple and safe operation, and thus save the patient from the ravages of a fatal disease, than to wait until the disease is pronounced, when to operate means not only great danger to the patient, but the certainty of a rapid recurrence of the disease.

Prognosis.—Cancer of the tongue, like cancer of other parts, if not operated on, proceeds invariably to a fatal termination. It is of the utmost importance that the disease should be recognized in its early stages, when it is a purely local affection. At this period, if operation by removal of the tongue be undertaken, the chances of the patient remaining free from the disease are greater, and should the disease recur the interval of freedom is much increased.

Treatment.—There is but one method of treatment of cancer of the tongue, viz., removal by surgical operation. Operation always relieves, if it does not cure. In Butlin's table of 80 cases already referred to, 70 were operated on, and 9 patients were in good health a year after the operation. Heath reports a case well eleven years after operation. Dr. Fenwick, of Montreal, reports a case in which the patient lived fifteen years after operation. Bryant,[28] of London, mentions a case well ten years after operation, and one in which the disease recurred fifteen years after operation. Barker[29] found 17 recoveries in 170 cases. According to Billroth's[30] statistics, 14 per cent. of cases are cured after operation. Even such a small percentage of cures is very creditable to surgery, and would in itself more than justify removal; but, putting aside the cures, the patient's life is prolonged and suffering is diminished by operation.

With regard to other methods of treatment by caustics, pastes, etc., they are not only useless but hurtful. It cannot be too strongly insisted on that the treatment of cancerous ulcers by caustics is bad treatment, and that the only chance the patient has of a cure is in the early removal of the disease by surgical operation. In cases of ulcers, warts, etc., on the tongue of a person over forty years of age, in which the diagnosis is doubtful, if any treatment is desired previous to removal, it should be of a soothing, non-irritating character; all irritating substances, as tobacco, spirits, highly spiced foods, etc., should be avoided. If the sore is produced by a sharp tooth this should be extracted. Caustics should be shunned, as nothing is more likely to convert a simple into a cancerous ulcer than continual irritation by caustics.

Operations for Partial and Complete Removal of the Tongue.—Small warts, whether they are on the border, tip, or dorsum of the tongue, are most easily removed with curved scissors; no anæsthetic is required. Should the growth be of larger size and far back it is better to anæsthetize the patient and place a gag in the mouth; then the tongue may be drawn out by a strong ligature passed through the tip, or by means of a vulsellum. The growth should be removed with a knife and the bleeding points secured with ligatures or arrested by the thermo-cautery. Some surgeons advise the use of the galvano-caustic loop, as by this method all fear of hemorrhage is banished and the tissues for a short distance round the base of the growth are destroyed.

Removal of a Portion of the Tongue.—Should the cancer of the tongue be confined to the tip or a small part of the border of the anterior half of the tongue, and should the submaxillary glands not be enlarged—in other words, if the ulcer be early recognized to be cancer,—the removal of a portion of the tongue is justifiable and gives a fair chance to the patient, without submitting him to the much more formidable operation of excision of the whole tongue. Partial removal of the tongue may be performed with galvano-écraseur, thermo-cautery, knife, or scissors. Czerny of late years has frequently used the thermo-cautery, and he thinks there are fewer recurrences after this method of treatment than when the knife is used. Roediger (*Beiträge zur Klin. Chirurgie*, vol. xxxi., 1901) also strongly recommends it, and says that after its use there was no fever, œdema, or secondary hemorrhage. The knife is to be preferred when it is necessary to remove only a small part of the tongue. Should the ulcer be on the border of the tongue, then the tongue should be split in the median line and the affected half removed with knife, scissors, or écraseur. In all operations on the tongue of any magnitude the mouth should be kept open with a suitable gag, such as Coleman's, Whitehead's, Hutchinson's, etc., and the tongue drawn out by a stout ligature passed through its tip, and the disease removed by the method recommended by Mr. Baker.

Baker's Method.[31]—A gag having been introduced, the tongue is drawn out by means of two ligatures placed one on each side of the median line of the tongue near the tip. The tongue is then split down the middle and the diseased half is freed from the floor and side of the mouth with scissors. Needles are now passed through the tongue behind the disease, and the loop of the écraseur is placed as far back as possible, tightened, and the affected half removed. The loop of the écraseur should be of wire or whip-cord. The objection to the use of the galvano-cautery is the troublesome slough which follows.

Removal of the Whole Tongue.—In cases in which the cancerous ulcer involves the posterior half of the organ or is very extensive, it is necessary to remove the whole tongue. The complete removal of the tongue is the better operation, even when the ulcer is small, for the chance of recurrence is much less than when only part of the organ is taken away.

In removing the tongue one of the chief dangers is from hemorrhage, and before proceeding further it might be as well to mention a very simple and efficacious method of arresting hemorrhage, occurring either accidentally during operation or afterward. This method was introduced by Mr. Heath, of London, and has been adopted by most surgeons. It is this[32]: "The forefinger, passed well down to the epiglottis, is made to hook forward the hyoid bone and drag it up as far as practicable toward the symphysis menti. The effect of this is to stretch the lingual arteries so as to completely control for a time the flow of blood through them, and in this way portions of the anterior part of the tongue may be cut off almost bloodlessly." In operating on the tongue for cancerous disease, the question arises as to the kind of operation which should be performed. After even the most radical operation the disease is apt to recur; in fact, the more severe the operation, as a rule, the more rapid the return of the disease. Some surgeons hold that the operation is merely palliative, especially if the glands are enlarged in the submaxillary region and under the sterno-mastoid. In such cases, they advise simply a removal of the tongue and non-interference with the glands.[33] Others again, as Kocher, hold that the extirpation of the diseased glands cannot be too thorough, and they in every case make an incision in the neck to search for enlarged glands, which cannot be found by external manipulations. They argue that if the glands in the axilla are removed in all cases of excision of the breast for cancer, it is quite as important to remove the submaxillary lymphatic glands in operation for cancer of the tongue. It is a simple enough operation to remove a portion of the tongue with the écraseur; the recovery from the operation is rapid, but so is also the return of the disease. In cases between the ages of forty-five and sixty a radical operation, with extirpation of the glands, is the proper one, but in cancer in old people approaching seventy years of age the case is different, and a simple removal of the tongue will probably be as successful as a most complete and radical operation. When there is extensive involvement of the glands of the neck, the case is hopeless and operation should be undertaken for the relief of the patient only, as it is impossible to remove all the disease in such cases.

Operations for the removal of the tongue, or part of the tongue, are much facilitated by dividing the cheek horizontally from the angle of the mouth to the border of the masseter muscle; this incision gives much more room and the scar left is insignificant. Jaeger first advocated this method, and Gant and Furnaux Jordan practised it in Great Britain. This procedure does not add to the risk of the operation, and it gives the operator greater facility for arresting hemorrhage.

Removal of the tongue through the mouth by the écraseur or scissors, without a submental incision, is only suitable in those cases in which the disease is limited to the anterior part of the tongue and when the glands are not involved; or it may also be practised in those cases in which the degree of gland infiltration is so great that extirpation is hopeless, and the tongue is removed purely for the purpose of relieving the patient from great suffering. In all other cases some form of submental operation should be practised, for then the enlarged glands can be easily reached and removed, and the chance of a permanent cure is much increased if the glands be extirpated. The points to be kept in view in operations on the tongue for malignant disease are: (1) The possibility of removing all the disease; (2) the prevention of hemorrhage; (3) the avoidance of the entrance of blood into the air passages; and, after operation, (4) the preservation of an aseptic condition of the mouth and secretions until healing is complete. In order to accomplish this, some form of submental operation is necessary. Operations involving division of the jaw are more serious, are disagreeable to the patient, and delay convalescence.

The operations which have been practised for the removal of the whole tongue are very numerous. The most popular operation with English surgeons at the present day is that known as Whitehead's, viz., removal of the tongue by scissors; this may be done with or without preliminary ligature of the linguals. A few years ago nearly every surgeon employed the galvanic or wire écraseur, but the occurrence of secondary hemorrhage when the slough separates is so frequent that the écraseur is much less popular with surgeons than formerly, and has been supplanted by the scissors. With scissors the entire tongue can be removed easily and simply.

Whitehead's Method.[34]—"1. The mouth is opened to the full extent with Mason's or any other suitable gag, the duty of attending to this important part of the operation being entrusted to one of the two assistants required.

"2. The tongue is drawn out of the mouth by a double ligature passed through its substance an inch from the tip. This ligature is given in charge of the second assistant, with instructions to maintain throughout the operation a steady traction outward and upward.

"3. The operator commences by dividing all the attachments to the tongue, to the jaw and to the pillars of the fauces, after the manner suggested by Sir James Paget, with an ordinary pair of straight scissors.

"4. The muscles attached to the base of the tongue are then cut across by a series of successive short snips of the scissors, until the entire tongue is separated on the plane of the inferior border of the lower jaw, and as far back as the safety of the epiglottis will permit.

"5. The lingual or any other arteries requiring torsion are twisted as divided. It is generally found that a moment's pressure with a piece of sponge held in sponge forceps, suffices temporarily, if not permanently, to arrest any bleeding; it is, however, regarded as desirable to twist, either immediately or after the tongue is removed, every bleeding vessel.

"6. A single loop of silk is passed by a long needle through the remains of the glosso-epiglottidean fold of mucous membrane, as a means of drawing forward the floor of the mouth, should secondary hemorrhage take place. This ligature may with safety be withdrawn the day after operation, and, as it is invariably a source of annoyance to the patient, it is always desirable to adopt this rule.

FIG. 4726.—Incisions for Operations on the Tongue. *a*, Incision through the cheek, after Jaeger; *b*, von Langenbeck's incision, with division of the jaw; *c*, incision for removal of glands and ligature of lingual arteries as practised by the writer.

"The after-treatment consists in feeding for the first three days absolutely and solely by nutrient enemata, satisfying thirst by occasionally washing out the mouth with a weak iced solution of permanganate of potash; forbidding any attempt at speaking, and requiring that all the wishes of the patient shall be expressed in writing or by signs. The difficulties and dangers of the operation are few and more imaginary than real. Hemorrhage, the *bête noire* of most surgeons who contemplate removing the tongue, is in reality easily controllable and frequently trifling. I have twice removed the entire tongue without having to secure a single vessel, and more than once have only had to twist one lingual artery." The operation practised by the writer is that commonly known as Billroth's, viz., excision of the tongue by scissors with preliminary ligature of the linguals. This operation enables the surgeon not only to avoid danger from hemorrhage, but also to remove the neighboring glands and structures which are involved in the disease through the same incision made for ligating the lingual arteries. In Billroth's operation the mortality is not greater than that following other operations.

Billroth's Operation.[35]—The head of the patient having been well thrown back and the chin turned to the side opposite to that on which the artery is to be tied, a curved incision is made from near the symphysis menti to near the angle of the lower jaw, the convexity downward, having its lowest portion running along the upper border of the great cornu of the hyoid bone. A careful dissection is then made through the platysma and deep cervical fascia, and if any veins are cut they should be ligatured before proceeding further with the operation. The tendon of the digastric muscle should now be searched for, and in the angle which this tendon forms with the hyoid bone, the artery will be found—but not immediately, for covering it we have the hyoglossus muscle with the hypoglossal nerve and ranine vein running over it. The hyoglossus muscle should be carefully divided, and then, all bleeding having been arrested by Pean's forceps and ligatures, the artery is felt pulsating at the bottom of the wound. Hemorrhage should now be completely arrested and the artery being brought into view can be easily tied. The artery on the opposite side having been secured in the same way, any glands that may be involved should be looked for and removed through these incisions in the neck. As a rule, they can be found without difficulty. It is a good rule to remove all the submaxillary lymphatic glands as well as the submaxillary salivary gland on the same side as that in which the cancer is. It is well before clearing the submaxillary space to ligate the facial artery.

The mouth should now be kept open with a gag and the tongue drawn out by a double ligature passed through its substance about an inch from the tip. The operator, holding the ligature in his left hand, draws the tongue outward and upward and removes it with a straight pair of scissors. The attachments of the tongue to the jaw and pillars of the fauces should first be freed and then the muscles at the base, and now, the attachment to the hyoid bone being divided with a few short cuts, the whole tongue will come away, leaving the epiglottis behind. The removal of the tongue takes, as a rule, only two or three minutes. If the tissues of the floor of the mouth be involved, they should now be attended to.

The wounds in the neck, which during the excision of the tongue should be filled with carbolized sponges, are then sewed up and dressed with aseptic gauze dressings. If the floor of the mouth has been removed it will be better to pass a large drainage tube into the mouth through the neck incision; in fact, this ought to be done in every case. The mouth is now packed with sticky iodoform * gauze and the operation is complete.

The after-treatment is the same as after excision of the tongue by other methods.

The advantages of the operation above described are many:

1. The diseased structures, and especially the glands, are discovered and removed with the greatest ease through the neck incisions.

2. The removal of the tongue is bloodless, and there is no fear of secondary hemorrhage.

3. The incision made by the scissors is a clean-cut one, and there is no bruising of the tissues as in the operation with the écraseur.

4. The tongue can be more completely and more easily removed with scissors than with any écraseur.

5. Drainage of the mouth can be more thoroughly carried out by means of the incisions in the neck.

6. The operation is easy of performance and few instruments are required, no more than every surgeon possesses, viz.: straight scissors, knife, and a few pairs of Pean's forceps.

Kocher's Operation.[36]—A still more radical and extensive operation than the one described above is the operation performed by Kocher, of Berne. It is the only operation for the removal of the tongue which aims at preserving the parts in a thoroughly aseptic condition. Tracheotomy is first performed and a well-fitting cannula introduced; the pharynx is then packed with a carbolized sponge with a cord attached, so that it can be easily re-

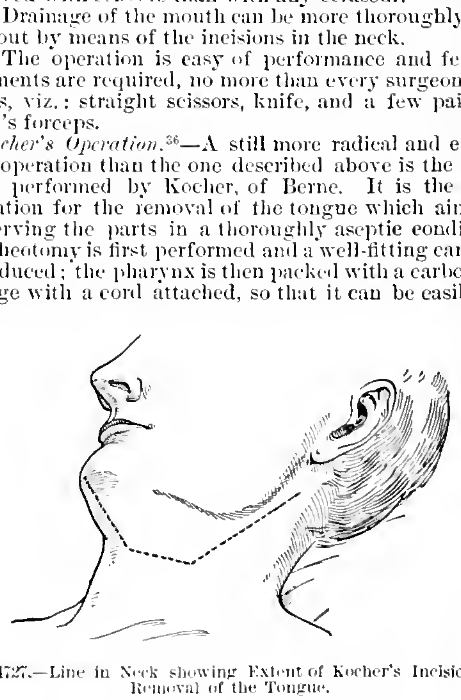

FIG. 4727.—Line in Neck showing Extent of Kocher's Incision for Removal of the Tongue.

moved when necessary. An incision is now made commencing a little below the tip of the ear and extending down the anterior border of the sterno-mastoid muscle to

* The sticky gauze is prepared with resin, alcohol, and iodoform. Weir, of New York, recommends the following formula as an improvement on that introduced by Billroth: Resin, 10 parts; castor oil, 6 parts; iodoform, 5 parts, and alcohol, 15 parts. This is rubbed into the gauze, and certainly, as the alcohol evaporates, it is sticky enough. The writer has, in cases in which the gauze failed to remain in the mouth, painted the surface over with the liquid.

about its middle, then forward to the body of the hyoid bone, and along the anterior belly of the digastric muscle to the jaw. The resulting flap is turned up on the cheek and the lingual artery is ligatured as it passes under the hyoglossus muscle. The facial artery and any veins that may be in the way are also secured. Commencing from behind, all the structures in the submaxillary fossa are removed, viz., the lymphatic glands, the submaxillary, and, if necessary, the sublingual glands. The opposite lingual artery is now tied by a separate incision if the whole tongue is to be removed. The mucous membrane along the jaw and the mylo-hyoid muscle are then divided and the tongue is drawn out through the neck incision, and removed with scissors or galvano-cautery; the latter is preferred by Kocher, as there is less liability to after-oozing. The after-treatment is most important; if the operation be an extensive one, the external wound should not be closed. Kocher's endeavor is to avoid the two great after-dangers of excision of the tongue, pneumonia and general septicæmia. To prevent the discharge causing infection, the whole cavity of the mouth and pharynx is plugged with carbolized sponges and iodoform gauze. The operation as first described was performed under the spray. The patient is fed by the rectum partly, but chiefly by the throat with a tube, twice a day, when the dressings are changed. Thus, if all the minute directions are enforced, the wound remains aseptic throughout, and no food or discharge from the wound can possibly enter the air passages. There is one thing that Kocher has not guarded against, and that is vomiting; should the patient vomit, as is so often the case after the administration of anæsthetics, the elaborate preparations against sepsis may come to naught.

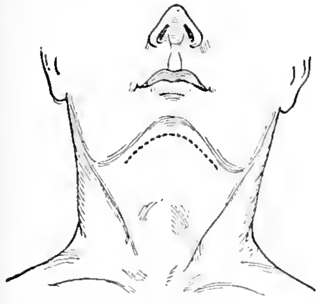

FIG. 4728.—Curved Line Below the Chin, showing the Extent and Situation of Billroth's Incision.

In Kocher's hands this operation has been most successful. He had one death in fourteen cases, eight recurred, one died a year afterward of pneumonia, one lived fourteen months, two five years, and one six and a half years.

With the modern methods of keeping the mouth aseptic, and performing all operations in the mouth with the patient in the Trendelenburg position, tracheotomy is rendered unnecessary. There is no doubt that it adds to the danger of the operation. The one death in Kocher's series of cases was caused by hemorrhage from the tracheotomy wound.

Billroth's modification of Regnoli's operation is very simple and much to be preferred to the original operation. The longitudinal incision is omitted and the curved incision is carried farther outward on each side, so that the linguals may be ligatured before removal of the tongue. It is a very suitable operation in those cases in which the submaxillary fossa is involved in the disease.

The tongue can be removed by scissors.

Removal of the Tongue after Division of the Lower Jaw.—This operation was introduced by Sédillot, of Strasburg, and afterward practised by Syme, of Edinburgh. It consists in making a vertical incision in the lower lip, sawing through the inferior maxilla at the symphysis, separating the two sides of the jaw, and drawing out the tongue and removing it by scissors, écraseur, or knife. The divided portions of the jaw are afterward wired together. It is a good plan to make the holes for the sutures before dividing the jaw.

Von Langenbeck[38] has advised a lateral section of the jaw opposite the first molar tooth. The skin incision is made from the angle of the mouth downward (see Fig. 4726). Division of the jaw adds to the danger of the operation, and makes it more unpleasant for the patient. Convalescence in these cases is usually prolonged. It is seldom necessary to divide the jaw in extirpating the tongue, even when the disease is most extensive, for the infiltrated glands in the floor of the mouth can be easily removed by one of the submental operations, with less danger and greater comfort to the patient. In some cases in which the disease has extended to the gums and bone itself, a portion of the jaw may require resection. It is often sufficient to remove the alveolar process only.

Occasionally, after removal of the tongue through the mouth, it is found that the glands in the submaxillary region subsequently become enlarged, although apparently healthy at the time of operation; then, if they appear movable and there is no recurrence of the disease in the mouth, a special operation for their removal is advisable. If, on the other hand, the glands are fixed and the tissues infiltrated, operation is of little avail. In cases of carcinoma in which the glands and the sterno-mastoid are first affected, operation is usually of little benefit.

Butlin[37] recommends that after removing part or the whole of the tongue, as the case demands, the surgeon should wait three or four weeks, and then by a separate operation remove the glands in the cervical, submental, and submaxillary regions. An incision is made along the anterior border of the sterno-mastoid muscle, from the mastoid to below the thyroid cartilage, and a second incision from the symphysis menti to the first incision about the level of the thyroid cartilage; the flap is lifted up from below and all the glands are removed, and then the flap is replaced and sutured.

The following list of operations, taken from Barker's article in "Holmes' System of Surgery" vol. ii., 1882, will prove of interest to the reader, and will serve to give him some knowledge of the history and progress of the operation of excision of the tongue.

EARLIEST IRREGULAR OPERATIONS.

1. *Pimpernelle.* Died 1658, was probably the first to excise the tongue with success.
2. *Marchetti*, 1664. Extirpated a cancer of the tongue by actual cautery; probably the first recorded extirpation for this disease.
3. *Val. Hoffmann*, 1692. Removed a tongue affected with macroglossia.
4. *Ruysch*, 1737. Excised tongue with knife.
5. *Memonista*, 1737. Cauterized with a hot iron.
6. *Heister*, 1743. Gave the first methodical description of operative treatment of cancer of the tongue.
7. *Burdorf*, 1754. Excised a true cancer of the tongue with knife.
8. *Guthrie*, 1756. Was probably the first English surgeon to excise a cancer of the tongue, using the knife, followed by cauterization of the cut surface.
9. *Louis*, 1759. Ligatured a fungus of the tongue, and in 1774 spoke in favor of total excision for cancer.

DEFINITELY DESIGNED OPERATIONS.

Ligature.

10. *Inglis*, 1803. Introduced ligature of the tongue from the mouth for cancer, the cords being drawn with needles through the tongue and round the tumor. (*Edin. Medical and Surgical Journal*, 1805, p. 34.)
11. *Major*, 1827. Split the tongue down the centre to apply ligature to the diseased half through the mouth.
12. *Cloquet*, 1827. Also split the organ, but introduced the ligature by suprahyoid incision and strangled the diseased half. (*Archives Gén.*, xii., 511.)

Wedge-shaped Excision.

13. *C. J. Langenbeck*, 1819. Introduced wedge-shaped excision of the diseased part of the tongue with careful suture of resulting flaps. ("Biblioth. f. Clin. u. Augenh.," Bd. 2, 187.)

Preliminary Ligature of the Lingual.

14. *Mirault*, 1833. Introduced preliminary ligature of lingual artery to give a clear, bloodless field for extensive incisions. He was followed later by Roux and Roser. (*Archives Gén.*, vi., 5, 656.)

Écrasement.

15. *Chassaignac*, 1854. Introduced the écraseur, employing Cloquet's suprahyoid method and defining it more exactly, *i.e.*, using puncture instead of incision. ("Traité de l'écrasem. lin., p. 31.)

16. *Middeldorpf*, 1854. Introduced the galvanic écraseur (*Schmidt's Jahrbücher*, Bd. 107, 260.)
17. *Nunneley*, 1856. Introduced the suprahyoid use of the écraseur into England. Adopting Chassaignac's modification. (*Med. Times and Gaz.*, 1862.)
18. *Girouard*, 1857. Employed circumpuncture with rods of caustic. (*Archives Gén.*, 1857.)

Division of the Cheek.

19. *Jaeger*, 1831. Was the first to divide the cheek for free access to the tongue. ("De Extir. Linguæ," 1831.)
20. *Maisonneuve*, 1858. Divided both cheeks from the angle of the mouth for same purpose.
21. *Collis*, 1867. Reintroduced Jaeger's operation, using the écraseur. (*Dub. Quart. Journ.*, xliii., 1867.)

Division of the Lower Jaw.

22. *Roux*. Died 1836. Was the first to divide the lower jaw and lip in mid-line in order to gain free access to the floor of the mouth and tongue. (Maisonneuve, Thèse, p. 146.)
23. *Sédillot*, 1844. Improved this method by dividing the bone by a serrated cut. (*Gaz. des Hôp.*, 1844, 83.)
24. *Syme*, 1857. Divided the jaw in mid-line and excised with knife. (*Lancet*, 1858, vols. i. and ii.)
25. *Billroth*, 1862. Divided the jaw and soft parts at the side in two places, and turned down the flaps of skin and bone so formed, replacing and wiring the bone afterward. (*Archiv f. Klin. Chir.*, 1862.)
26. *B. von Langenbeck*, 1875. Divided the jaw and soft parts opposite the first molar tooth on one side, in order to gain access to the side of the mouth for removal of tongue, glands, and part of palatal arch and tonsil.

Intramaxillary Operations.

27. *Regnoli*, 1838. Opened the floor of the mouth from below by an incision from middle of hyoid bone to chin, ending in another semilunar incision along the border of the jaw. The tongue was drawn through the opening and excised. (*Bull. Sci. méd. Bologna*, 1838.)
28. *Czerny*, 1870. Modified Regnoli's procedure, forming lateral flaps.
29. *Billroth*, 1871–76. Modified it still further, extending both ends of the curved incision much farther backward, and omitting the incision in mid-line. (*Archiv f. Klin. Chir.*, Bd. 16, Hft. 2.)
30. *Kocher*, 1880. Introduced a method of opening the mouth from behind and below the angle of the jaw to reach the base of the tongue and remove it with all the lymphatic glands situated there. (*Deutsche Zeitschrift f. Chir.*, Bd. xiii., 146, 1880.)

Results of the Operation.—The immediate results following excision of the tongue are fairly good, considering the severity of the operation. Whatever operation for excision of the tongue is practised, the mortality in a series of cases is about the same, so that the method of operating seems to have less effect on the result than the after-treatment. Still, certain operations are more favorable than others as regards the recurrence of the disease, and it is reasonable to suppose that when the disease is most completely removed it is least likely to return.

Whitehead in 139 operations had 20 deaths, or 14.3 per cent. Butlin [37] has collected 333 cases of excision of the tongue from the statistics of 4 operators, and finds that there were 42 deaths due to the operation. Of 202 uncomplicated cases only 14 died. In 109 cases in which there was either division of the lower jaw or excision below the jaw, the mortality was 25. About twenty per cent. of patients live three or more years after operation.

With regard to the *frequency of recurrence* it may be said that recurrence is the rule. Barker [39] has collected 170 cases in which the whole or part of the tongue was extirpated, and in only 17 cases was there non-recurrence after an interval of a year. According to the same author the duration of the disease, in cases not operated on, was 11.7 months, and in those operated on 19 months, a clear gain of 7.3 months. The longest period of freedom from the disease after operation seen by the writer was 28 months. It is to be hoped, with the modern methods of antisepsis which are now so universally practised, that the excision of the disease will be more complete, and hence the period of freedom from recurrence prolonged, and also the mortality after operations much decreased.

Dangers of Excision.—Formerly the danger most dreaded during and after operations on the tongue was hemorrhage, primary and secondary. Since the galvanic écraseur has been discarded, secondary hemorrhage is much less frequent, and both primary and secondary hemorrhage is avoided by preliminary ligature of the linguals. This procedure is a very simple one when the tongue is removed by one of the submental operations, as Billroth's, Kocher's, etc. Even should the linguals not be previously ligatured, there is usually little danger from hemorrhage, owing to the facility with which a bleeding vessel can be seized by the modern artery forceps.

The greatest danger connected with excision of the tongue is without doubt septic pneumonia, or other lung affection, produced by direct infection from the fetid discharges of the decomposing wound. In some cases there is gangrene of a portion of the lung, or numbers of small, foul, circumscribed abscesses; in others a condition of bronchopneumonia. Whatever affections of the lung ensue after excision of the tongue or severe operations on the mouth and jaws, they are all due, either to the inhalation of fetid gases from the sloughing wound in the mouth, or to discharges from the same source passing down the trachea to the bronchi and lungs. In other words, the lung affection is produced by direct infection from a foul wound. Barker [40] has collected 52 cases of death following operation; of these 30 were fatal from some pulmonary affection; 12 from septic affections, in 6 of which no mention is made of the condition of the lungs; and in the remaining 10, death was due to various causes, as shock, collapse, asphyxia, exhaustion, etc. The passage of blood into the trachea during operation is another cause of lung affection, and, to avoid this, anæsthesia should not be too profound. Usually symptoms of pneumonia and bronchopneumonia appear soon after the operation. The case may go on favorably for two or three days, then there is a troublesome collection of ropy mucus in the mouth and the wound becomes very fetid, cough is complained of, the temperature and pulse run up, respirations are very rapid, and the patient becomes cyanosed and dies in a few days with symptoms of pneumonia. The breath during all this period has been horribly fetid. The autopsy discloses acute congestion of the trachea and bronchi, and in the lungs are numerous small foul-smelling abscesses with, in places, patches of gangrene. Cases occur also in which the patient dies of simple pneumonia threatening to become gangrenous.

Treatment after Excision.—The most important point in the after-treatment is to preserve a condition of asepsis in the wound, for, as has been shown above, the greatest danger is due to direct septic infection from the wound itself. Again, the swallowing of blood at the time of operation, tainted with the foul discharges of the cancerous ulcer, should be carefully guarded against by having the mouth thoroughly and frequently washed out with some antiseptic solution, as Condy's fluid, carbolic acid, etc., before operation, and, during operation, avoiding a condition of too profound anæsthesia. After operation the wound in the mouth should be packed with sticky iodoform gauze as recommended by Billroth, painted over with alcoholic solution of iodoform and resin, or at least dusted with iodoform crystals. Billroth, as already mentioned, had seventeen cases of excision without a death or even a serious symptom, owing to the mouth being kept thoroughly aseptic by the packing with sticky iodoform gauze, which in a day or two becomes incorporated with the wound. The writer has found great difficulty in keeping the gauze in the mouth after the first day; he has found that it becomes loose and covered with mucus, and that the patient finds it very troublesome. He has used with good results the following paint, advocated by Weir, of New York, to impregnate gauze: Iodoform, 5 parts; resin, 10 parts; castor oil, 6 parts; and alcohol, 15 parts. When painted on, the alcohol evaporates and leaves the resin and iodoform behind coating the surface of the wounds. This should be painted on twice daily. The first three or four days after operation the patient should be fed entirely by the rectum, and occasionally allowed to rinse out his mouth with water to allay thirst. After this, feeding should be by the mouth through a tube introduced into the œsophagus. A very good arrangement is a soft catheter with a piece of rubber tubing attached to it, and to this again is attached a glass funnel; by pouring liquid food into the funnel the patient can be easily and comfortably fed. Should any fœtor appear in the wound, the mouth should be frequently washed out with a solution of Condy's fluid, carbolic acid, or chlorate of potash. Washing out is much facilitated if there is a drainage tube through the incision in the submaxillary region.

Palliative Treatment of Cancer of the Tongue.—The object is to relieve pain and lessen fœtor and salivation. To relieve pain, division of the lingual nerve is advised, and also the administration of opium. Fœtor and salivation may be controlled by frequent washings with some antiseptic solution, as Condy's fluid or carbolic acid, and afterward the dusting on of iodoform or salicylic acid. Bleeding, which so frequently terminates the case, may be controlled by styptics, or by lint soaked in tincture of the muriate of iron and kept continually pressed against the bleeding points with forceps. Should the bleeding be distinctly arterial, then ligature of the lingual artery of that side is the only remedy.

Excision or Stretching of the Lingual Nerve.—Division of the lingual nerve was first put in practice by Hilton[41]; then Moore[42] advised a more simple procedure than Hilton's. This was to make an incision with a curved bistoury through the mucous membrane in a line from the last molar tooth to the angle of the jaw. The simplest method is as follows, and this method is suitable for division, excision, or stretching. The writer has practised it and found no difficulty in reaching the nerve. The mouth should be opened with a suitable gag, then a ligature is to be passed through the tongue near the tip, and the tongue drawn out to the side opposite to that on which it is desired to stretch the nerve; this puts the nerve on the stretch and it can be felt standing out as a cord at the side of the tongue: a sharp hook is passed under it, and then the nerve is exposed by a small incision, pulled out by a blunt hook, and excised or stretched as the necessities of the case may indicate. Mr. Clement Lucas[43] was the first, as far as the writer's knowledge goes, to put this plan in practice.

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REFERENCES.

[1] Diseases of the Tongue, p. 231.
[2] System of Surgery, vol. i., ed. 1884, p. 585.
[3] Treatise on Hæmophilia, 1872.
[4] Oester. medicinische Woch., 1846.
[5] Legouest: Traité de chir. de l'armée, 1872.
[6] Diseases of the Tongue.
[7] Lancet, August 26th, 1837, quoted by Fairlie Clark.
[8] Histoire de l'Acad. Roy. des Sciences. 1742, p. 247 of Memoirs, quoted by Barker in Holmes' System of Surgery, vol. ii., 1883.
[9] Chalk: Transactions of Pathological Society of London, vol. viii., p. 305.
[10] Fehleisen: Berlin. klin. Woch., No. 50, 1887.
[11] Fergusson: Practical Surgery, fifth edition, p. 519.
[12] Pitha and Billroth, Band 6, 1866–73.
[13] Stromeyer: Chir. Krankh. d. Kopfes, 1868.
[14] Clinical Surgery of India.
[15] Pitha and Billroth: Handb. d. Chirurgie, p. 329.
[16] Transactions of the Pathological Society, vol. xii., p. 234.
[17] *Ibid.*, vols. xv. and xviii. [18] *Loc. cit.*, p. 213.
[19] *Loc. cit.*, p. 247. [20] *Loc. cit.*, p. 250. [21] *Loc. cit.*, p. 95.
[22] *Loc. cit.*, p. 107. [23] *Loc. cit.* [24] *Loc. cit.*, p. 590.
[25] Klin. Chir. [26] *Loc. cit.* [27] *Loc. cit.*
[28] Practice of Surgery, fourth edition, vol. i., p. 663. [29] *Loc. cit.*
[30] Koenig: Lehrbuch der Chirurgie, Bd. 2, p. 451.
[31] Brit. Med. Journ., vol. ii., p. 765, 1883.
[32] International Encyclopædia of Surgery, vol. v., p. 508; and British Medical Journal, April 21st, 1888.
[33] Heath: British Medical Journal, April 21st, 1888.
[34] Transactions of the International Medical Congress of 1881, vol. ii.; and Lancet, October 22d, 1881.
[35] Shepherd: Annals of Surgery, November, 1885.
[36] Deutsch. Zeitschrift für Chirurgie, 1880.
[37] The Operative Treatment of Malignant Disease, second edition, 1900.
[38] Vorlesungen über Akiurgie, Berlin, 1888.
[39] *Loc. cit.* [40] *Loc. cit.*, p. 610.
[41] Guy's Hosp. Rep., second series, vol. vii., 1852.
[42] Med. Chir. Trans., vol. xlv., 1862.
[43] British Medical Journal, November 15th, 1884.

TONICS.—Tonics are medicines that promote nutrition and thus increase the strength of the body when it is reduced. The term tonic is derived from the Greek word *tonos*, tension, and was applied to agents that restore the normal strength, because it was supposed that they specially increase the tone or tension of the contractile tissues, that is, restore the constant, active, but weak, involuntary contraction normally existing in all organs containing such tissues. They were held to act either directly upon the contractile tissues, or upon the nerves by which they are innervated. This view is no longer entertained, as it is evident that the tone or strength of all organs and tissues depends upon the state of their nutrition, any diminution of which becoming manifest in more or less weakness and loss of functional power.

For practical purposes all tonic medicines may be divided into three classes: *gastric tonics*, *blood tonics* or *hæmatinics*, and *general tonics*. Gastric tonics improve the digestive process when it is enfeebled, thus enriching the blood, and supplying all the organs and tissues with an abundance of nutritive material. Blood tonics, or hæmatinics, supply the blood with material in which it is deficient, especially increasing the number of red blood corpuscles. General tonics increase the nutrition and weight of the body by augmenting or otherwise modifying the process of assimilation in the tissues.

GASTRIC TONICS.—Some of the medicines that improve the process of digestion when it is weak or imperfect, act directly upon the organs of digestion, enabling them to perform their function more powerfully; others, however, have no direct influence upon the stomach and intestines, and act only upon the substances undergoing digestion, hastening this process. The latter are distinguished from the former by the term *digestives*.

Nearly all gastric tonics have an intensely bitter taste, and act similarly upon the digestive organs. Hence they are called *bitter tonics*. Since they closely resemble one another in action, it is unnecessary to consider them separately, with the exception of the principal alkaloids of cinchona and nux vomica, which are supposed to promote nutrition by acting also upon other organs.

BITTER TONICS.—All bitter tonics increase the secretion of saliva, and, soon after coming into contact with the gastric mucous membrane, produce a feeling of hunger. In consequence of the stronger appetite a larger quantity of food is eaten. In cases of atonic dyspepsia the digestion of the large meal is not attended by the feeling of heaviness and discomfort, and other symptoms which usually result from slow and imperfect digestion, showing that the bitter tonics cause some decided improvement in the digestive process. This improvement, however, follows only when the bitter tonics are given in moderate doses; excessive doses, especially if frequently repeated, soon causing symptoms of gastro-intestinal catarrh, nausea, vomiting, and diarrhœa.

In regard to the mode of action of bitter tonics the following facts have been ascertained:

1. They increase the salivary secretion. The saliva hastens the digestion of amylaceous food and stimulates the gastric glands, and thus excites an abundant secretion of gastric juice. It has been held that this sufficiently accounts for their utility in cases of atonic dyspepsia (Leube).

2. They gently irritate the gastric mucous membrane, and thus, it is supposed, excite the feeling of hunger. As the larger quantity of food consumed is digested more easily and speedily in cases of dyspepsia, it may be assumed that the secretion of gastric juice becomes augmented, either directly by the moderate irritation, or indirectly by the greater relish of the food. It is supposed that in many cases of dyspepsia due to slight catarrh of the stomach, the moderate irritation gradually restores the normal circulation of the gastric mucous membrane.

3. In experiments it has been found that bitter tonics retard fermentation and putrefaction. The small doses usually effectual in atonic dyspepsia may doubtless exert some antiseptic influence, but it is improbable that their utility is chiefly due to this action.

4. Cetrarin and calumbin, injected into the jugular vein of animals, cause a rise of the general blood pressure by exciting the vaso-motor centre (Koehler). Hence it has been supposed that possibly all bitter tonics may to some extent act like digitalis, which, in indigestion dependent upon enfeebled heart action, improves the

digestive process by causing the supply of arterial blood to the stomach to be increased. But no changes of the blood pressure have been observed after the administration of bitter tonics until a notable improvement of the general nutrition of the body has resulted. It seems probable, however, that the action of quinine and strychnine upon the digestive organs is in part due to an improvement of the general circulation.

The bitter tonics display their therapeutic power most markedly in atonic dyspepsia, that is, in cases of dyspepsia in which the slow and imperfect digestion results solely from weakness of the stomach. In such cases the appetite is feeble, and the tongue clean or only thinly coated, and generally pale and flabby. Unless only very digestible food be eaten, in moderate quantities, the meals are soon followed by a feeling of weight in the epigastrium, and often by fulness and eructations which sometimes have a rancid taste. But decided pain in the region of the stomach, and thirst, fever, and vomiting are absent.

The bitter tonics are also employed in dyspepsia due to chronic catarrh of the stomach; generally small doses, in slight or mild cases, soon cause a notable abatement of the symptoms; but they generally aggravate severe catarrh, and are decidedly injurious in ulcerative affections of the stomach. They should therefore not be used when there are present severe pain and tenderness of the epigastrium, a heavily coated tongue, and vomiting of blood or large quantities of mucus.

As the bitter tonics improve general nutrition and strength solely by their action upon the digestive organs, they are useless in all forms of general or local debility which are not attended by enfeebled or disordered digestion.

As a rule, the bitter tonics should be given a short time before meals, so that a keen appetite may set in as soon as food is taken. Of the official preparations, the tinctures are the most useful in atonic dyspepsia; generally the compound tincture of gentian, the compound tincture of cinchona, the tincture of quassia, and the tincture of calumba are sufficiently active in doses of one-half to one drachm. The tincture of nux vomica is effective in doses of five to ten drops, and even smaller quantities sometimes in slight catarrh of the stomach.

If no other morbid state is present requiring active remedies, the bitter tinctures may be prescribed undiluted, the patient being told to take each dose in a small quantity of water or sweetened water. Sometimes they are ordered with a small quantity of syrup or with an aromatic water to modify their taste. The following formulæ illustrate the usual modes of prescribing in atonic dyspepsia: ℞ Tinct. cinchon. comp., ℥ iss.; syrupi, ℥ ss. M. Sig.: A teaspoonful in water before meals. ℞ Tinct. gentian. comp., ℥ iss.; syrup. aurantii, ℥ ss. M. Sig.: A teaspoonful in water before meals. ℞ Tinct. quassiæ, ℥ iss.; syrup. zingiberis, ℥ ss. M. Sig.: A teaspoonful before each meal. ℞ Tr. nucis vom., ʒ i.; aq. menth. pip., aq. destill., āā ℥ i. M. Sig.: A teaspoonful before each meal.

Quinine.—In dyspepsia due to weakness of the stomach the salts of quinine seem to act in the same manner as other bitter tonics. But they are more efficient than the latter when dyspepsia is associated with malarial affections, or is consequent upon pulmonary and cardiac diseases. Probably this is due to the fact that, given in moderate tonic doses, they somewhat increase the general blood pressure.

The opinion is prevalent that quinine may sustain the strength of the body under circumstances contraindicating bitter gastric tonics, such as prolonged fevers with a high temperature. Very commonly doses of two or three grains are given three or four times daily, or even more frequently, in typhoid fever, pneumonia, pleuritis, and other similar diseases. Whether this use of quinine is ever beneficial is very doubtful, and there is reason to suppose that in typhoid fever, especially if the quinine be not given in acid solution, it may increase the tendency to hemorrhage and perforation.

As gastric tonics the salts of quinine should be given in small doses, one-half to one grain, or at most two grains, preferably in solution. ℞ Quin. sulph., gr. xvi.; acid. hydrochl. dil., q.s.; tinct. cinchon. comp., syrup. aurantii, āā ℥ i. M. Sig.: A teaspoonful before each meal. ℞ Quininæ hydrochl., gr. xvi.; glycerini, ℥ ss.; aq. menth. pip., ℥ iss. M. Sig.: A teaspoonful before meals.

Strychnine.—The salts of strychnine are frequently employed as gastric tonics, and are very efficient. They are preferred to all other bitter medicines when feeble digestion is associated with diseases of the respiratory organs impairing the breathing process, such as phthisis, chronic bronchitis, and emphysema. Doses of one-thirtieth grain often notably ameliorate both dyspnœa and dyspepsia. In those diseases of the heart which are productive of disorder of the general circulation, and of slow and feeble digestion, strychnine also should be preferred to those bitter tonics which act solely on the digestive organs. In cases of dyspepsia complicated with habitual constipation, small doses of strychnine sometimes restore normal intestinal peristalsis. As a gastric tonic it should be given in solution or in powder. ℞ Strychn. sulph., gr. ss.; acid. hydrochl. dil., ʒ ss.; tinct. gentian. comp., syr. aurantii, āā ℥ i. M. Sig.: A teaspoonful before meals. ℞ Strychn. sulph., gr. ss.; sacch. lactis, ʒ i. M. Div. in partes æquales xvi. Sig.: One powder before each meal.

Alcohol.—As a tonic no substance is more beneficial when properly used, or more detrimental when abused, than alcohol. Taken in small quantities well diluted, as contained in some alcoholic beverages, especially light wines and malt liquors, it is doubtless the most pleasant and active remedy in cases of atonic dyspepsia. It was observed from time immemorial that wine, taken very moderately with meals, enables a weak stomach to digest food more easily and speedily, and increases the general vigor of the body. Hence the advice of St. Paul to Timothy: "Drink no longer water, but use a little wine for thy stomach's sake, and often infirmities."

In experiments it has been found that alcohol, applied in small quantity to the gastric mucous membrane, causes a more copious secretion of gastric juice than any other substance. Doubtless it is this action, a decided increase of the secretion of gastric juice when wine is taken with full meals, which augments the appetite and enables the stomach easily to dispose of the larger quantity of food. Taken in excessive quantity alcohol retards digestion and causes gastric catarrh. This effect always results if large quantities are rapidly imbibed so as to produce decided intoxication. It is frequently observed also in individuals who habitually drink to excess, especially in those who take ardent spirits before meals. Some persons, however, who indulge excessively in beer or light wine, do not exhibit any symptoms of gastric disorder.

In cases of atonic dyspepsia only light wine or malt liquor should be recommended for prolonged use, as the danger of excessive indulgence and hence injury to the stomach is much greater from ardent spirits. If it become necessary to use whiskey or other strong alcoholic, the patient should be warned against taking it undiluted before meals.

Alcohol is superior to other gastric tonics not only because it is more agreeable, but because it exerts a more favorable influence on general nutrition. It is now well established that alcohol is nearly completely consumed in the body, and that in undergoing oxidation it yields heat and other force, and thus behaves in the same manner as other non-nitrogenous food. Robust persons with strong digestive organs, who easily dispose of sufficient food to maintain perfect nutrition, do not require alcohol as a nutrient; but those who naturally have a weak stomach and "often infirmities," are decidedly benefited by moderate quantities.

Alcohol displays its greatest utility in diseases so profoundly disordering the digestive organs that little or no ordinary food can be digested. In typhoid fever it is often the means of saving life. As it requires no digestion and is quickly absorbed, it may be given when no gastric juice is secreted. In chronic wasting diseases in which the digestive process gradually becomes more and more enfeebled, alcohol is capable of maintaining for a long time a fair state of the general nutrition.

The quantity of alcohol to be taken for therapeutic purposes varies with the nature of the disease. In atonic dyspepsia a few ounces of wine with the principal meal often suffice. Many persons having a weak stomach prefer to take a small quantity of wine with a little bread or other light food between the ordinary meals. Thus they eat more frequently, but never overload the stomach.

In febrile diseases, when little or no ordinary food can be digested, alcohol should be administered, like other medicines, at regular intervals. The quantity to be given will depend chiefly upon the temperature and general condition of the patient. If the temperature is very high and ordinary food cannot be digested, more will be required than when the temperature is less elevated and the digestive power is somewhat better preserved. So, too, more is usually required when the patient is very weak than when he is in a fair state of strength. Whiskey or other form of spirits should always be diluted before administration.

In all cases in which patients seem to require the prolonged use of alcohol in any form, and its recommendation is deemed advisable, they should be informed that its excessive use will surely produce serious pathological changes, and that "1 gm. of absolute alcohol per kilogram (two pounds) of body weight is the average limit per diem that cannot safely be exceeded." (See article on *Alcohol*.)

Digestives.—Digestives are medicines that act directly upon the food in the digestive organs, causing it to digest more rapidly and perfectly. They are used when the stomach is unable to secrete a sufficient quantity of gastric juice, or when the juice secreted has an abnormal composition. The digestive power of the gastric juice depends upon the presence of hydrochloric acid and pepsin. If either one of these be deficient, digestion may become tardy and imperfect, and the symptoms of dyspepsia supervene. Recently cases have been reported in which digestion seemed perfect, although no trace of free hydrochloric acid could be detected in the gastric contents. In other cases prolonged superacidity was found without any notable gastric disorder.

Hydrochloric acid is sometimes secreted in insufficient quantity in cases of atonic dyspepsia. Usually the bitter tonics, especially the preparations containing alcohol, excite a more abundant secretion, and hence suffice to allay the symptoms of defective digestion. But sometimes the symptoms persist notwithstanding their proper and continued use. When this is the case, recourse should be had to hydrochloric acid, which is generally followed by rapid improvement.

It is best, as a rule, to administer the acid soon after meals, and, if necessary, to repeat the dose once or twice at intervals of two hours.

Some writers hold that in cases of dyspepsia in which acid eructations frequently occur, the acid should be given before meals, as by its astringent action upon the gastric mucous membrane it will tend to diminish the excessive secretion of acid. The presence of an excess of acid in the stomach during the digestive process is usually due to fermentation which gives rise to abnormal acids; generally the administration of hydrochloric acid after meals prevents such fermentation. Should, however, this method of administration fail to give relief, the acid may be given before meals, as, of course, it is not impossible that an excess of it may be secreted.

The dose of the official dilute hydrochloric acid may vary from ten to thirty drops. It should be diluted with several ounces of water, and may be given in mixture with a bitter tincture and a small quantity of syrup. ℞ Acid. hydrochlor. dil., ʒ ij.; tinct. gentian. comp., syrup. aurant., āā ℥ i.; aq. destill., q.s. ad ℥ vi. M. Sig.: A tablespoonful after meals.

Pepsin, like hydrochloric acid, is essential for normal digestion. But, inasmuch as it is a ferment, a small amount may suffice to digest very large quantities of albumen if there be constantly present a sufficient quantity of acid. As a digestive it is indicated when the stomach is unable to secrete a sufficient amount; but it is impossible to state when this is the case. The contents of the stomach of dyspeptic patients, removed at various intervals after meals, were rarely found to digest fibrin more rapidly after the addition of pepsin, while this almost invariably took place after the addition of hydrochloric acid (Leube). So, also, the contents of the stomach of typhoid-fever patients, while constantly found destitute of hydrochloric acid, always seemed to contain a sufficient amount of pepsin (Gluzinski). Hence, in cases of dyspepsia, if hydrochloric acid, properly given, have failed to improve digestion, pepsin may be used together with the acid. The dose of pepsin is about ten grains, and is administered soon after meals. The official solution of pepsin, containing some hydrochloric acid, is given in doses of half an ounce.

Extract of malt, when properly prepared, contains a small quantity of diastase, and hence may promote the digestion of amylaceous food. For this purpose it may be taken with the meals, in quantities of one to four drachms, either alone or mixed with milk, bouillon, or wine. It has been recommended as a nutrient in wasting diseases, but should not be employed unless it is not possible to administer more useful s 'bstances.

Pancreatin has been recommended in cases of imperfect intestinal digestion. It is doubtful whether it can pass through the stomach without losing its activity. In some cases of dyspepsia it has been found to give relief when administered together with a little soda about two hours after meals.

Papain, a ferment obtained from the juice of *carica papaya*, digests fibrin and albumen more readily than pepsin does, and has therefore been recommended in dyspepsia in doses of five to ten grains.

HÆMATINICS.—This term is applied to medicines that increase the coloring matter of the blood, the hæmoglobin. The most important of these are the preparations of iron or the

Chalybeates.—Iron is an efficient remedy in most forms of anæmia. Usually the symptoms due to the defective state of the blood gradually vanish when it is properly administered for some weeks; the integuments lose their waxy pallor and resume a healthy glow; the pulse again becomes full and forcible; the vertigo and headache cease; and the languor and depression give way to the normal strength and vigor. This remarkable action was observed long before it was known that iron is a component of the hæmoglobin of the red blood corpuscles. Since it has been ascertained that a diminution of the coloring matter of the blood indicates a deficiency of iron, it has been held that chalybeates cure anæmia by supplying material necessary for the rapid regeneration of the red blood corpuscles.

It is generally supposed that the preparations of iron produce little or no effect in healthy persons, if given in such forms as not to cause serious gastric disorder. But careful observations recently made (see *Therapeutische Monatshefte*, Bd. ii., p. 11, 1888) show that even minute doses of chloride of iron, repeated day after day for several weeks, may induce notable disorder of the stomach, accelerate the heart's action, and cause severe attacks of dyspnœa, a feeling of general heat, occasional flushing of the face, itching of the skin, acneiform eruptions, and slight conjunctivitis.

In anæmia, if the cause of the defective state of the blood be irremediable, iron fails to produce any marked or permanent increase of the red blood corpuscles. Hence its use in chronic wasting diseases and in organic affections is generally futile. Its utility is most strikingly manifested in chlorosis; often a steady increase of the hæmoglobin from day to day is observed, and in a few weeks the blood again contains the normal number of red blood corpuscles. It is also very efficient, though usually less essential, in the anæmia remaining after severe acute diseases and after hemorrhages; but is almost powerless in pernicious or idiopathic anæmia.

In all cases of anæmia it is essential for success in the use of iron that all the circumstances influencing nutrition be favorable; that the patient have a plain nutritious diet, that he take a sufficient amount of bodily exercise, that he spend a considerable part of each day in the open air, and that he be regular in all his habits.

Iron is contraindicated as a hæmatinic when the temperature is abnormally elevated, when there is present an organic disease of the stomach, or any affection of the lungs attended with congestion of the pulmonary circulation.

The official preparations of iron are excessively numerous, and young practitioners are often in doubt as to the most efficient ones. When the object is simply to hasten the regeneration of the red blood corpuscles, it is immaterial which preparations are selected, as all, if given in such doses and forms as not to disorder the digestive organs, act equally well.

The dose should be small, even of those preparations which have little local action. The quantity of iron contained in the food daily consumed by a vigorous person is about one grain; it is doubtful whether a much larger quantity can be assimilated when iron is given as a medicine. It may be observed, even when small doses are given, that the greater part is not absorbed and is voided with the fæces.

The preparations most frequently used are reduced iron, saccharated carbonate, mass of carbonate, citrate, pyrophosphate, iodide, and tincture of the chloride.

Reduced iron is given in doses of one to two grains, generally in pill or powder. ℞ Ferri reducti, 5.0 (gr. lxxv.); pulv. rad. althææ, 4.0 (ʒ i.); gelatin., q.s. ut ft. pil. No. 90. Sig.: At first one and gradually two or three pills three times daily. If properly prepared these pills are soft, and hence well borne by the stomach (Leube). ℞ Ferri reducti, gr. xij.; sacch. albi, ʒ i.; ol. menth. pip., gtt. ij. M. Div. in part. æqual. xij. Sig.: One powder after each meal.

Saccharated carbonate of iron is given in doses of from five to ten grains. In cases of atonic dyspepsia with anæmia, it may be given together with quinine as follows: ℞ Ferri carb. sacch., ʒ i.; quin. sulph. gr. xij. M. Div. in part. æq. No. xij. Sig.: One powder after each meal. It may also be administered in the form of an effervescent draught as follows: ℞ Ferri carb. sacch., sodii bicarb., āā ℈ iv. M. Div. in part. æqual. viij. Sig.: No. 1. ℞ Acid. tartarici, ℈ ij.; sacch. albi, ℈ ij.; ol. limonis, gtt. ij. M. Sig. No. 2. Dissolve one powder of No. 1 in some water, add one powder of No. 2, and drink while effervescing.

Mass of carbonate of iron is given in pill. It is frequently ordered together with quinine as follows: ℞ Quin. sulph., gr. x.; mass. ferri carb., ℈ ij. M. Ft. pil. No. xx. Sig.: One or two pills after meals.

Citrate of iron is usually ordered in solution, and sometimes in powders and pills. The bitter wine of iron is an excellent preparation in atonic dyspepsia and anæmia, given in doses of one or two teaspoonfuls after meals. Pyrophosphate of iron is given like the citrate, in doses of five to ten grains after meals, usually in solution.

The syrup of the phosphates of iron, quinine, and strychnine is frequently employed in atonic dyspepsia and anæmia, in doses of one or two teaspoonfuls.

The tincture of chloride of iron contains about five per cent. of metallic iron. It is given in cases requiring an astringent preparation, in doses of ten to thirty drops, largely diluted. Glycerin modifies its taste very markedly. ℞ Tinct. ferri chlor., ʒ ij.; glycerini, ʒ xiv. M. Sig.: A teaspoonful in a wineglassful of water after meals.

GENERAL TONICS.—Some general tonics act chiefly as nutrients, gradually increasing the weight of the body, and invigorating all the organs by supplying needed material; others seem to exert a stimulating or modifying action upon the tissues, in consequence of which they assimilate the nutritive material of the blood more rapidly.

Cod-liver Oil.—In chronic wasting diseases and in various kinds of malnutrition, cod-liver oil displays remarkable power. Usually it improves the appetite, invigorates the digestive organs, augments the number of red blood corpuscles, and increases the body weight.

Besides the ordinary constituents of oil, it contains free fatty acids, the quantity varying with the kind of oil. According to a recent analysis, the quantity of free oleic acid in the pale variety of oil varies from 0.18 to 0.71 per cent., and in the dark variety from 2.54 to 5.07 per cent. Cod-liver oil contains also traces of iodine, bromine, chlorine, phosphorus, sulphur, ammonia, and trimethylamin, and the dark variety, biliary matter.

The superior digestibility of cod-liver oil has recently been satisfactorily explained (Buchheim, 1874). It had long been observed that this oil diffuses itself through animal membranes more rapidly than do other oils. As the presence of bile greatly increases the diffusibility of other oils, and the early analyses of cod-liver oil had shown the presence of bile in it, the remarkable digestibility of the oil was attributed to the biliary matter. But Buchheim showed that the pale oil contains no bile, and that its digestibility is solely due to the free fatty acids. The modifying influence of the fatty acids can be readily observed by placing a small amount of dilute solution of soda (3 to 1,000) in a test tube and adding a few drops of cod-liver oil. In a very short time the mixture becomes milky, the union between the soda and the fatty acids completely emulsifying the oil.

It is well known that all fats and oils, before they can be absorbed, must undergo a similar process in the small intestine. This is accomplished chiefly through the influence of the pancreatic juice, which contains a peculiar ferment having the power to decompose fats into glycerin and free fatty acids. The free fatty acids, coming into contact with the alkali present in the intestinal juices are quickly saponified and thus enabled to emulsify any undecomposed fat.

Cod-liver oil, containing free fatty acids, becomes emulsified more readily than other fats in the alkaline intestinal juice; hence many persons, who are soon disordered by other fats, perhaps from defective secretion of pancreatic juice, readily digest cod-liver oil.

Perhaps the utility of cod-liver oil is not fully explained by its great digestibility; it may after absorption differ in action from other fats. It is said to have been observed in horses that the fat laid on from corn is tolerably permanent, while that produced by feeding on grass is soft and quickly disappears when the animal is put to work (Brunton). Possibly cod-liver oil is so useful in some wasting diseases by promoting the growth of cells more rapidly than do other fats and oils. It certainly, in many cases of anæmia, rivals iron in the rapidity with which it causes an increase in the number of red blood corpuscles.

Cod-liver oil is indicated in all chronic diseases attended by anæmia and emaciation. It has been found, by the most careful observers, to be the best means of sustaining and increasing nutrition in chronic pulmonary affections, especially phthisis and chronic bronchitis. Often, soon after its use is begun, the symptoms of phthisis greatly abate, and in some cases, when little pulmonary tissue is invaded and injured, a complete cure results. It is also successfully employed in debility of the nervous system resulting from prolonged overwork, and in hysteria and neuralgia. Usually it is strikingly beneficial in diseases of the bones, rickets, chronic rheumatism, and tertiary syphilis; in malnutrition of the heart with defective general circulation, and in scrofulous affections of the glands, mucous membranes, skin, and bones.

The dose of the oil should at first be small, about a teaspoonful. As soon as the stomach has become accustomed to it, and eructations having the taste of the oil have ceased, the quantity should be rapidly increased to one or two tablespoonfuls three times daily. Children rarely require more than a dessertspoonful. As the alkaline intestinal juices are most abundantly secreted after meals, the oil should be taken a little while after eating. As a rule, the various means used to disguise its taste, except perhaps alcoholics, soon become repulsive. Children, and many adults, soon become accustomed to its taste, and often take it with a relish.

Lipanin.—This term has recently been applied by J. von Mering, of Strasburg (see *Therapeutische Monatshefte*, Bd. ii., p. 49), to a substitute for cod-liver oil, consisting of pure olive oil and six per cent. of oleic acid. Like cod-liver oil, it speedily emulsifies in weak solutions of soda. It has an agreeable taste, and hence is readily taken even by fastidious patients. In numerous cases it was found to agree well with the stomach, even during the summer months, and in no instance did it cause nausea, vomiting, or diarrhœa. Given to adults in doses of from two to six tablespoonfuls daily, it notably increased the general strength and the body weight. J. von Mering concluded, after observing its action in numerous patients, that it is well adapted to all affections in which cod-liver oil is successfully used, and especially to cases in which a deficiency of pancreatic juice and bile in the small intestine renders the absorption of ordinary fats difficult or impossible.

Probably other oils, to which oleic acid has been added, such as cotton-seed oil, will be found to be equally digestible and useful.

Arsenic.—Arsenious acid and Fowler's solution, given in minute doses in cases of impaired general nutrition, slowly increase the body weight and the power of all the functions. Under their prolonged use, diseases due to malnutrition, especially those of the skin, nervous system, lungs, and stomach, generally improve, and sometimes completely subside.

Even in the healthy state of the body, arsenic may increase nutrition. Thus Kopp, who had been experimenting with arsenic and could not entirely prevent its access to his organism, in two months gained twenty pounds in weight. It is now well established that in Styria some peasants have the habit of consuming arsenic at regular intervals for the purpose of increasing their powers of endurance. In numerous careful experiments upon animals, Gies (*Arch. f. exper. Path u. Pharm.*, Bd. viii., p. 175) found that arsenious acid greatly promoted nutrition and decidedly increased the weight of the animals, and especially hastened the growth of osseous tissue.

In doses but little larger than those which promote nutrition, arsenic may cause incipient symptoms of poisoning—thirst, nausea, pain in the epigastrium, headache, sleeplessness, fever, conjunctivitis, and œdema of the eyelids. Usually these symptoms quickly subside when the use of arsenic is discontinued.

Arsenic is employed in numerous diseases due to malnutrition—the early stage of phthisis, chronic diseases of the skin, irritability of the stomach from catarrh, ulcer, or cancer, chorea, and in various forms of neuralgia. In malarial affections it is often used successfully, even when quinine fails, especially in the anomalous forms known as masked ague. According to late reports, it has proved more useful in idiopathic or pernicious anæmia than iron, cod-liver oil, and other remedies which augment the number of red blood corpuscles.

As a rule, the dose of arsenious acid should at first be minute; if necessary it may be gradually increased until the pathological condition for which it is given has improved, or until the incipient symptoms of its poisonous action become manifest. As soon as any of these take place, especially gastric irritation or conjunctivitis, the dose should be diminished or discontinued. In some cases, especially diseases of the skin, small doses should be given for some time after the symptoms of disease have disappeared, in order to prevent their recurrence. The minute dose of one-fiftieth grain of arsenious acid, or two drops of Fowler's solution, given after each meal, will usually produce a notable effect upon the general nutrition in one or two months. Prudence requires that Fowler's solution be ordered in a dilute form. ℞ Liq. potassii arsen., ʒ ss.; aq. menth. pip., aq. destil., āā ℥ i. M. Sig.: A teaspoonful after meals. ℞ Liq. potassii arsen., ʒ ss.; tinct. gentian. comp., ℥ iss.; syr. aurant., ℥ ss. M. Sig.: A teaspoonful after meals.

Phosphorus.—In minute doses phosphorus markedly promotes the growth of osseous tissue. In larger doses it augments the interstitial tissue of the stomach and liver, and induces chronic inflammation of these organs with atrophy of the secreting cells. Poisonous doses rapidly cause fatty degeneration of the stomach, pancreas, liver, kidneys, heart, muscles, and blood-vessels. As it forms a chemical component of nervous tissue, it has been supposed to be specially useful as a nutrient for the nervous system; but nothing indicating such action has been observed after the prolonged administration of minute doses, except that functional nervous diseases sometimes improve during its use.

Phosphorus is indicated in diseases of the bones requiring a more rapid or perfect growth of osseous tissue, such as osteomalacia, rickets, and insufficient ossification after fractures. It has been recommended also in various diseases of the nervous system, and seems sometimes to have been successful in those of a functional nature, such as neuralgia, nervous debility, incipient dementia, and impotence. It has been used with alleged success in obstinate skin diseases, and in leucocythæmia.

The dose of phosphorus ranges from gr. $\frac{1}{150}$ to gr. $\frac{1}{12}$. In rickets a daily dose of gr. $\frac{1}{120}$ was found sufficient. In neuralgia and other functional diseases of the nervous system, some practitioners have succeeded with doses of gr. $\frac{1}{100}$ to gr. $\frac{1}{50}$ given thrice daily. As much as gr. $\frac{1}{12}$ every four hours for twenty-four hours has been given in severe neuralgia.

The official *phosphorated oil*, containing one per cent. of phosphorus, and the *pills of phosphorus*, each containing gr. $\frac{1}{100}$, are convenient forms for administration. ℞ Olei phosphorati, ♏ xvi.–xxxvi.; mist. amygdalæ, ℥ ij.; ol. gaultheriæ, gtt. viij. M. Sig.: A teaspoonful one hour after meals.

Phosphide of zinc contains one-fourth its weight of phosphorus and is given in pill, in doses of gr. $\frac{1}{20}$ to gr. $\frac{1}{4}$.

Mercury.—Until recently it was supposed that mercury in minute as well as in large doses, given for some time, always exerts a deleterious influence on the general nutrition. In 1869 Liègeois reported that he had observed that subcutaneous injections of minute doses of corrosive sublimate had increased the body weight of healthy men. Bennet (1874) found that small doses increased the weight of dogs. Keyes (1876) carefully investigated the effect of small doses of mercury upon the red blood corpuscles and the general nutrition, and concluded that mercury acts as a tonic upon persons in fair health and not syphilitic, increasing the number of red blood corpuscles and the body weight. Schlesinger (1881), who made numerous careful experiments upon rabbits and dogs, fully confirmed the facts found by the above-mentioned observers.

Although no physician will be inclined to use mercury as a tonic in ordinary forms of emaciation and debility, yet it seems rational to employ it when the low state of nutrition occurs in persons who present symptoms of syphilis. According to Keyes ("Venereal Diseases," p. 119, New York, 1880), tonic doses may be continued steadily during several years without injury to the patient.

Samuel Nickles.

TONSILS, THE.—(Faucial tonsils. Amygdalæ. Tonsillæ.) (Tonsils of Luschka. Lymphoid or adenoid tissue at vault of pharynx.) (Tonsils of the Tongue. Lymphoid tissue at base of tongue.)

These organs are essentially collections of lymphoid tissue, differing in location and somewhat in appearance and function, but composed largely of the same elements. They are so situated as to form an interrupted circle extending completely around the pharynx. In the normal condition their presence is hardly perceptible.

Pathologically, while each may be affected by diseases peculiar to itself, there are many conditions from which all may suffer alike, since their histological structure is identical. It will be convenient, therefore, to study in one of them the minute anatomy and the pathological conditions common to them all, thus avoiding unnecessary repetition. The one most available for this purpose is the faucial tonsil.

I. FAUCIAL TONSILS.

General Anatomy.—The faucial tonsils are two glandular organs situated one on each side of the fauces, and between the anterior and posterior pillars of the soft palate. They consist essentially of reduplications, more or less extensive, of the oral mucous membrane, in which are enclosed an abundant deposit of adenoid or lymphoid elements, the whole organ having an identity and a special function of its own. The gross structure of the tonsil varies. Its usual shape is ovoid, and it more or less completely fills the triangular space between the anterior and posterior pillars of the palate. Its base is generally defined clearly, and corresponds with the greatest antero-posterior diameter of the tonsil. Its average vertical diameter is 20 mm., and its transverse diameter is 13 mm. Often a collection of lymphoid tissue lies below the tonsil, and sometimes above it, large enough to look like a small additional tonsil. Sometimes it extends as a narrow but slightly elevated strip far lower down in the pharynx than the usual limit. The gland is sometimes divided by a deep sulcus running across its antero-posterior diameter, generally above the centre, and thus separating it apparently into two distinct lobes. A supernumerary tonsil, the *tonsilla accessoria*, has been described.

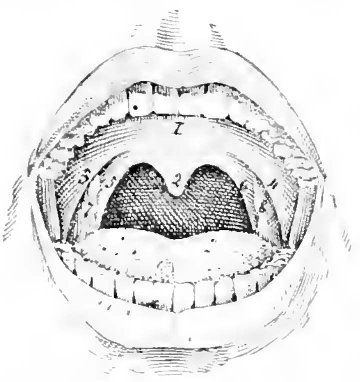


Fig. 4729.—The Tonsils. 1, Hard palate; 2, uvula; 3, 4, anterior pillars; 5, 6, posterior pillars; 7, 8, tonsils.

In early infancy it is sometimes impossible to demonstrate the presence of the tonsil, or, in fact, of the lymphoid ring, at all, while in other cases all of the elements of the latter have been found in a condition of marked hypertrophy soon after birth. Its period of greatest activity is just before puberty. It tends to atrophy with old age.

The surface of the tonsil is perforated by a varying number of depressions, slit-like or circular, the common orifices of the system of cavities which it contains. If the tonsil of the rabbit be considered as a single lingual follicular gland, we have in man a multiplication of this to the number of from eight to eighteen, the interval between any two adjacent glands forming a lacuna tonsillaris, crypt, or one of the system of cavities mentioned above. Many of them are spacious in extent, and they often penetrate deeply into the substance of the gland, sometimes almost reaching to its hilum. Often there are found in the interior of the tonsil single larger cavities, each of which includes several follicular folds and secures their common discharge at the periphery. The crypts of largest size and greatest depth are, as a rule, found in the middle part of the tonsil. By reason of this arrangement of the crypts the surface of the tonsil is thrown into numerous and extensive folds, and an extraordinary increase in the superficial extent of the gland is obtained. The crypts generally are filled more or less with a yellowish substance, composed of fat molecules, loosened pavement epithelium, lymph corpuscles, small molecular granules, and cholesterin crystals. Opening into the supratonsillar fossa, the triangular space at the top of the tonsil, are often numerous crypts, sometimes of large size. They are apt to be the exciting cause of acute or chronic inflammatory conditions of the tonsils, or of the parts in their vicinity, and they constitute an important feature of the anatomy of the part. In all examinations of the pharynx the supratonsillar fossa should be carefully studied.

In its minute anatomy the tonsil is for the most part like other so-called lymphoid glands. In common with the rest of the oral cavity it is invested with a thick covering of pavement epithelium. Proceeding from without inward, the surface epithelium is scaly, each cell having a flattened, circular nucleus. Beneath this the cells and their nuclei become less flattened. Still lower are found several layers of polyhedral cells, which have spherical nuclei and are connected together by intercellular cement substance. Among them are a certain number of prickle cells. The whole rests upon a single layer of columnar epithelial cells with oval nuclei, and is furnished abundantly with simple papillæ. Under the epithelium is a delicate endothelioid basement membrane. Following this is a tolerably compact mucosa formed of interlacing bands of fibrous connective tissue and containing many connective-tissue corpuscles. In the normal adult tonsil this structure is so delicate that sometimes it is hardly recognizable. In chronic disease of the gland it may become enormously increased. From it bands of connective tissue extend centrally into the larger tonsillary folds, and the whole forms essentially both an enclosure and a framework for the adenoid tissue or proper substance of the gland, as well as a nidus for its vessels.

The lymphoid tissue consists of a dense meshwork of fine, homogeneous fibrils which contains, besides occasional endothelioid connective-tissue cells, a large number of lymph corpuscles. These are small, round cells, each of which has a distinct spherical nucleus surrounded by a very thin covering of cell protoplasm. Near the cortex the lymph corpuscles are collected by means of delicate septa given off from the inner stratum of the capsule into a single row of oval masses called lymph follicles. Throughout the rest of the gland the lymph cells are diffused without any particular arrangement. Occasionally they extend so near the periphery as to penetrate the mucosa and encroach upon the epithelial layers. This is particularly the case in the interior of the crypts, where the epithelial layer is, as a rule, either wanting altogether or to be found only in occasional patches and in modified form, and where its thickness tends to decrease as the bottom of the lacuna is approached. In other words, the epithelial and subepithelial layers, thick at the periphery, become rapidly more delicate the deeper we trace them down the crypt wall, until, toward the lowest depth of the lacuna, they generally disappear. The tonsil is supplied abundantly with racemose mucous glands.

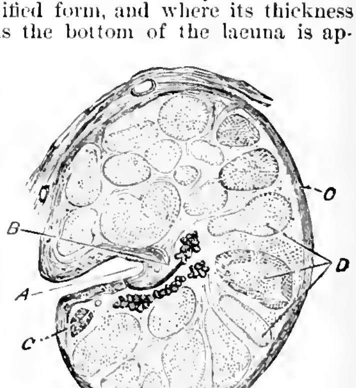


Fig. 4730.—Section of Normal Tonsil. (Morell Mackenzie.) *A*, Hilum; *B*, mucous gland; *C*, epithelial covering; *D*, lymphatic follicles; *E*, stroma.

The arteries which supply the tonsil are larger and more abundant toward its lower part. They accompany the connective-tissue sheath and its septa, give off a branch to each follicle and to the papillæ of the mucous membrane, and divide into a network of capillaries which unite to form one or more veins.

A lymph sinus, in open connection with a network of lymphatic vessels of the neighboring tissue, surrounds each follicle over more or less of its circumference, and sends prolongations outward.

The minute distribution of the nerves is not definitely known. Fibres from the sympathetic undoubtedly are supplied to the tonsil.

From its peculiar position with regard to important adjacent parts, and by reason of the frequency with which operative interference is called for in the treatment of pathological conditions to which it is liable, the surgical anatomy of the faucial tonsil is of the utmost interest.

The average interval between the free borders of both tonsils has been estimated to be 2.5 cm. (1 inch), so that, when the mouth is closed, the inner aspect of the tonsil touches the tongue.

In cases of normal size the tonsil extends but slightly, if at all, beyond the anterior palatine arch, which is formed by a projection of the palato-glossus muscle, and not at all beyond the posterior pillar, formed by the palato-pharyngeus. With both of these muscles it has fibrous attachments. A loose submucous cellular tissue extends from the anterior and posterior palatine arches toward the pharyngeal side of the tonsil, which facilitates infiltrations and the formation of abscesses, particularly in the anterior arch. Small bundles of muscular fibres, apparently independent, are to be found in the connective tissue of the external side of the tonsil which corresponds with the hilum. This side is also surrounded by fibres from the superior constrictor of the pharynx. Its outer aspect, moreover, is directed toward the internal pterygoid, from which it is separated by the above-mentioned muscular fibres, by the bucco-pharyngeal fascia, and by a thin layer of fat.

The relations of the tonsil with the internal carotid artery are not so intimate as is commonly supposed. Both carotids are behind it, the internal carotid a little over half an inch and the external carotid three-quarters of an inch distant from its lateral edge. The supply of blood conveyed to the tonsils is, if the size of these bodies be considered, remarkably large. They are nourished by the tonsillar and palatine branches of the facial artery, and by branches from the descending palatine, and from the ascending pharyngeal and dorsalis linguæ.

The ascending pharyngeal is often anomalous, for it not only varies greatly in its place of origin from the carotid, springing occasionally from the occipital or the internal carotid, and now and then being double; but also that branch which is distributed to the pharynx is often much larger than normal when the ascending palatine branch of the facial artery is unusually small. Cases are not infrequently observed in which the pulsations of the artery, enlarged as above stated, are plainly visible upon inspection of the pharynx. The vessel seems, generally, to lie directly behind the tonsil, and to be of considerable size.

Physiology.—The physiological function of the tonsil has never been established. From the experiments of Goodale and others it would seem that one of its offices is the arrest and destruction of pathogenic micro-organisms, although the extent to which it is capable of this is limited, and when the limit is exceeded, the tonsil becomes a potent carrier of infection.

Acute Inflammation.—*Tonsillitis.*—In the tonsil, as in other parts of the body, the general term inflammation includes a great variety of affections. Not only do we find in this organ the ordinary inflammatory conditions, general and specific, which may attack its various structures, but besides these there may occur special affections not commonly met with in other parts. The study, therefore, of the inflammations of the tonsil becomes a matter of unusual interest.

Acute inflammations of the tonsil are undoubtedly due to the influence of various micro organisms. In a certain number of cases the Klebs-Loeffler bacillus is found, although the clinical signs of diphtheria may be absent. More commonly are found the streptococcus, the staphylococcus, the diplococcus, the tetracoccus, and sometimes the pneumococcus. The presence of the Klebs-Loeffler bacillus does not seem necessary to render the disease infectious, and even when it is absent the risk of infection to other persons is to be considered. When paralysis follows tonsillitis, it is probable that diphtheria bacilli were present.

While acute inflammations of the gland in general possess characteristics of greater or less similarity the one to the other, the symptoms being quite uniform, it is nevertheless important to understand what symptoms are common to all cases, and what indications they offer for treatment, and also to appreciate the special conditions and needs which may exist in a given case.

Owing to the similarity in structure of the different parts of the lymphoid ring the inflammations which may affect them are practically the same. The conditions which are present in tonsillar inflammation, therefore, will well describe them all.

In general proliferative tonsillitis the follicles become enlarged through increase in the number of their lymphoid cells, particularly in the direction of the nearest crypt, and of the endothelial cells of the reticulum. According to Goodale, the proliferation of these endothelial cells gives rise to large phagocytic epithelioid cells that are characterized by a relatively large amount of markedly acidophilic cytoplasm, and an irregular, lightly staining, eccentrically situated nucleus. They contain in their interior from one to ten or fifteen cell fragments, which are generally lymphoid cells or red blood corpuscles in various stages of digestion. The lymphoid cells between the follicles are increased in number and closely packed together. The blood-vessels are dilated, filled with red and white blood corpuscles, and show more or less marked proliferation and exfoliation of their endothelial cells.

The epithelium of the crypts is diminished in bulk, from a widening of the intercellular spaces, which are crowded with escaping lymphoid and plasma cells. Bacteria, chiefly cocci, occur superficially in the epithelial lining of the crypts, but apparently they are absent in the lymphoid tissue. The crypts are filled with exfoliated epithelial cells, leucocytes, bacteria, amorphous débris, and in severe cases fibrin, which encloses cells and bacteria in a delicate network. At times the fibrin may extend from the crypts into and even beyond the epithelium, penetrating most deeply in the interfollicular region. Bacteria are most abundant near the surface of the crypt, gradually diminishing in numbers toward the base.

Suppurations below the mucous membrane may be local or diffuse. In some cases of tonsillitis abscesses form in the interior of the follicles, and finally discharge into the crypts. They have been found particularly in association with the streptococcus pyogenes. The growth of the abscess is usually in the direction of the nearest crypt. Sometimes peritonsillar inflammation is the result of the discharge of the intratonsillar abscess into the efferent lymph channels.

In diphtheria a diffuse necrosis of the epithelium may occur, or there may be a necrosis or ulceration extending into the lymphoid tissue from the crypts. Tuberculosis may affect all the parts of the ring, as may syphilis and mycosis.

Pathology.—Chronic enlargement of the tonsils is a true hypertrophy or hyperplasia, in which, according to Virchow, there is not only increase in volume of the gland, but an actual multiplication of all of its constituent parts. The epithelium covering the tonsil usually shows little change, but the papillæ underneath are often more numerous and less elevated than in the normal state; while, in the crypts, there seems to be a tendency for the membrane to become thinner as the bottom of the crypt is approached.

The substance of the gland may show one of two varieties of alteration. Either the lymphoid elements alone may be increased in amount, the stroma of the gland being little affected, or the fibrous tissue which constitutes the stroma may be greatly in excess of the normal degree. In the latter condition the lymphoid elements may be in excess, for a condition of general atrophy may be present. The external appearance of the tonsil in the first-named variety of disease is quite characteristic, the surface being rough and irregular in outline, dark red in color, and the substance of the gland being soft and compressible. The mouths of the crypts are usually more or less open, and the whole organ is deeply congested. Microscopical examination shows that while the lymphatic follicles are increased in number and size, the stroma is not markedly augmented. Such a tonsil may be removed easily, and, as a rule, without pain. In the other variety the surface is smooth and often glazed, the color is pink or even dull gray, the consistence firm and unyielding; while the mouths of the crypts are apt to be partly occluded, and the crypts themselves filled with broken-down excreta. Microscopically, the most striking feature of the section will be the remarkable proliferation of the fibrous stroma, which may be found more or less thickened at the periphery, and in the interior of the gland may be so greatly increased in amount as to encroach extensively upon the adenoid elements. In performing tonsillotomy in such a case great resistance to the knife or the tonsillotome may be experienced, and considerable pain caused by its passage through the tonsil. Again, the main blood-vessels ramify in the stroma. When the latter is normal or not excessive in amount, the walls of the vessels, when divided, easily close and bleeding is stopped. In fibrous tonsils, however, the excess of connective tissue surrounding the blood-vessels makes it difficult for the latter to undergo the normal process of retraction when divided, so that bleeding after the removal of such a tonsil is apt to be more prolonged than in the case of the first-mentioned variety.

The fibrous form is found during childhood, but is more common in adult life. Hence the greater liability of the adult to hemorrhage after tonsillotomy, the rule being that, in patients under twenty years of age, the operation is almost absolutely devoid of danger.

Etiology.—The causes of tonsillitis may be both predisposing and exciting. Of the former the most important factor seems to be youth, since it is most prevalent between the ages of fifteen and twenty-five years. It is rare in early childhood and after fifty, although a case is recorded in which suppurative tonsillitis took place in a child of only seven months. In many cases the tendency to tonsillar inflammations seems to be directly hereditary, and not referable to any mediate condition. Climate may play an important part.

Hypertrophy of the tonsils greatly increases the liability of the individual to acute attacks of tonsillitis. Sometimes this seems to be due to the retention, in the enlarged lacunæ, of excretory matter, which acts septically and so excites the adjacent tissue that a tonsillitis supervenes. Again, the tonsil seems, in many cases, to be a vulnerable spot, which is apt to sympathize with various irregularities of the body, and to be subject to inflammation as the result of dyspepsia, menstrual irregularities, rheumatism, and gout. A general condition of ill health may predispose to tonsillitis, and it is a matter of common observation that it may be caused by mental depression and by unusual anxiety or care.

The exciting causes of tonsillitis are usually ascribed to exposure to wet and cold. Septic influences, however, play an important part in their production.

In the latitude of New York tonsillitis is most frequent in the spring, next most frequent in the winter, less so in the fall, and least prevalent in the summer. It is most frequent in March, and least frequent in September. The disease is uncommon in tropical and in very cold climates.

Tonsillitis may be present as a complication in scarlet fever, measles, and smallpox. It may also be caused by the inhalation of irritating vapors or the swallowing of caustic substances. Finally, it may arise from various traumatisms, such as wounds, laceration from or impaction of foreign bodies in swallowing, and from the irritation due to accretions in the tonsillar crypts.

Classification.—Tonsillitis may be divided into several varieties, a convenient classification being as follows:

1. Superficial or lacunar tonsillitis, characterized by diffuse inflammation of the mucous membrane of the tonsil and accumulation of fibrinous exudation and desquamated epithelium in the crypts, which appears at the surface in patches of whitish exudation.
2. Parenchymatous tonsillitis, in which the deeper tissues of the tonsil are inflamed, and there is considerable swelling.
3. Croupous tonsillitis, in which a false membrane forms upon the tonsil.
4. Acute ulcerative tonsillitis.
5. Gangrenous or phlegmonous tonsillitis.
6. Peritonsillitis, with or without the formation of abscess.

Symptoms.—The symptoms which usher in an attack of tonsillitis are, in general, much the same for all varieties of the disease. In fact, it is often impossible for the physician, or even for the experienced patient, to predict, at the outset, the probable course of the illness.

In lacunar tonsillitis, supposing the case to be one of simple catarrhal inflammation, and not diphtheritic, the swelling of the tonsil is less considerable than in the suppurative form, but the mucous membrane is of a bright red color, and a whitish exudation is seen issuing from the mouths of the lacunæ, giving to the surface of the tonsil the appearance of being covered with a number of small, rounded patches.

Sometimes the deposit extends beyond the mouth of the crypt, and, this happening in the case of two or more lacunæ, the surface of the tonsil may present a considerable area of exudation from the coalescence of several individual patches. Follicular tonsillitis usually undergoes spontaneous resolution in from two to five days.

Another variety of tonsillitis is that in which there is observed upon the surface of the gland a distinct herpetic eruption, the mucous membrane and the parenchyma at the same time being violently inflamed. This condition generally runs the course of a simple acute tonsillitis, subsiding in two or three days. It is often associated with the earlier symptoms of some more serious affection, and particularly with those of pneumonia.

Acute ulcerative tonsillitis is sometimes seen in persons who have been exposed to debilitating influences, and who are at the same time surrounded by bad hygienic conditions. It is characterized by the appearance upon the tonsil of a deep, unhealthy, more or less extensive sloughing ulcer, which gives rise to much local pain and profound general disturbance. Its course is slow, and convalescence may be attended with much prostration.

Gangrenous or phlegmonous tonsillitis includes erysipelas and acute inflammatory œdema, grave conditions due to infection and described in Vol. VI, under the heading, *Pharynx, Diseases of: Acute Phlegmonous Pharyngitis.*

Peritonsillitis may end in resolution or in abscess. While abscess of the tonsil itself may occur, the pus generally discharging through one of the crypts, it is common for the abscess to be located outside of the tonsil, in the loose connective tissue upon which the latter rests.

Obstinate constipation almost invariably precedes and accompanies tonsillitis. The urine is highly colored, loaded with urates, contains an excess of urea, and is deficient in chlorides; albumin is sometimes found. The existence of albumin in the urine seems to be indirectly dependent upon the height of the temperature. When this is over 103° F., a trace of albumin is often present; but there are no casts, and the albumin generally disappears when the temperature begins to fall. Its presence is of no more importance than the transient albuminuria of pneumonia and erysipelas, although upon first finding it one is apt to feel uncertain as to whether the affection of the throat may not be diphtheritic.

In many cases of true-suppurative tonsillitis there is from the first a sensation of deep-seated pain and throbbing, which to the experienced sufferer marks the attack as one of quinsy. The general symptoms are malaise, chilliness, and febrile temperature, more or less pronounced, together with a sense of stiffness and dryness of the throat, and more or less pain in deglutition. As the soreness of the throat becomes worse the temperature tends to rise, until it may reach as high as 106° F. It is apt to rise most rapidly and to the highest point in the young, and, in the follicular form of the disease, may attain a maximum in a comparatively short time. Generally, however, the constitutional symptoms are more marked in the suppurative form. In patients of debilitated constitution the fever may assume almost a typhoid character, while the tonsils become dotted with a grayish exudation or are actually covered with sloughing, unhealthy ulcerations. In some instances the disease seems epidemic, attacking several persons in the same household and constituting the so-called "spreading quinsy," a disease suggestive of septic infection, and rarely observed without the coexistence of a definite source of infection. The progress of the disease may be unfavorable, leading to a true phlegmonous condition closely allied to genuine erysipelas, if not identical with it, and to extensive infiltration of the tissues of the neck in the vicinity of the tonsil, which has been known to extend downward as far as the clavicle; while the violence of the inflammation not infrequently produces an œdematous condition of the throat, which is occasionally fatal. The inflammation usually extends to the mucous membrane lining the Eustachian tube, causing decided temporary loss of hearing, and sometimes inflammation of the middle ear. Dysphagia in a severe case of quinsy is often intense, the patient being unable to swallow even his own saliva, and absolutely refusing to take food, because of the inordinate pain caused by every attempt at deglutition, and because, from the tumefied state of the parts, the stiffening of the muscles, and the general local disability, the act of swallowing is a physical impossibility. The patient may be unable to move the jaw, the mouth becomes covered with a thick yellowish-gray deposit, the breath is fetid, the teeth are covered with sordes, and the countenance presents an expression of great anxiety and suffering, characteristic of the disease. The location of the abscess may be either in the parenchyma of the tonsil or in the layers of connective tissue which lie between it and the outside of the pharynx. In the former case death has more than once been produced by the sudden rupture of the abscess during sleep, and the consequent strangling of the patient. When the abscess is peritonsillar this danger is also present. Instances are recorded in which, through the presence of a peritonsillar abscess, the walls of the internal carotid have become eroded, and rupture, with speedy death, has taken place.

Differential Diagnosis.—The diseases which may be mistaken for tonsillitis are diphtheria, phlegmonous pharyngitis, retropharyngeal abscess, scarlatina—when the rash is not well developed,—syphilis, cancer, and pharyngo-tonsillar mycosis.

In suppurative tonsillitis, the inability to separate the jaws, the fetid breath, the coated tongue, and the peculiarly anxious and suffering expression of the countenance, together with the comparatively slight systemic disturbance which often accompanies its earlier stages, are fair evidence of its nature. Examination of the tonsil by palpation will often be of material assistance; the organ feels hard and prominent, while the slightest pressure upon it gives rise to intense pain. By means of the finger the presence of pus may be demonstrated, the tissues having a characteristically doughy feeling, or else actually presenting fluctuation. In cases in which pus is suspected, but in which fluctuation is not apparent, Stoerk has suggested that, while the exploration of the tonsil is being made with one hand, the gland be supported from the outside by pressing gently with the other hand, behind and below the ramus of the jaw.

It is in follicular tonsillitis that the greatest difficulties of diagnosis will present themselves, the desideratum being to distinguish the simple forms of that disease from true diphtheria. While simple follicular tonsillitis is generally distinguished from diphtheria by the absence of glandular swelling of the neck, albuminuria, and subsequent paresis of the pharynx, nevertheless, all of these symptoms may be present. The nature of the exudation also may be misleading. Usually the catarrhal exudate is confined to the mouths of the crypts, and may be easily stripped from the surface of the mucous membrane and dragged from the crypts, leaving the subjacent membrane intact; while in diphtheria the membrane is deposited in patches upon the surface of the gland, is adherent, and, when torn from its place, leaves the membrane underneath distinctly eroded and bleeding. Nevertheless, these differences are not always to be depended upon. The relative height of the temperature and the quality of the pulse are important diagnostic signs. In follicular tonsillitis the temperature is usually high, rarely under 102° F. and occasionally as high as 106° F., rising suddenly and, in many cases, falling with almost equal rapidity. In diphtheria it seldom rises above 102° F., gradually attaining that point, and remaining in its neighborhood for a considerable length of time. In follicular tonsillitis the pulse, although perhaps rapid, is usually full, bounding, and regular. In diphtheria it is rapid, markedly depressed, and sometimes irregular.

If albumin be found for the first time on the second or third day, the temperature being at 103° F. or more, and if it disappear on the fourth, we are almost surely dealing with a case of simple tonsillitis. The diagnosis will, of course, be rendered more simple if a history of exposure to the diphtheritic poison can be obtained, or if the Klebs-Loeffler bacillus can be demonstrated.

Tonsillitis may be differentiated from the sore throat of scarlet fever by the absence of the characteristic exanthem and of the symptoms of the latter disease usually seen upon the tongue and pharynx. It must be remembered, however, that in true tonsillitis there is, rarely, a slight skin eruption.

Syphilis may be differentiated from tonsillitis by the symmetry of its manifestations and by the presence of ulceration, the latter being an unusual condition excepting in the former disease.

On several occasions the writer has seen primary cancer of the tonsil mistaken for quinsy. The gradual development of the former and its duration, extending over a period of weeks or months, will exclude tonsillitis, while the facts that cancerous disease is unilateral, that it almost invariably occurs in patients over forty years of age, and that it is unattended with febrile symptoms, point clearly to the true nature of the affection.

Duration.—The duration of an attack of simple parenchymatous tonsillitis is generally from three days to a week. In follicular tonsillitis the disease may run its course in a surprisingly short time. From two to five days would be a fair estimate of its average length. In quinsy the probable duration is most uncertain, and there is in many cases a tendency to relapse; or, the process having been completed on one side, the opposite tonsil may become affected, and the whole tedious history of suppuration be repeated. Thus, the time required may extend over several weeks.

Prognosis.—The prognosis in the milder forms of tonsillitis is almost invariably good, and the progress toward recovery often wonderfully rapid. This is by no means invariably the case. Follicular tonsillitis is often followed by marked debility, while an attack of suppurative tonsillitis may be succeeded, in persons of debilitated constitution, by a tedious convalescence and long-continued general depression. Moreover, one attack seems to predispose to others, and with some patients every year brings with almost certain regularity one or more exacerbations. Death from quinsy has been known to occur in one of three ways: By sudden rupture of a large tonsillar abscess during sleep, resulting in suffocation; by the violence of the inflammation causing infiltration of the neighboring parts, which, extending to the larynx, produces œdema of the glottis; and by erosion of the walls of one of the large arteries adjacent to the tonsil, followed by fatal hemorrhage.

Treatment.—In all forms of tonsillitis the treatment, to be effective, must be both general and local.

General Treatment.—Rest in bed should be enforced. Since acute tonsillitis is almost invariably attended with constipation, the first and most important measure is the administration of an effective purgative. Attention to this feature must be paid throughout the course of the attack. This holds true for all varieties of the disease.

With regard to general therapeutic measures directed toward the disease itself, innumerable plans and drugs have been proposed. In almost every instance they have proved valueless. Some, however, have gained a fair reputation for usefulness. The effect of drugs upon tonsillitis varies greatly in different individuals. What may be almost a specific for one seems with another to be inert.

To be effective, general treatment must be instituted as soon as possible after the commencement of the attack. For a simple case in an adult the best plan is to administer, alternately, every fifteen minutes, half a drop of tincture of aconite (Fleming's) and half a drop of tincture of belladonna, watching carefully for indications of the physiological effects of the drugs and stopping the medicine upon their appearance. This method promises much better results than the administration of opium in the form of a ten-grain Dover's powder, or of a large dose of sulphate of quinine, although both of the latter are occasionally serviceable.

In the cases which seem to be of rheumatic origin three remedies have been highly recommended. These are salicylic acid, guaiacum, and the bicarbonate of soda. Of these the first is, in the experience of the writer, the most reliable. A convenient form for its administration is in capsules, each containing five grains of salicylate of soda, with a small quantity of quinine, generally about one grain, one such capsule to be taken every two, three, or four hours, as the case may require. The use of guaiacum has never been popular in this country, and at present is practically abandoned. The use of bicarbonate of soda, taken internally and also applied locally to the tonsil, has gained many supporters.

In all forms of tonsillitis iron is invaluable. While there are many preparations of greater elegance, none is so effective and reliable as the tincture of the chloride, which not only acts constitutionally, but, in the process of deglutition, is applied locally to the surface of the tonsil, where its antiseptic and astringent effects are most salutary. It may be administered most conveniently in glycerin, in the proportion of three parts of the latter to one of iron; from half a drachm to one drachm of the mixture to be given, as the case may require. The addition to the dose of the iron and glycerin mixture of about one ounce of cold Vichy water makes a decidedly palatable drink, and prevents the iron from staining the teeth. Quinine may also be given in tonic doses, and the nutrition of the patient must be carefully maintained. During convalescence the administration of bitter tonics and iron will materially hasten recovery.

Local Treatment.—The employment of well-selected local measures in the treatment of acute affections of the tonsils is of the utmost importance. It is not too much to say that there is no case of tonsillitis, whatever may be its nature or its degree of severity, which cannot be benefited, and the more distressing symptoms palliated, by means of applications made directly to the affected parts; and while the use of local applications cannot do away with the necessity for the constitutional treatment of the general condition underlying a given attack, the two should go hand-in-hand, each being essential to the successful working of the other.

Local applications may be made either to the neck, in the region of the tonsils, or directly to the glands themselves. If the onset of the attack be recognized at an early period in its history, much may be done to abort it by the use of cold applied to the neck over the region of the tonsils. The application may be made in one of several ways. The old-fashioned plan of dipping a folded handkerchief in cold water, wringing it out, and tying it over the neck in the neighborhood of the tonsils by two or three turns of a flannel bandage, is often productive of good results. Lennox Browne gives excellent directions for making a wet compress for the throat, and advises as follows: Take a piece of lint twice as large as may be required to cover the desired area—that is, from angle to angle of the jaw—or a piece of linen four times as large, the former to be folded twice, the latter four times. Saturate this with cold water, apply it over the region of the larynx (or tonsils), and cover it with a piece of oiled silk, rubber tissue, oiled paper, or other waterproof material, which must be at least half an inch larger than the compress in every direction. By lining the oiled silk with flannel, greater adaptability is obtained. Secure the compress by means of a handerkchief tied twice around the neck. Far more convenient is spongiopiline, as commonly made and sold in this country. By means of this most convenient dressing, applications of either heat or cold can be made, and with the least possible annoyance to all concerned.

In the later stages of suppurative tonsillitis, poultices of linseed meal or spongio-piline, are often of great benefit. The application to the throat of dry cold is a valuable therapeutic measure in a large variety of inflammatory conditions. The writer has employed it in certain cases by partly filling a small bladder with pounded ice and laying it over the neck so as to cover the space adjacent to the tonsils. Sitwell's improved surgical water bandage or temperature regulator, made of the best quality of soft india rubber, is extremely light in weight and elastic, and hence remarkably adaptable, convenient, and comfortable.

For outside application the use of pigments, counterirritants, and leeching is, as a rule, not to be recommended, since they are far more likely to increase than to diminish the discomfort of the patient. When required, a simple stimulating liniment of ammonia well answers the purpose, while the use of cold, as already described, early in the attack, or of warm poultices later, will be found both grateful to the patient and beneficial.

When excessive secretion is an annoying feature of the case, some advantage may be derived from the external application to the throat of belladonna liniment.

Internally, the use of inhalations of steam and of hot sprays has become unpopular. Much better is the following process: Let the patient lie upon his back, partly fill the mouth with hot water, turn the head until the face is uppermost, and thus allow the water to gravitate toward and upon the affected parts. This will succeed as well as any ordinary act of gargling, and with little or no discomfort. It may be repeated as often as necessary. It is generally productive of so much comfort that the patient soon realizes its value and will desire its repetition. This is true even of children. If desirable, the fluid may be medicated, the addition of a small proportion of bicarbonate of soda, or of borax, being especially helpful in facilitating the removal of the viscid secretions common in such cases.

An extensive area lies behind and above the tonsils, which may be more or less filled with irritating secretion, and which washes, applied as above, cannot reach. For cleansing these parts, no method is more satisfactory or more gentle than the careful injection of spray, through the anterior nares and backward into the pharynx. This may be done by the patient himself, or by an attendant, by means of any good hand-ball atomizer throwing a horizontal jet, and when properly employed it is capable of giving the greatest relief. The same spray may be used through the mouth, directly toward the tonsils and pharynx. The use of the post-nasal syringe in acute inflammations of the tonsils and pharynx is dangerous, and should never be allowed. Even the spray may enter the Eustachian tubes. In order to prevent this the patient should be directed to avoid blowing the nose, and always to draw the fluid from before backward and into the pharynx. While in chronic conditions harm has probably very seldom been done by the use of the spray, in acute cases it has been beyond question the cause of serious middle-ear inflammation. Applications of medicated fluid to the tonsils may be made to the best advantage with a hand-ball atomizer. One of the best applications in the early stages of tonsillitis is a saturated solution of the extract of suprarenal glands.

For purposes of cleansing and disinfection, an alkaline solution containing some good disinfectant will be most useful. Dobell's solution, if employed at all, should be largely diluted with water.

In suppurative tonsillitis, as in the formation of abscesses in other parts of the body, the most important consideration is the early recognition of the formation of pus and its speedy evacuation. A tonsillar abscess left to run its own course will, without doubt, and in due time, break. The question of surgical interference, however, must be considered, and for two reasons: First, because of the possibility of danger from the sudden rupture of a large abscess during sleep. Second, and far more important, because by a timely incision the abscess may be evacuated, the progress of the disease cut short, and the patient saved perhaps many days of extreme suffering and depression, and, possibly, the danger of blood-poisoning.

In the use of the knife in such cases, certain rules should be observed and precautions taken:

1. Scarification of the surface of an inflamed tonsil, while sometimes beneficial, is generally irritating, and not likely to afford more than a questionable amount of temporary relief.

2. In quinsy incision is indicated when, from the presence of distinct fluctuation, the spot at which the abscess is pointing may be evident; or, when the tissues are swollen and boggy, and there is reason to believe that pus may underlie them. The instrument most convenient for the purpose is a common scalpel, of medium size, the blade of which should be protected to within half an inch of the point, so that not more than the above amount of the cutting surface is exposed. In selecting the point at which incision should be made, it must be remembered that the abscess may be quite superficial and in the substance of the gland, or deep and involving more the connective tissue outside the tonsil. In the former case, it is best to enter the tonsil itself, making the incision horizontally and from without inward. When the abscess lies more to the outside of the tonsil, palpation of the gland may fail to demonstrate any sign of pointing. If, in such a case, the finger be applied to a point opposite the tonsil, outside of the anterior pillar of the velum, it will often be possible to detect distinct fluctuation; the space between the palato-glossus and the palato-pharyngeus muscles being covered simply with mucous membrane. If now the knife be entered at this point, and made to penetrate to only a moderate depth, pus may be found and the abscess opened, when incision of the tonsil itself would have failed.

In such a case the line of incison should be from above downward and slightly outward, following the direction of, and parallel with, the anterior pillar.

In cases in which the swelling of the tonsils is so great as to threaten suffocation, and in which simple incision does not seem sufficient to evacuate the abscess or reduce the tumefaction, one of two surgical procedures may be resorted to. Either the tonsil may be excised and its inflamed and swollen tissue removed, or tracheotomy may be performed. Intubation is, of course, inadmissible, since the obstruction is not in the larynx, but above and outside of it. The writer has seen two cases in which a timely tracheotomy would have saved the patient's life. On the other hand, when the tonsils themselves are enormously enlarged and the tissues around them not too greatly infiltrated, when the abscess is evidently in the substance of the gland or immediately in its vicinity, and when there is danger of septic infection, excision offers an effective, speedy, and tolerably safe means of relief. In acute exacerbations of tonsillitis, particularly in children whose tonsils are chronically hypertrophied, instances are not wanting in the experience of most specialists in which a tonsillotomy, promptly performed, has averted a dangerous issue.

3. When, as is often the case in chronic hypertrophy of the tonsil, the patient suffers from recurrent attacks of quinsy, excision of the tonsil is of the greatest value, and in many instances the operation will effect a radical cure. As a rule, tonsillotomy should not be performed while the gland is in a state of acute inflammation.

4. In some cases the tonsils are sufficiently enlarged to admit of excision only during an acute attack. In these it is better to operate at once, and at the beginning of the acute inflammation. Thus, the redundant tissue may be more thoroughly removed, the present attack cut short, and future trouble avoided. Pain is greater from such an operation, and hemorrhage is more likely to be active. Experience, however, proves its value.

Chronic Inflammation of the tonsils, although generally associated with more or less hypertrophy, is sometimes observed as a disease of the crypts of the gland, the so-called chronic lacunar tonsillitis—an annoying, and often an obstinate, condition of disease attended with inflammation, dilatation, and obstruction of these follicles. The crypts are often found to contain white or yellowish masses of cheesy detritus which have a particularly bad odor. The presence of these masses is very irritating to the patient. They are likely to cause more or less inflammation of the surrounding parts, sometimes to the extent of producing abscess. Many large crypts open into the supratonsillar fossa, and there is often a large and deep sulcus formed by adhesion of the anterior pillar of the velum to the tonsil. These cavities are particularly liable to become diseased. The treatment of this condition is simple and effective. It consists in the free opening of each crypt, from top to bottom, by means of a sharp, specially constructed knife, or by the galvano-cautery and the subsequent application of a strong solution of iodine to the walls of the crypt. Few operations are capable of giving more relief. The parts soon resume a healthy condition, and the symptoms, local and reflex, disappear.

Chronic Hypertrophy.—*Etiology.*—Hypertrophy of the tonsils is sometimes congenital. It is often noticed when the child is but a few months old. Sometimes it becomes developed about the age of puberty. In the experience of the writer, many cases owe their origin to diphtheria, an attack of which has left the throat inflamed and highly sensitive to irritating influences, in which state the tonsils become permanently enlarged or liable to recurrent attacks of acute inflammation, through which hypertrophy takes place. Scarlatina, measles, or whooping-cough may serve as a starting-point for it, and syphilis, congenital or acquired, and tuberculosis may also be its chief causes, while many cases seem to result from recurring attacks of quinsy. Often the condition appears to be excited by the irritating effects of acid indigestion.

It appears that the tendency to enlargement of the tonsils is in direct relation with the general activity of the gland, and that, active at birth, the susceptibility increases rapidly until at the time of puberty it is at its height. From this time there seems to be a decline, which becomes progressively rapid until, beyond thirty, the disease is more and more uncommon. While atrophy may and does occur at or about puberty in a few instances, in quite as many cases tonsils hitherto normal become enlarged; and hypertrophy may take place in them, not only at the time of puberty, but at any period within fifteen years or even more after the age of adolescence. If, therefore, it be true that even a healthy tonsil may become chronically hypertrophied after puberty, how much more probable is it that one already enlarged in childhood may continue in that condition.

Symptoms.—The symptoms of tonsillar hypertrophy are usually pronounced.

In a well-marked case the first signs to which attention will be called are those seen upon the countenance of the patient. The complexion is pale, cachectic, and transparent, the veins standing out in distinct relief; the lips are often dull pink, or even blue; the eyes are heavy and lifeless and their lids are drooping; the mouth is partly open, and often the upper teeth project forward. When the child is stripped his body is seen to be emaciated, and his muscles flabby, the intercostal spaces are retracted, and the breast bone is prominent.

These appearances are such as would arise from obstructed nasal respiration.

Voice.—Another mechanical effect is the alteration in the voice, which in such cases is generally thin, nasal, and lacking in resonance. The explanation of this lies in the fact that the pharynx and the air cavities above act, in the production of tone, as resonators. Obstruction of the pharynx directly prevents the proper formation of tone and thus impairs the quality of the voice. Again, the voice is injured by the effect of the lymphoid inflammation upon the soft palate, which in such cases is generally relaxed, and hence unable to fulfil its functions in a proper manner. In consequence of this, articulation is interfered with, the patient speaking with thick utterance, and the palatal consonants being in particular mispronounced. When we add to the above the injurious effects upon the laryngeal mucous membrane of the catarrhal inflammation often associated with, and aggravated by, chronic hypertrophy of the tonsils and pharyngeal adenoid tissue, the deleterious influence of this condition upon the voice may be fully appreciated.

Respiration.—Mouth-breathing is one of the commonest symptoms of naso-pharyngeal obstruction, and it is associated with a variety of evils. Moreover, the amount of air admitted to the lungs is often entirely insufficient. A patient suffering in this manner almost invariably gives a history of respiratory difficulty, particularly well marked during sleep, at which time the mouth is widely opened and respiration is noisy, and nearly always accompanied with loud snoring; sleep is restless and broken, the patient being feverish and tossing about and dreaming incessantly, often muttering or talking, and sometimes, it is said, indulging in somnambulism. In severe cases intense reflex phenomena manifest themselves, among which a not uncommon symptom is for the patient to be awakened by sudden attacks of

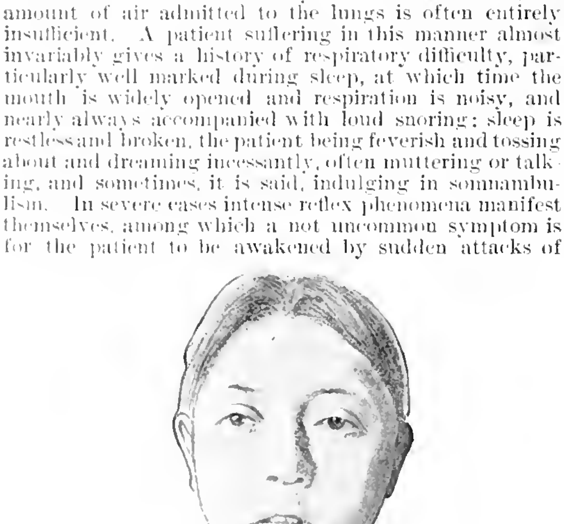


FIG. 4731.—Facial Expression Characteristic of Pharyngeal Adenoid Hypertrophy. (After Gerber.)

dyspnœa, so severe in some instances as to threaten suffocation, and attended with severe exhaustion and alarm.

The patient awakens after such a night feeling dull and tired, and often with a headache. The throat is dry and parched, the breath fetid, and the appetite impaired.

The respiratory function of the nose being abolished, the air in its passage to the lungs is neither moistened, nor warmed, nor freed from impurities. In consequence of this the respiratory passages are rendered abnormally dry, the lungs are subjected to the danger of irritation from cold, and the whole tract, from the naso-pharynx downward, is made liable to the effects of whatever foreign matters may be inhaled. The effect of obstruction to nasal respiration is such as to exert an important influence upon the nutrition and development of the nose itself. Without question, a proper supply of air and the normal exercise of the part are necessary for its proper and complete development. Hence, as long ago suggested by the writer, deformities of the bony structures of the nose, so commonly found in mouth-breathers, are caused by the effect of the mouth breathing upon the development of the nose, and that asymmetry of the nasal cavities, and indeed of the superior maxilla itself, may be due to the same influence when exerted unilaterally.

In many children in whom obstruction to breathing is serious, there will be noticed a marked effort on the part of the walls of the chest to complete the act of respiration, the intercostal and infraclavicular spaces sinking inward with each attempt. Under such circumstances serious changes in the thoracic parietes may take place.

Hearing.—The effects of nasal obstruction upon the hearing are highly injurious. They are exerted in two different ways, each of which is capable of producing marked results. The catarrhal inflammation commonly present in the pharynx of such a patient produces a general chronic swelling and congestion of its mucous membrane, with thickening and retraction of the drum membrane and loss of hearing. This same retraction of the drum head is caused in certain cases by the mouth-breathing habit, the upper pharynx not being properly supplied with air. This opinion is sustained by the fact that after removal of the obstruction the hearing distance is often greatly increased, and with as much promptness as it is after the use of the Politzer inflator. The danger to the auditory sense from hypertrophy of the lymphoid tissue, particularly that at the vault of the pharynx, is decided, and its importance cannot be overestimated. When, therefore, there is reason to suspect that deafness may be due to it, the necessity for the thorough investigation of the pharynx becomes strongly emphasized.

Smell and Taste.—Owing to the catarrhal inflammation present in lymphoid hypertrophy of the pharynx, the senses of smell and taste are often impaired or altogether lost. In the case of olfaction the diminished special sensibility is also due to the occlusion of the pharynx and to mouth-breathing, by reason of which the odoriferous particles are prevented from reaching the olfactory region. On the other hand, the constant presence of fetid discharges makes itself apparent to the patient himself and to those about him. With lymphoid hypertrophy there is generally associated much chronic catarrhal irritation of the neighboring mucous membrane. Removal of the hypertrophied tissues will be followed in most cases by marked amelioration of the catarrhal symptoms, the improvement commencing immediately after the operation and continuing more or less steadily for months.

In the diseased state of the pharynx, the secretion becomes greatly increased in amount, and it, together with the abundant supply of mucus given off by the neighboring membrane, is a source of much disturbance. Not only does the pharynx become filled with it, by which respiration is rendered more difficult, but when swallowed it is apt to give rise to indigestion. Again, through failure to enjoy it, the act of eating is accomplished rapidly, and the food is swallowed in large masses without having been properly masticated. Thus the nutrition of the patient is directly attacked; for, through loss of taste and smell, and through the depressing influences of a lack of oxygen, the appetite is generally impaired at the outset, while, by reason of the faulty mastication and of the dyspepsia, the food ingested is not properly utilized.

When it is remembered that loss of oxygen, loss of sleep, and loss of nourishment may all arise from the disease under consideration, its influence upon the general health cannot but be recognized.

Lymphoid hypertrophy may occasion various reflex nervous phenomena. Of these, the most important is the occurrence of attacks of dyspnœa, generally during sleep, which seem to be due to a veritable spasm of the glottis, and in the course of which the patient is awakened suddenly from a sound sleep to find himself choking. For a few seconds inspiration is almost impossible, and efforts to accomplish it are accompanied by loud, stridulous breathing, and intense apprehension and alarm. It may be urged that such accidents might arise from the presence of a deposit of thick, tenacious mucus in the larynx, and such, no doubt, is often the explanation of them. However, in certain instances, observed by the writer and others, there can be little doubt as to the spasm being of a purely neurotic nature.

Severe spasmodic cough is sometimes seen in children and in young adults. It is generally dry and hacking in character, and in some cases is almost incessant.

Again, chorea and even epilepsy are sometimes observed.

The influence of lymphoid hypertrophy upon the circulation is a matter of importance, deficient oxygenation of the blood not being the only result which may be traced to this condition in such cases. Anæmia is a common symptom, and one which is often particularly well marked. Some believe that enlargement of the heart by dilatation may be directly due to this impoverishment of the blood. Disturbed cerebral circulation, as a result of pressure exerted by the enlarged masses, has been suggested by Chassaignac.

Diagnosis.—The diagnosis in chronic hypertrophy of the faucial tonsils may usually be made with the greatest ease, the history of the patient, his general appearance, and his symptoms pointing almost invariably to the source of the trouble. Any doubt may be dispelled by the simple inspection of the pharynx. Upon opening the mouth and looking into the throat, the tonsils will appear extending beyond the normal limit and toward the median line, and their relative size, their consistence, and the condition of the crypts may be ascertained. During easy, deep inspiration the tonsils will assume their normal position behind the anterior pillar of the velum, a minimum of their volume being projected toward the median line. If now the patient be made to gag, the tonsils will be rotated forward and thus brought out from behind the velum and into plain view. Any doubt which may exist as to the real size of the gland may be removed by placing one forefinger just below the angle of the jaw externally, and the other behind the tonsil, when the whole extent of the enlargement may be recognized.

Prognosis.—Hypertrophy of the tonsils may exist to a considerable degree, both in children and in the adult, without giving rise to serious symptoms. In some cases the presence of this condition may pass unnoticed. Usually, however, the contrary is the case. It may be said, in general, that the younger the child the more injurious is the effect likely to be. While the tonsils may sometimes regain their normal condition at puberty, the occurrence of this atrophy is uncertain, as has already been pointed to in the section relating to the etiology of the disease. Meanwhile the general health of the patient may be undergoing serious injury, and irreparable damage may be inflicted upon adjacent parts. The prognosis, therefore, in pronounced cases of tonsillar enlargement is unfavorable as to the ultimate subsidence of the difficulty.

As to the effect of enlarged tonsils upon the life of the patient, there can be no question that they may be an indirect cause of death. The writer has seen a case in which, operation having been refused, death from asphyxia resulted in a child two and one-half years old, suffering from enormous hypertrophy of both tonsils. Such a thing, fortunately, is extremely rare; but it is worthy of record if for no other reason than to prove the possible danger of the condition, and to emphasize the folly of temporizing with it.

In cases of moderate hypertrophy of recent standing, in which there is little deposit of fibrous tissue, and in which the enlargement depends upon an increased vascularity and dilatation of the crypts, much good may be done by general and local hygienic measures and by local medication. Careful attention should be paid to the dietary, physical exercise, and general surroundings of the child, and any diathesis discoverable should be diligently treated.

In some cases the administration of the iodide of iron and of cod-liver oil will be found beneficial. Externally, a valuable measure is the habitual application, every morning, of a cold bath of salt water. This should be applied to the neck and throat by means of a sponge, the water being at a temperature sufficiently low to produce a reaction, but not so cold as to shock the patient. Meanwhile, the throat should be well rubbed, and special attention paid to the region over the tonsils, which, by a process of massage gently applied, may be successfully stimulated, and the blood-vessels caused to act with greater liveliness and tension. The application of massage directly to the tonsil has been recommended, but has not generally commended itself. The application, to the inflamed tonsil, of the constant galvanic current is a measure deserving of attention.

Local applications to the tonsil are usually ineffective, as are the measures suggested above. Sooner or later, in the great majority of cases, their futility will be recognized and surgical measures accepted.

Removal of the tonsils has been practised from earliest times. For its accomplishment several methods have been employed, some of which are still in vogue.

An exhaustive history of the subject is given by Sir Morell Mackenzie in his classical work.

In 1757 Caqué proved indisputably that the great dread of hemorrhage which had existed was chimerical, and that the resulting wound healed readily in a short time. From this date excision of the tonsils became one of the recognized operations of surgery.

The surgical treatment of this condition extends backward for many centuries. When we add to this the fact that the disease is common, and that it has been extensively studied in recent years, it will also appear that our present knowledge of the subject is based upon the views of a vast number of distinguished and highly experienced authorities. Of the methods for removing the tonsils most commonly used at the present time may be mentioned cauterization, by chemical or electrical escharotics; écrasement, by means of the galvano-caustic loop or of the cold wire; abscission, by means of some modification of the knife or scissors. Both the tying off of the tonsil by means of a ligature, and the injection into its substance of various supposed absorbents, only need be mentioned to be condemned. The practice of enucleating the tonsil with the finger has been lately revived in some quarters. It is of questionable value and propriety.

The use of the galvano-cautery, as advocated by Voltolini, has had many supporters. As compared with the knife or cold snare, however, the process is slow and painful, the reaction often severe, and the resulting cicatrices in no small number of cases a permanent source of irritation and disability. The method is distinctly inferior.

Écrasement by means of the galvano-caustic loop is sometimes an effective and valuable method, although in simple hypertrophy, uncomplicated with malignant disease, it will be found less convenient and far more painful than other methods. When this instrument is used two precautions are necessary: The electric current should be employed intermittingly, and traction should be made upon the loop only during the passage of the current. Thus hemorrhage may possibly be avoided and the danger of injury to the pillars of the fauces by diffusion of heat may be prevented. Any unevenness remaining may be removed by subsequent cauterizations. Inclusion of the greater part of the tonsil within the loop may usually be effected by dragging it inward by a forceps or by means of a transfixion needle. Local anæsthesia may sometimes be obtained by injecting into the parenchyma of the gland, before operation, six or eight minims of a four-per-cent. solution of cocaine. The amount of tissue actually removed by the snare does not represent the total effect of the operation, since the parts remaining are cauterized to a considerable depth.

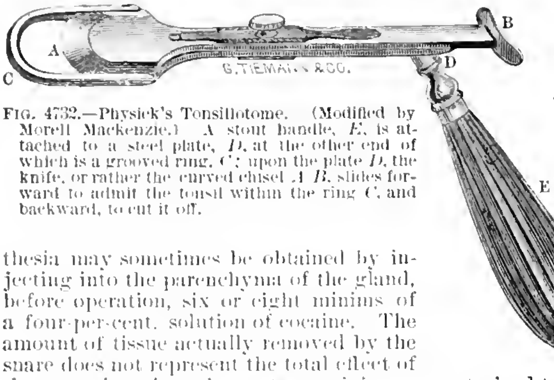


FIG. 4732.—Physick's Tonsillotome. (Modified by Morell Mackenzie.) A stout handle, *E*, is attached to a steel plate, *D*, at the other end of which is a grooved ring, *C*; upon the plate *D*, the knife, or rather the curved chisel *A B*, slides forward to admit the tonsil within the ring *C*, and backward, to cut it off.

In certain instances, in which the tonsil is very large and fibrous, and the patient an adult, it may be desirable to use the cold wire écraseur. The operation is tedious and in many cases extremely painful, and, unless it is performed while the patient is under the influence of an anæsthetic, it is not likely that it will be tolerated by any but a remarkably hardy individual. On the other hand, if it be performed under general anæsthesia—as, for example, in the course of an operation for the removal of adenoids and upon a tonsil which is fairly pedunculated—it is the best method at our command. More of the tonsil is removed, the resulting wound is much smaller, and the bleeding is reduced to a minimum. Healing is more rapid and is accompanied with considerably less pain.

Tonsillotomy.—Of all methods hitherto proposed for the removal of enlarged tonsils, none can compare in general popularity, utility, thoroughness, and, on the whole, humanity, with tonsillotomy. As time has gone by, the value of the procedure has become more and more completely established. Meanwhile the instruments for its performance have appeared in large numbers and in great variety.

In the Physick tonsillotome, as made after the pattern represented in Fig. 4732, a high degree of simplicity and perfection has been attained, and although many modifications of this instrument are offered for sale, it is safe to say that, up to the present time, it stands unrivalled.

It is the favorite tonsillotome of nearly every recognized authority. It is absolutely simple in construction, not liable to get out of order, comparatively easy to clean, and, what is far more important, it is a safe instrument to handle, the accidents to which the Fahnestock instrument (Fig. 4733) is liable being with it impossible. With it the danger of hemorrhage is reduced to a minimum.

For the convenient and successful performance of tonsillotomy the aid of a trained assistant is indispensable. With adults and with children old enough to be under good self-control, he will be of use in steadying the patient's head and in supporting the tonsils; while with young children the possibility of operating at all will sometimes depend upon the manner in which the patient is held.

During the operation the patient should sit facing a good light, the operator with his back to it. Those surgeons, however, who are familiar with the use of the head-mirror will generally prefer to use this instrument for illuminating the field of operation. The patient, if an adult, should sit upright and well back in the chair, the head fixed against a properly adjusted head-rest or supported by an assistant. The latter should stand directly behind the chair, and, while holding the head with both hands, should place the fingers of each hand over the tonsillar region of the corresponding side, that is, immediately below the angle of the jaw. Thus the tonsils may be prevented from receding before the pressure of the tonsillotome when it is introduced, and the operation may be performed with greater accuracy, and, if necessary, with greater thoroughness.

In the case of a child the assistant should be seated in front of the operator, and the patient seated across one of his thighs, facing inward, so that the legs of the latter may be grasped and firmly held between the thighs of the assistant. The body of the child is partly turned so that he faces the operator, and his head is rested against the breast or the shoulder of the assistant, who controls the arms and body of the child by throwing one of his arms across the patient's chest, while with the other hand he steadies the child's head firmly against his own body. The use of a mouth gag is unnecessary. The blade of the tonsillotome is now drawn backward and the instrument introduced flatwise and in the median line, as if it were a tongue depressor, as far back as the pharynx. It is then rotated, by raising the handle outward from the vertical to the horizontal position, until the plane of the blade becomes parallel with the plane of the desired incision. Following this comes one of the most important manœuvres of the whole operation, and one to which too much attention cannot be paid, namely, the engaging of the tonsil in the ring of the instrument. In carrying the tonsillotome outward from the median line, the tendency is for the handle of the instrument to be carried out too rapidly. In other words, the angle of the mouth is used as a fulcrum against which the middle of the instrument rests, and while the handle is carried outward the other end is carried in the opposite direction, or inward, and away from the tonsil. The result is that, instead of squarely grasping the gland at as deep a position behind it as before, the end of the tonsillotome slips over the back of the tonsil, and the operation results in simply slicing off a section from its top. To avoid this it is necessary to observe the rule that the blade of the instrument must always be kept parallel with the median line, and that if any deviation is made it should be to carry its distal extremity outward. Having engaged the tonsil in the ring of the instrument to the required depth, push the blade firmly and steadily through the included tissue, separate the fragment of tonsil, and, withdrawing the instrument quickly, remove the excised gland adhering to it. Then with the greatest possible expedition—and before the patient realizes that there is to be a second operation—before bleeding sets in, and without giv-

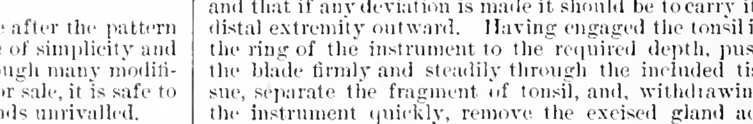


FIG. 4733.—Fahnestock's Guillotine. (Modified.) In the variety shown here the instrument consists of three principal parts: *A*, A ring made to receive the thumb of the operator, and attached to a rod upon the end of which are the pronged forks *D*; *C*, a staff, at the end of which is a ring, *E*; *B* and *B*, two rings made to receive the fore and middle fingers of the operator's hand, and attached to another rod which plays upon the staff *C*, and at the end of which is a ring-knife which rests within a groove in the ring *E*. In using the instrument the thumb-piece *A* is pushed forward for a certain distance, when by the automatic releasing of a spring-catch the rod with the knife attached is drawn forward by the rings *B*, *B*, so that the tonsil, already engaged in the ring *E*, and drawn still farther through it by the forks, is excised.

ing him a chance to cough or clear his throat—reintroduce the tonsillotome on the opposite side and remove the remaining gland. By this means both tonsils may be removed at one sitting, so that but one convalescence is to be endured. Few young patients will submit to a repetition of the operation. Several ingenious modifications of the Physick tonsillotome have been made, by which the handle may be reversed so that the operator may use it first in one hand and then in the other. A far better plan, however, is to gain through practice sufficient dexterity to change the instrument from one hand to the other, and to operate thus on both sides with equal facility. With a quiet and tractable patient the operation may be done very quickly, from ten to fifteen seconds being ample time in which to complete it.

In most cases the actual pain caused by cutting through the tonsil is very slight, the patient often complaining more of the introduction of the instrument into the pharynx and the consequent reflex than of the operation itself. The injection into the tonsil of cocaine is an undesirable procedure. General anæsthesia, from either chloroform or nitrous oxide, is objectionable, not only because it is, as a rule, unnecessary, but because it is desirable to have the active co-operation of the patient in clearing the throat the moment that the operation is completed. To this rule, however, there are exceptions. When a child is highly irritable, nervous, and timid, and when the operator may be tempted to abandon the case rather than subject the patient or himself to the inevitable struggle which with such children must be undergone, the administration of nitrous oxide will prove of great assistance. If the child is fairly well and strong, the best plan is to be frank with him, place him upon his mettle, and proceed with the operation. If, on the other hand, he is delicate and easily frightened, it will be wise to consider to what extent he may be coerced without producing an undesirable degree of shock; and, as chronic hypertrophy of the tonsils is apt to be associated with these very conditions of nervousness, such children should be managed with the greatest gentleness and consideration.

As hypertrophy of the tonsils is commonly associated with pharyngeal adenoids, the removal of both upon the same occasion under general ether anæsthesia has proved by far the best and most satisfactory way in which to deal with these cases.

According to most authorities, hemorrhage after the operation is usually slight and soon ceases spontaneously. If it persists it may be readily checked, and generally by simple means. Of the latter the most effective is the direct application to the cut surfaces of a mixture consisting of one part gallic acid and three parts tannic acid, reduced to the consistence of cream by the addition, drop by drop, of a small quantity of water. This or the sucking of cracked ice will usually prove effective.

The view taken by most specialists is, that the operation is attended with little or no real danger. On the other hand, there are some practitioners who look upon it with dread.

In reality, during the last twenty years, death from hemorrhage following tonsillotomy in patients under eighteen years of age has been extremely rare. Over eighteen several cases are recorded. Serious bleeding may occasionally occur. Moderate bleeding, requiring means to check it, is, on the whole, uncommon. In hemorrhage after tonsillotomy several varieties of bleeding may occur. These are:

1. Arterial: from the division of one or two comparatively large arterial branches.
2. Arterial: from the division of a large number of small arterial twigs.
3. Venous: from the division of the small plexus of veins which lies below and outside of the tonsil.
4. Capillary from the presence of the hemorrhagic diathesis.

Of the above varieties, the first two seem to be the most common.

Ligation of the carotid, common, external or internal, has generally proved ineffective.

Hemorrhage in general, it is unnecessary to say, is likely to cease during syncope. In bleeding after tonsillotomy, the excitement of the patient and the consequent stimulation of the heart and activity of the brain result in great increase in the general circulatory force and in the amount of blood actually carried to the brain. As long as this condition lasts bleeding will continue, the tendency being for it to grow more, rather than less, severe, even although the common carotid may have been tied. When, however, the heart's action becomes weak and the brain anæmic through syncope, bleeding from the tonsil will cease. This circumstance would, it seems, tend to prove the futility of ligating the common carotid.

In general, it may be said that the operation of tonsillotomy should not be performed unless ample means are at hand for controlling any ordinary amount of hemorrhage which may occur, and, although the chances of bleeding are infinitely slight, no surgeon is justified in incurring them unprepared. Since the amount of bleeding present may vary from the loss of a few drachms up to a hemorrhage of considerable importance, it follows that the means selected for its arrest must vary with the nature and severity of the case.

In the vast majority of instances, the bleeding, even though sharp at first, will subside spontaneously within a few minutes after the operation. In these cases the patient should be directed to keep the head upright, as far as possible; to refrain from making efforts at clearing the throat; to gargle the throat quickly, and several times in succession, with ice water; or, instantly upon the removal of the tonsils and, if possible, before bleeding has begun, the surgeon should apply to the wounded surfaces the tanno-gallic mixtur of Morell Mackenzie, already mentioned, all preparations for the application having been made beforehand.

Should the bleeding continue, grasp a smooth, rounded piece of ice in a pair of long forceps and hold it firmly against the bleeding surface. Or wrap, somewhat tightly, a pledget of absorbent cotton around the end of a suitable rod, saturate it with the tanno-gallic mixture, and then press it against the wound. In any case the pharynx of the patient should be illuminated by the best attainable light, the neighborhood of the tonsil diligently cleared of clots, the cut surface thoroughly exposed to view, and careful search made for the exact source of the hemorrhage. Sometimes this precaution will be rewarded by the discovery of one or two spirting points. These will generally be found low down in the pharynx, corresponding with the inferior part of the tonsil, in which the larger arterial branches seem to be received. Such points, having been discovered and precisely located, should be seized with long slender forceps and thoroughly twisted; or they may be touched with a small galvano-caustic point; or the tip of a probe upon which nitrate of silver has been fused may be pressed into them, the spot having previously been well cleared of blood.

Such hemorrhage is apt to occur in cases in which the incision has been carried low down in the pharynx, and may usually be arrested by the above means. Upon inspecting the thoroughly cleansed wound, however, there may appear innumerable little vessels, none of which is large enough to be seized, but all vigorously bleeding. These are the cases in which the fibrous stroma containing the nutrient vessels is markedly increased and the vessels themselves are large and abundant. Encased as they are in fibrous tissue, it is difficult for them to contract; hence the bleeding, abundant, persistent, and exceedingly difficult to control.

In these cases the ordinary means for stopping hemorrhage are often ineffective. The iron styptics are worse than useless, while the cautery only seems to make the bleeding worse. If the tonsil has been thoroughly removed, there is nothing left around which a ligature may be applied.

About the best suggestion for such a case is that of Levis, who transfixes the bleeding base with the hook of a small tenaculum, performs torsion, and directs the patient to hold the flat handle of the tenaculum fixed between his teeth. By passing a bandage around the head and under the chin this position may be maintained for many hours. The method has proved very effective. Pressure of the common carotid may be maintained, although in the personal experience of the writer and of others it has often proved useless. Meanwhile, several general measures of great value may be employed.

Since the object desired is to quiet the circulation and allay nervous excitement, the administration of opium is decidedly indicated.

Arterial tension may be relieved by shutting off a part of the supply of blood. This may be accomplished by constricting the patient's thighs, as is sometimes done in hæmoptysis.

Finally, in most instances of tonsillar hemorrhage of the class last described, the bleeding has continued in spite of all efforts to stop it until, at last, the patient has fainted. Upon the occurrence of syncope the flow has promptly ceased, nor has it, with the return of consciousness, recurred. While, therefore, the means which seem best adapted to the case in hand are being applied, any tendency to fainting should be encouraged rather than repressed. Should the above means all prove ineffective, and the question of ligating one of the great vessels be entertained, it should be remembered that ligation of the internal carotid is useless; that ligation of the common carotid has sometimes succeeded, but has often failed; and that the choice of a successful operation lies between tying the external carotid near the bifurcation of the common carotid, or the ligation of both the common and the internal carotid arteries.

The occurrence of a venous hemorrhage is unusual. The writer has seen one such case, which was checked without great difficulty by means of cold and pressure.

Capillary hemorrhage may be stopped by the tannogallic mixture, by pressure, by cold, or, finally, by the gargling of water taken as hot as can be borne.

Of a very large number of cases of tonsillotomy known to the writer, in only one has severe hemorrhage occurred in a child. This patient had hæmophilia. Recurrence of the bleeding was evidently caused by the swallowing of food. The patient was nourished by rectal alimentation for three days, with complete success.

Finally, annoying and persistent bleeding may occur from the accidental wounding of the anterior pillar of the velum palati in the course of tonsillotomy. The adhesions which often exist between the anterior pillar and the tonsil should be broken up before the removal of the gland is attempted.

The after-treatment in tonsillotomy is exceedingly simple. The general condition may be estimated to equal about that of a patient suffering from a mild attack of tonsillitis. He should be kept quiet for two or three days. Solid food should be withheld for thirty-six hours, and then such articles selected as shall produce neither chemical nor mechanical irritation. A gargle of simple borax and water, or containing besides a trace of carbolic acid or thymol or some other good disinfectant, should be used after the first day, unless it causes pain in the throat, in which case the fluid should be used with an atomizer. Gum arabic may be occasionally dissolved in the mouth. The wound usually heals with rapidity and without accident. Sometimes, however, in unhealthy subjects infection from some of the numerous bacteria of the buccal cavity takes place and it becomes covered with a thick, whitish membranous deposit, which may even appear to be diphtheritic, and which may be associated with more or less constitutional disturbance. This, in the majority of cases, soon yields to local disinfectant measures, and the internal administration of iron.

In addition to the healing of the pharyngeal wound, in the case of children, three points at least (in addition to the general tonic treatment sometimes required) should be carefully attended to:—

First, the mouth-breathing habit must be overcome, even when the pharyngeal obstruction has been removed. To this end the patient should be encouraged, while waking, to breathe through the nose. When asleep he may need the benefit of some artificial help.

Secondly, the defects of pronunciation commonly met with in the subjects of enlarged tonsils, become, like the mouth breathing, matters of habit, and do not always disappear when the condition upon which they depend has been relieved. This matter should be explained to those having the child in charge, and suitable exercises in reading and pronouncing recommended.

Finally, the deformity of the chest will in many cases need attention. Light gymnastics and, more particularly, the systematic practice of chest expansion, will often bring about a surprisingly rapid and beneficial result.

The results of tonsillotomy are immediate and marked, and the child who was before weak, ill nourished, underdeveloped, will in many cases begin to grow with remarkable rapidity; his whole appearance at the end of several months being greatly changed for the better.

It is not easy to understand why the excision of enlarged tonsils should meet with the opposition which is sometimes brought to bear against it. Still less is it explicable when the ground of the opposition is explained.

Among the principal objections which have been urged against tonsillotomy are the following:

1. That the tonsils will atrophy spontaneously at puberty; or, as some express it, that the child will "grow to his tonsils."

2. That tonsillar hypertrophy exercises a protective influence against infections. Also, that it protects against bronchitis and phthisis.

3. That the removal of the tonsils will injure the voice.

4. That their removal will impair the patient's virility.

5. That the tonsils will be likely to grow again.

6. That milder measures than excision will answer the same purpose.

7. That the operation should be indefinitely postponed because the patient may be weak.

In every one of the seven objections quoted the objection is absolutely and exactly contrary to the truth.

Foreign Bodies in the Tonsils.—From their peculiar structure and position, the tonsils are prone to the arrest and lodgment of small pointed foreign bodies. These may be found fixed in one of the deeper lacunæ or thrust into the substance of the gland itself. Their presence is characterized by a limited degree of pain at the seat of impaction, and sometimes by slight dysphagia. Occasionally, however, the pain is referred to a point more or less remote.

Commonly, in tonsils which are the seat of chronic inflammation, the secretion of the lacunæ may be increased in quantity and retained within the crypts, as before described in this article. These soft concretions, which are of a white or yellowish color and cheesy consistence must not be mistaken for tonsillary calculi, which are entirely different both in character and in composition, and which are actually of rare occurrence. The composition of such concretions is principally phosphate and carbonate of lime. They are, therefore, not of gouty origin, as has sometimes been supposed. Besides the above-named salts, they contain small quantities of iron, soda, and potassa. Their presence gives rise to few symptoms which may not be observed in any inflamed tonsil. A slight pricking sensation is often complained of, and, when the concretions are large, there is dysphagia. Sometimes small concretions are discharged spontaneously, and sometimes their presence predisposes to severe attacks of quinsy, in the course of which an abscess may form which may be very slow in healing. The presence of a tonsillar calculus may be determined by the discharge of pieces of the calculus, by inspection, a part of the calculus projecting from the lacuna far enough to be visible, or by direct examination with the finger or a probe.

In the treatment of these cases the concretion may be removed by means of a hooked probe, or by small forceps. It will generally happen that the tonsil will be enlarged, and then the extirpation of more or less of the gland will be called for. Indeed, this is the simplest way of relieving the whole trouble. The use of the tonsillotome may be impossible on account of the hardness of the calculus; in which case resort to the bistoury will be necessary.

Parasites in the Tonsils.—Mackenzie quotes several instances in which certain parasites, such as hydatids and trichocephali, have been found in the tonsils. Dupuytren relates the case of a woman twenty-one years of age, who for eleven months had suffered from attacks of inflammation of the tonsils. The left gland was considerably swollen, and the surgeon having diagnosed an abscess, plunged a bistoury into the tumor. As a result, nearly two ounces of watery fluid gushed out, and ultimately a large hydatid cyst, the size of a hen's egg, was extracted. The patient died soon after, and a hydatid cyst, the size of a child's head, was found attached to the left kidney. A similar case, excepting that the patient was a man, is reported by Davaine, and the same observer relates an instance in which a trichocephalus was found lodged in the left tonsil. The parasite had probably attained this situation through being expelled from the stomach during the act of vomiting.

SYPHILIS OF THE TONSIL.—*Chancre.*—Chancre upon the tonsil is occasionally observed. While chancre of the lips and buccal cavity is not uncommon, its occurrence on the wall of the pharynx is practically unknown. The explanation of its appearance upon the tonsils is plain when the structure and position of those organs is remembered. There are many cases in which, without question, it has been innocently acquired. While chancre of the tonsil is generally unilateral, it has sometimes been observed upon both glands.

The diagnosis of chancre of the tonsil is apt to be difficult, since the symptoms vary considerably, and the situation of the trouble is so remote that it easily passes unobserved or unrecognized.

The signs of infection generally begin with slight redness and swelling, and without perceptible induration. Soon there are pain in deglutition, increased redness, and hypertrophy, which is followed by a superficial erosion, having an indurated base, and more or less glandular involvement of the affected side. The hypertrophy and general tumefaction of the tonsil itself are important signs, and seem to be a constant accompaniment of the disease. The second important symptom is the superficial erosion, increasing to an actively ulcerating surface, generally covered with a grayish-white coating of greater or less thickness, granular in character, and distributed over the surface of the ulcer in a somewhat irregular manner. Sometimes the erosion is very superficial and ill-defined, while in other rare cases it has assumed the phagedenic form, presenting a deep, sloughing ulcer, with a high degree of inflammation and tumefaction of the neighboring parts.

Induration of the base of the ulcer is not a constant factor. In many cases it is conspicuously absent. Ptyalism is an early and marked symptom.

Enlargement of the submaxillary lymphatic glands of the affected side is a constant symptom, the engorgement being hard, indolent, and sometimes extensive. Suppuration does not seem to have been observed. The duration of chancre of the tonsil has been thought to be shorter than that of the same lesion in other places. There is more or less dysphagia, often severe, and, when the ulceration assumes the phagedenic form, pain in swallowing may become very severe.

The immediate diagnosis of chancre of the tonsil is often by no means easy. It will generally be difficult to obtain a history of contagion, through either the reticence or the ignorance of the patient. The unusual situation of the lesion, its diversity of appearance and form, the absence of corroborative evidence, all render the case in many instances obscure. It is necessary to differentiate it from malignant disease, especially epithelioma; from tuberculous ulceration; from psoriasis of the mouth and from the so-called smoker's patch; from mucous patches; from the ulcerating gummata of tertiary syphilis; from diphtheria; and, finally, from gangrenous ulceration of the tonsil.

It is often impossible to arrive at a decided conclusion until the development of constitutional phenomena and the results of treatment unite in confirming the diagnosis. The treatment, constitutionally, must depend upon the views of the practitioner with regard to the management in general of early syphilis. Should mercury be administered, the cyanide, one-sixteenth of a grain three times daily, as recommended by Morell Mackenzie, has been found especially valuable by the writer. In simple cases emollient gargles will answer every indication; while, if the sore becomes phagedenic, cauterization with the acid nitrate of mercury and the application of antiseptic sprays or gargles will be indicated.

Erythema of the tonsils is common in early syphilis. It may be general at first, but soon shows a disposition to limit itself by well defined margins and to assume a symmetrical arrangement.

Mucous Patch.—The occurrence of mucous patches upon the tonsil is very common, especially in cases in which the tonsils have already been hypertrophied and inflamed. They may be slight and barely perceptible, or large, well defined, and extensive, varying in color from an opalescent grayish-white to a dull yellow. In the latter case they are often mistaken for the exudation of follicular tonsillitis and for diphtheria, from which they may readily be distinguished by their chronicity, their appearance, and by the history and coexisting signs of syphilis. The tonsils themselves meanwhile are generally much enlarged and inflamed. Local treatment is best carried out by applications, to the patches, of solutions of iodine, and by cleansing sprays or gargles. For the erythema an astringent spray will hasten resolution.

Gummy tumor may be recognized by the characteristic appearance of the ulceration; by the comparative freedom from pain, which distinguishes it from cancer and from tuberculosis; by the absence of the signs characteristic of tubercle in other parts of the body, including the high evening temperature; and by the fact that in the latter disease the ulcers are smaller and less deep. The best effects may be obtained from the internal administration of the iodide of potassium, while, locally, the progress of the ulcer may be checked by applications of the nitrate of silver or the acid nitrate of mercury. Indolent ulcers may be stimulated by means of solutions of the sulphate of copper, or of the sulphate or chloride of zinc.

TUBERCULOUS ULCERATION.—Tuberculous ulceration occurring primarily in the tonsil is rare. Consecutive to the appearance of the disease in other organs, it is not very uncommon, a fact which may be explained by the position and vulnerability of these organs. The appearance of the ulcer, when not too broken down, presents most of the following characters: The surface is uneven, pale, and devitalized; it is granulated or often covered with yellowish-gray, viscid or coagulated mucus; the edges are sometimes sharply cut, sometimes levelled, seldom elevated, everted, or undermined; the surface is not usually very red, but often more reddened than the surrounding tissue; there is little or no surrounding induration; the shape of the ulcer is not constant, but it is usually ovoid; its depth varies, but it is usually superficial; there is generally ulceration of some of the neighboring parts; pain in swallowing is usually very severe.

As to the local treatment of these ulcers, much will depend upon the stage of the general disease and the condition of the surrounding parts. Primary ulceration is best treated by the destruction of the infected area, either by scraping or by means of the galvano cautery; this should be followed by applications of lactic acid or of a solution of iodine, the healing process being encouraged by any suitable means. When the ulceration is secondary to general tuberculous infection and to the development of ulceration in neighboring parts, less vigorous means will probably be indicated.

In these cases the best results have been obtained by first spraying the surface of the ulcer with a solution of resorcin of a strength of two or three per cent., or with a weak dilution of Dobell's solution, and then applying to it lactic acid. If cocaine has been previously used the last application is painless. The strength of the lactic acid may be made to vary from thirty to one hundred per cent. In many cases the application of a four-per-cent. solution of cocaine will be found effective in relieving the intolerable pain and dysphagia. Anæsthesine and orthoform are both good local sedatives, as is also morphine, and they are to be preferred to cocaine in many cases. Treatment, to be effective, must be carried out with great thoroughness and regularity, and the general nutrition of the patient must be maintained with care.

Pharyngomycosis.—A parasitic disease which affects the tonsils rather more frequently than other parts will be described in the article on *Mouth, etc.*, in The Appendix.

Tumors of the Tonsil.—*Benign.*—Benign growths springing from the tonsil are somewhat uncommon. The varieties most frequently met with are papillomata, fibromata, lymphomata, lipomata, and angiomata. Papilloma of the tonsil is similar to the same growth in other parts of the body. Such tumors are generally of small size. They are apt to spring from the upper part of the tonsil, and to be pedunculated, creating little or no disturbance by their presence until they attain dimensions sufficient to render them mechanically irritating. Their appearance is that of a warty growth, with irregular outlines, their consistence is soft and yielding, and their color usually pink.

Fibromata are very similar to the above, excepting that they develop from the peritonsillar connective tissue, appearing like polypoid growths, or, as happens occasionally, growing in the connective tissue of the gland itself. The surface of the tumor is smooth and glistening, and its consistence is firm. In the case of papillomas and fibromas which are pedunculated, the best treatment is to put the pedicle well upon the stretch and then divide it close to the healthy membrane by means of a galvano-cautery knife.

Lipoma, or fatty disease of the tonsil, is rare. There are no gross features which particularly distinguish it, so that a diagnosis must be made by the aid of the microscope.

Lymphoma, although histologically similar to simple hypertrophy, is generally associated with leucocythæmia and general lymphadenitis. It is sometimes seen as a consecutive manifestation after the neighboring glands have become enlarged. Suppuration of the tonsils in this condition rarely occurs. When thus affected, the tonsils attain such a size that they obstruct the pharynx and are otherwise annoying, they may be excised. The advantages of the operation, however, will be largely mechanical.

Angiomatous tumors of the tonsil and nævus of the same organ, although sometimes observed, are exceedingly rare.

Malignant Growths.—Although not a favorite seat for the development of malignant growths, such tumors occasionally appear in the tonsils, and occurring there they are, from their history and prognosis, of the utmost importance.

Primary cancer of the tonsil is rare. Of the two principal types, sarcoma and carcinoma, the most common is the round cell sarcoma. In addition to this are found the spindle-cell sarcoma and the lympho-sarcoma.

Of carcinomas the squamous-celled or true epithelioma is the most common. While the sarcomas and spheroidal carcinomas generally form distinct and prominent tumors, growths of the epitheliomatous variety break down more or less early in their course and form deep and sloughing ulcerations. The symptoms of cancer of the tonsil are more pronounced in the carcinomatous varieties. In the latter, pain of an intermittent and lancinating character is usually an early and pronounced sign. Dysphagia soon follows.

In some cases, however, pain is not experienced at the seat of the difficulty, but is reflected to other parts of the throat. Such, for example, are cases in which otalgia, due to reflex irritation from malignant disease of the pharynx, has been treated locally for some time before attention was directed to the difficulty in the throat.

Whatever the nature of the disease, its progress is marked by infiltration of the adjacent structures, most often the soft palate or palatine arches.

The course of the disease is rapid. Both in sarcoma and in carcinoma the cervical glands are almost invariably involved, and early in the history of the case.

Cancer of the tonsil may be secondary to the appearance of the disease in other organs. In a case of extensive sarcoma of the tonsil operated upon by the writer, the disease was multiple. The tumor of the tonsil was large, smooth, and resisting, and it filled the pharynx and overhung the larynx to such a marked degree that deglutition and respiration became impossible. It had been of slow growth and its removal was attended with marked and long-continued relief. In several cases of sarcoma mentioned by Butlin the immediate cause of death was hemorrhage, both in those not operated upon and in those which were recurrent. In other cases death is caused by exhaustion due to dysphagia and sepsis, or to a combination of various causes, among which the secondary involvement of other organs plays an important part.

Hemorrhage from the ulceration of an epitheliomatous growth is not common.

The diagnosis of malignant growth of the tonsil is, generally, not difficult. It is unusual before middle life. It is unilateral. Pain, either local or reflex, and enlargement of the glands at the angle of the jaw are almost constant symptoms. As between epithelioma and sarcoma, the diagnosis is not always easy. In the former, however, pain is apt to occur earlier in the progress of the disease and to be more severe, while the tendency to ulceration rather than to the formation of a considerable tumor distinguishes epithelioma from sarcoma, which at the same time is slower in growth, much more firm in consistence, and likely to attain a much larger size.

The microscopical findings are often unsatisfactory, as the growth is apt to develop in the deep tissues, so far away from the surface that a specimen for examination cannot be obtained, and long before the surface has become involved the diagnosis may be made from the clinical signs.

The prognosis is bad, especially in epithelioma, as few patients live more than a year. It is more serious, of course, when glandular involvement has taken place, or when the neighboring structures have become infiltrated.

Treatment.—In the treatment of these cases, both the sarcomatous and the carcinomatous, an early diagnosis is of the first importance; and this is particularly the case if the disease of the tonsil be primary. For, while removal of the tonsil by the natural passages is by no means a difficult operation, the reverse is true of the extensive operation required for its removal from the outside. Thus far, neither the *x*-ray nor the toxins of erysipelas have succeeded in curing cancer of the neck. The application of the *x*-ray, however, is generally productive of positive results in relieving pain, in diminishing the secretions of the part, and in actually retarding the progress of the disease. For these reasons alone its application seems desirable, especially in cases otherwise beyond remedy. Aside from palliating the condition, little can be expected from any course of treatment which is not surgical in its nature. The local application of astringents and the internal administration of various drugs calculated to delay the progress of the disease, can only succeed to a slight degree in accomplishing the desired result.

For the removal of the tonsil several methods have been proposed. The one selected must depend mainly upon the character of the disease and the presence or absence of involvement of the lymphatic glands. The tonsil may be removed either from within the mouth, or through an opening in the side of the neck. When the lymphatic glands are enlarged, removal of the organ through the mouth can be regarded as only palliative.

Removal through the natural passages may be justifiable under certain favorable conditions, such as a slowly growing tumor, plainly located in the tonsil itself, and accessible through the mouth, and in the absence of glandular involvement. Some of the sarcomas reported as successfully cured have been of this description.

In operating the surgeon should anæsthetize the patient through the medium of a tube or some similar apparatus, introduced at the side of the mouth or through the nose; the mouth must be widely separated with a gag, and the patient's head should be slightly raised and turned toward the best light obtainable.

Excision of the affected tonsil may be best accomplished by means of a galvano-caustic knife, a galvano-caustic loop, or a cold-wire écraseur. Of these methods, the galvano-caustic écraseur will probably prove most useful in the majority of cases. While the cold wire may be used, with almost no hemorrhage, the galvano-caustic écraseur accomplishes as much and possesses besides several advantages over it. The amount of tension required for the latter is small, so that the loop is not apt to be dragged from its place, and fixation needles, if they are used, are not torn from the tumor by the pressure of the wire From the effect of the cautery any remnant of the growth is apt to be destroyed at the time of the operation, and the chances of recurrence are thereby lessened.

Care should be taken not to allow the temperature of the wire to rise too high, for the slower its progress the less will be the liability to hemorrhage. Usually bleeding is slight. Instead of the methods just described, the enlarged mass may sometimes be efficiently enucleated by means of the finger of the operator.

In cases of severe hemorrhage, and when there is considerable obstruction of the larynx from the effects of the tumor, immediate or remote, the performance of tracheotomy may be necessary. Whether or not a tampon-cannula should be used must be determined by the necessities of the case in hand. When the larynx is obstructed to any extent by the growth, or when the rima glottidis has been narrowed by œdema or otherwise, the wisest course will be, probably, to perform a preliminary tracheotomy. No unnecessary time should be consumed in inserting the tracheal tube. Should bleeding occur the best hæmostatic is the galvano-cautery. In operating upon such cases great assistance in illuminating the pharynx may be obtained by means of a small incandescent electric light.

Even in certain cases in which the disease of the pharynx has extended beyond the tonsils to the soft palate and base of the tongue, the operation through the mouth with the galvano-cautery has been successfully employed. In advanced cases, however, and in those in which the cervical glands are involved, the above operation can only be palliative.

Removal of the tonsil through an incision in the neck was first proposed and practised by Cheever, of Boston. Valuable modifications of it have been made by Czerny and by Mikulicz. Unfortunately, recent statistics relating to these operations do not exist. The cases themselves are rare and the unfavorable ones are seldom reported, so that it is impossible to know with any accuracy the actual value of the radical operation. In view of the necessarily fatal termination of the disease, however, if left to itself, it is encouraging that in some cases at least a cure has been effected, McBurney and other surgeons having instances to their credit in which the patient is alive and well several years after operation.

II. PHARYNGEAL TONSIL, OR LUSCHKA'S TONSIL.

Lymphoid hypertrophy in the upper pharynx was noticed by Schneider as early as 1655. Prof. Wilhelm Meyer, of Copenhagen, was the first, however, to estimate it at its true value, and to propose efficient means for its relief. His first article on the subject, published in 1868, is classic.

Luschka's tonsil is susceptible of two classes of difficulty. The first of these is an acute or subacute inflammation, attended with temporary enlargement, the said enlargement subsiding with the disappearance of the exciting cause. While this cannot be called a true hypertrophy it is a lesion of great importance, both on account of the temporary inconvenience which it causes and also by reason of the tendency which it manifests to leave behind a permanent enlargement of greater or less degree.

This permanent or chronic enlargement in the course of time constitutes a true hypertrophy, and, although its actual degree may vary under the general influences which cause it to grow better or worse it seldom entirely subsides. Chronic hypertrophy, as commonly met with, is clinically of two varieties. In the first the adenoid element predominates. The consistence of this variety is one of its chief characteristics, for it is soft to the touch, friable, easily broken up, and shows a tendency, when torn away, to separate in large spongy masses.

In the second variety the hypertrophied mass is composed more largely of fibrous tissue elements. Operation upon the latter variety is more difficult than upon the former, as its dense structure offers greater resistance to the efforts of the surgeon, which, when successful, result in the removal of but small masses of firm tissue, in marked contrast to the large fragments which are easily torn away in cases representing the variety first mentioned.

The location of the growth is of practical importance, both as regards its effects and as to the comparative difficulty of its removal. Its size may be so great as practically to fill the retronasal space, or, on the other hand, it may be so slight as to make it difficult to determine whether or not its condition is pathological. The hypertrophied tissue may be confined strictly to the vault, or it may be diffused over the posterior and lateral walls of the pharynx, or upon the posterior wall of the pharynx alone, in a large, well-aggregated, tumor-like mass.

The symptoms have already been described in dealing with the subject of obstructed nasal breathing (page 815).

The diagnosis of lymphoid hypertrophy at the vault of the pharynx is usually easy, the symptoms being sufficiently apparent in most cases to suggest at once the nature of the difficulty. The diagnosis is established by examination of the upper pharynx. This may be accomplished by one of several methods.

1. *Posterior Rhinoscopy.*—The upper pharynx may be demonstrated by the mirror, even in children of four years old, if sufficient patience and skill be exercised. This method is highly desirable, as it does not alarm the child.

2. *Palpation.*—With the tip of the forefinger carefully inserted into the pharynx the presence of hypertrophied tissue can be accurately demonstrated. Great care should be taken not to inflict pain nor cause injury. The end of the finger should be carefully prepared for the purpose, and the mistake of trying to insert a finger-tip too large readily to enter a small pharynx should be avoided.

3. *The Probe.*—In very young children a probe, made of a very small English woven bougie, may be passed into the pharynx and the presence of hypertrophied tissue thus demonstrated.

4. *By Anterior Rhinoscopy.*—A strong light thrown into the nasal cavity may sometimes bring to view the thickened masses at the upper and posterior part of the pharynx.

In very young infants three diagnostic points may be observed, namely, mouth-breathing, snoring, and inability to perform the act of nursing without stopping to take breath. All of the above are due to nasal obstruction.

The symptoms commonly met with in lymphoid hypertrophy have already been described in the earlier part of this article. In addition to them should be mentioned the effect of disease of the faucial and pharyngeal tonsils upon the cervical lymph nodes. These are often caused to become inflamed, to swell, and to suppurate from absorption of various septic organisms originating in the tonsils. When glandular swellings of the neck are found to occur, either in occasional exacerbations or chronically, examination of the pharynx should always be carefully made. The removal of diseased tonsils in such cases, unless performed too late, is followed by remarkably beneficial results.

The treatment of an hypertrophied Luschka's tonsil must depend in some degree upon the nature of the growth, the size to which it has attained, and the age of the patient. In a few instances, in which the disease is

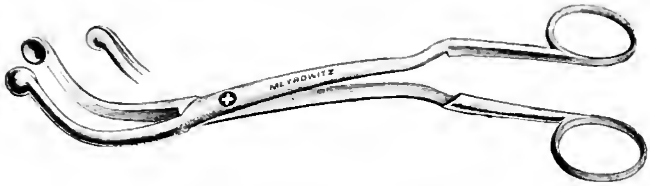


FIG. 4734.—Loewenberg's Forceps, modified.

acute or subacute, where the tissue is soft, and where the growth is small, or finally, where the patient is old enough to submit to local treatment, the application of resorptives and the administration of alterative and tonic medicines, together with careful attention to hygiene, may accomplish a cure. Almost invariably, however, these means will be found unsatisfactory, and the question of radical measures will present itself.

As to the methods by which the offending tissue may be removed the use of local applications for the reduction of adenoids has not yet been a success. The attempt to reduce them also by escharotics is highly objectionable, as both with the ordinary caustics and with the galvano-cautery much difficulty is experienced in making the application and great danger is incurred of injuring important neighboring structures. Hence some form of surgical operation seems in the present state of our knowledge to be unavoidable.

The relative thoroughness and safety with which an operation can be performed will depend somewhat upon the kind of instrument employed. It is necessary therefore that the instruments commonly used for the purpose should be described.

Beginning with the finger-nail and Meyer's ring knife, an almost unlimited number and variety of instruments for the removal of hypertrophied lymphoid masses have been devised. They may be classified into several groups—namely, those made upon the principle of (*a*) the curette, (*b*) the forceps, (*c*) the wire loop, and (*d*) the adenomatome.

(*a*) The curettes are of three kinds: The ring knives of comparatively small size, the sharp spoon, and the Gottstein instrument. To this class may be added the finger nail.

(*b*) The forceps include those instruments which are constructed with comparatively blunt edges and which are intended to tear away the tissue rather than to cut through it. Of these, the Loewenberg is the best example. Many modifications of it have been made, some of which are very satisfactory.

(*c*) The wire snare or loop has been used by some, either in a simple curved canula or in an instrument especially designed for the purpose. While it has possibilities of usefulness, it appears that they have not yet been fully realized.

(*d*) By the name adenomatome is meant an instrument constructed more or less upon the principle of the scissors and intended to make a clean incision through the substance of the growth.

Nature's instrument, the finger nail, is undoubtedly useful in completing the work of other implements by the separating of partly detached fragments of tissue and by the removal of it from corners difficult for an instrument to reach. Gottstein says: "It is clear that with the finger only a very little can be removed, and, moreover, it must be recognized that from the point of view of asepsis the finger nail is a decidedly undesirable instrument." The artificial finger nail is practically never used.

Of the curettes, the small ring knives are valuable for the removal of limited areas of tissue, especially those left after operation with larger instruments. They are also very useful for operations upon the adult, where, under local anæsthesia and with the aid of the mirror, small quantities of tissue can be removed at a time with comparatively little pain and irritation.

The sharp spoon has been justly condemned because of the amount of bleeding which it causes and the difficulty experienced with it in separating the fragments of tissue from the pharyngeal wall.

Of the instruments of this class, Gottstein's knife (Fig. 4736) and its modifications must claim the greatest popularity. There are several things to be said in its favor.

If pain is of no account and speed of more importance than thoroughness, then Gottstein's knife would be ideal. The objections to it, however, are serious, for its use is painful, and it is seldom that the shape of the instrument is so perfectly conformed to the pharynx, the base of the growth so limited in its extent, and the management of the knife, so well directed, that the necessary thoroughness can be attained. It will often be found that the Gottstein knife has simply cut through the lower part of the growth, or has removed a certain amount from one side, leaving the other side full, or has fairly cleared the vault, leaving abundant deposits upon the posterior and lateral pharyngeal walls.

In the forceps, modified to suit the size of the pharynx and the location of the growth, we have an instrument by which the lymphoid masses can be seized and, by proper manipulation, torn away, much larger fragments than the part caught in the grasp of the instrument usually being separated at each attempt. In skilled hands the forceps can be turned in all necessary directions and its blades made to grasp everything in their way. The pharynx can thus be thoroughly cleared, and with the loss of less blood than is common with sharp instruments. The operation, however, is painful.

It would appear that the prime object of the adenomatome is to enable the operator to remove the whole or as much as possible of the growth at one introduction of the instrument. Many varieties of them are of large size or of improper shape, and are not fit to be inserted into the nasopharynx, while their great strength places at their mercy any object which they may grasp. Even in experienced hands they are probably the most dangerous of this class of instruments. As to their thoroughness, one glance at the construction of their blades will show that there must be certain parts of the pharynx which they cannot possibly reach, while the risk of cutting too deeply or in wrong directions is evident. Such instruments are better suited to adult cases and can hardly be intended to be used upon the child.

FIG. 4735.—Hooper's Palate Retractor.

Of the instruments described, the ones most generally useful are some good modification of the Loewenberg forceps and the sharp curette. A recent addition to the latter consists of an attachment by which the detached fragment of tissue is seized and thus prevented from falling into the patient's throat on the withdrawal of the knife. In general, the instrument used should be adapted as well as possible to the size and shape of the pharynx and to the particular growth to be removed. The importance of the structures adjacent to the pharynx calls for great care and skill in operations in this region.

The other instruments necessary for operating under anæsthesia are, a mouth gag and a retractor for the soft palate (Fig. 4735). The latter should be made of hard rubber, with a shank broad enough to protect the uvula from injury during the progress of the operation.

The position of the patient during operation is of considerable importance. Two methods are in common practice. In the first, the child is held upon the lap of an assistant in the sitting posture, with the head upright and turned toward a good light. The head is steadied by a second assistant, who also manages the mouth gag. The soft palate may be drawn upward by means of the palate retractor, or it may be secured by tapes passed inward through the nose and outward through the mouth and the ends tied outside after Wales' method. With the head inclined forward in this position the blood caused by the operation will tend to escape from the mouth instead of being swallowed. Moreover, the pharynx can be well illuminated and the steps of the operation better directed by the aid of vision. The position upon the back is preferred by many good operators, requiring, as it does, the services of fewer assistants and being the one to which a large majority of surgeons are better accustomed. It is not so favorable as regards the admission of light to the pharynx, and therefore it requires a greater degree of skill on the part of the operator, whose tactile sense must be highly educated by way of substitute. Blood, instead of flowing out of the mouth, is swallowed into the stomach. This is not a disadvantage, for it trickles down the posterior wall of the pharynx and escapes into the œsophagus, almost without making its presence felt, unless the flow excited has been considerable.

FIG. 4736.—Gottstein's Sharp Curette.

A possible objection to the upright position is the additional risk of fragments of detached tissue falling into the larynx and thus causing asphyxia. Such an accident has been reported. It is not probable that it could occur under the use of the forceps, although it is by no means impossible with the ring knife.

The management of the palate retractor as well as of the anæsthetic should be intrusted to a skilled assistant, as upon this the convenience, and, to some extent, the success of the operator, will depend. Great care should be taken to place the retractor in such a position that the antero-posterior diameter of the entrance to the upper pharynx be made as wide as possible, and that the most perfect protection be afforded to the uvula. Preliminary to operation the most thorough rhinoscopic examination possible should have been made and the situation, form, size, and texture of the growth well studied. Where this is impossible, examination by means of the finger is admissible, and digital exploration of the pharynx should always be made after the child has been anæsthetized and immediately prior to the operation. Should the growth be large and its attachments not easily demonstrated by the finger, a curved probe will lend useful aid in mapping them out. By the practice of careful preliminary examination a fair idea of the amount of tissue to be removed may be gained and if, during the operation, the fragments removed be preserved, it will be easy to estimate what part of the growth has been withdrawn and how much of it still remains.

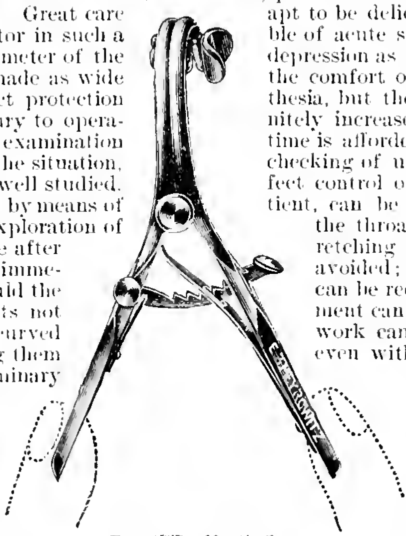


FIG. 4737.—Mouth Gag.

The removal of adenoid tissue from the pharynx is attended with more or less bleeding, and this, while generally of no importance, may sometimes be considerable. It is best, therefore, that the tissue be torn away, rather than cut. This method has the additional advantage of greater thoroughness. Remnants of adenoid tissue left behind by the forceps may be removed by the finger nail of the operator, by Hooper's modification of the Loewenberg forceps, or by means of a small carefully guided curette. Should the removal of a mass of adenoid tissue be followed by undue bleeding it is well to defer further attempts at operation for a few moments, until the hemorrhage shall have ceased, or, at least, until it shall have sufficiently diminished. Too great force in the separation of a fragment of tissue must be avoided. It is better to release the mass included in the grasp of the forceps and seize a smaller portion, or else, by applying the instrument in a somewhat different position, to separate adherent fragments than it is to attempt to accomplish too much at once. To prevent laceration of the mucous membrane in the removal of a fragment of adenoid tissue the tip of the forefinger should be passed upward and under the jaws of the forceps, and firm pressure made against the inferior attachment of the mass while the latter is being detached. As large masses of hypertrophied tissue often exist upon the posterior wall of the pharynx as well as upon the vault, it is necessary to secure the removal of this with the rest. The corners of the upper pharynx also, immediately above the Eustachian prominences, must be carefully cleared.

The manipulation of the instruments used in this operation as well as the *tactus eruditus* necessary to the clear understanding of what is being done, are accomplishments which, of course, are best gained by practice and experience.

In operating upon the upper pharynx anæsthesia is of the greatest possible value both to the physician and to the patient. The almost universal testimony, both from children and adults, is to the effect that the removal of adenoid tissue from the pharyngeal vault is exceedingly painful. Exceptions to this are occasionally met with, and in the case of the strong and phlegmatic, and where the growth is soft, it may be well to dispense with a general anæsthetic in favor of cocaine. As a rule, however, patients who suffer from adenoid hypertrophy are apt to be delicate, nervous, and timorous, susceptible of acute suffering, and likely to undergo much depression as the result of operation. Not only is the comfort of the patient secured through anæsthesia, but the convenience of the operator is infinitely increased. With general anæsthesia ample time is afforded for careful examination and for the checking of undue bleeding should any occur; perfect control of the operation, as well as of the patient, can be maintained; thorough relaxation of the throat can be secured; the inducement of retching from pharyngeal irritation can be avoided; troublesome remnants of the growth can be recognized and removed; undue excitement can be prevented; and, finally, the whole work can be accomplished without pain and even without the slightest knowledge on the part of the patient of what has been done.

Again, the safety of the surrounding parts is far more likely to be sacrificed when the operation is done hastily upon a struggling child. Serious injury has thus been inflicted upon the posterior edge of the nasal septum, the turbinated bodies, the Eustachian eminences, and the lateral and posterior walls of the pharynx. The more humane the method of operating, the more will the work of the operator be facilitated and the best interests of the patient secured.

The anæsthetics suitable for such cases are, for local anæsthesia, cocaine, and bromide of ethyl; for general anæsthesia, ether, chloroform, and nitrous oxide gas. The advantages of cocaine are that it renders the introduction of the instrument into the upper pharynx much easier and diminishes the pain and local spasm otherwise sure to occur. Its disadvantages are the length of time which it takes to produce its effect, the general toxic symptoms which it often causes, and its failure after all greatly to modify the actual pain of the operation.

Of the three general anæsthetics, nitrous oxide gas is suitable for short and rapid operations, but it is difficult of administration to a patient who is too young to follow the directions of the anæsthetist, and to those in whom the upper air passages are seriously obstructed. Chloroform is unquestionably dangerous, and, on the whole, not superior to ether. In the hands of a skilful anæsthetist and properly administered, ether will, as a rule, prove most satisfactory. Under deep anæsthesia the pharynx is completely relaxed and ample time is afforded for all the care and thoroughness necessary, the patient meanwhile being free from pain. The theoretical objections that ether is dangerous, that the children are apt to be injured by it, and that its action increases the amount of bleeding at the time of the operation, are not true. If more blood flows with anæsthesia than without, it is largely because under the former condition a much greater amount of tissue is removed.

Much caution should be employed in the after-care of the patient. He should not be at once dismissed, but should be put to bed, and kept there for at least twenty-four hours, and until all signs of disturbance or shock have subsided. Attention to this detail will be amply repaid, for it lessens the possibility of bleeding, prevents infection, guards the patient against taking cold, and greatly reduces the general depression due to the slight shock of the operation.

Meanwhile the administration of tonic doses of iron and quinine will materially hasten recovery. In other words, to this surgical condition the ordinary rules of surgical treatment should be applied.

It must not be considered that with the performance of the operation the case is completed and all possible help to the patient afforded. The general condition should be made as perfect as possible, to which end change of air is often of great benefit, and, most important of all, the patient should be carefully examined in order to determine whether or not the operation has resulted in a thorough and complete success. Should the contrary prove to be the case, further treatment may be called for, and although when properly performed at first, it will seldom be necessary to repeat it, there is no reason why this should not be done when required. Indeed, it is well, in difficult cases, to mention to the parents beforehand the existence of such a possibility.

The pharynx being freed from the offending tissue, such conditions as catarrhal inflammation, relaxation of the uvula, and the general tendency to local congestion can be greatly benefited by topical treatment, although in most instances special interference will be unnecessary.

The second variety of treatment relates to the cure of certain direct results of the naso-pharyngeal obstruction, namely, to mouth breathing, to errors of pronunciation, and to deformities of the chest walls and of the framework of the nose.

When free nasal respiration has been actually established every possible encouragement should be held out to the patient to close the mouth and breathe through the nose, both while awake and when asleep.

The operation for the removal of hypertrophied adenoids is not so simple and easy as many suppose it to be. On the contrary, its successful performance requires knowledge, experience, and skill.

III. TONSIL OF THE TONGUE.

[Glandular (or adenoid) tissue at the base of the tongue.]

This tissue, the existence of which has long been known, is analogous to the structure of the faucial tonsils and of the tissue at the vault of the pharynx. It completes the circle of glandular tissue which surrounds the pharynx.

Histologically, the principal difference between the faucial tonsil and the lingual lymphoid masses is, that while in the tonsils the lymphoid tissue is collected together into a circumscribed and well-defined mass, the lymphoid tissue at the base of the tongue is disseminated in small groups over a considerable surface. Strictly speaking, these groups are not glands, since they have no excretory duct nor outlet, but are enclosed bodies and belong in reality to the lymphatic system. They are usually three or four lines in diameter, and are loosely embedded in the submucous tissue. Their hilus is covered with a thin mucous membrane. Their sac contains a varying number of follicles, closely resembling those of Peyer's glands of the intestines. The existence of the lingual tonsil, so-called, is a normal condition. The collections of tissue are located between the circumvallate papillæ and the epiglottis. Normally they are not conspicuous, nor is their presence manifest excepting upon irritation, when it will be discovered that the region which they occupy is highly sensitive, and liable to marked reflex phenomena.

In examining the base of the tongue with the laryngoscope there is found, normally, a free interval between the base of the tongue and the epiglottis. When the lymphoid tissue is hypertrophied, this interval is more or less filled up, and the tip of the epiglottis may be seen impinging against the tongue or, apparently, buried in a mass of enlarged and prominent glands. The hypertrophy may extend laterally, and thus shut off the view of the pyriform sinus. It is often more markedly developed upon one side than upon the other. The glands may be seen projecting backward, each one more or less distinct and by itself, and the whole forming an aggregation which is clearly more prominent and conspicuous than is seen in the natural state of the parts. Dilatation of the blood-vessels of the neighborhood is generally present. As to what constitutes the normal condition of the base of the tongue, it may be said that in the vast majority of cases pathological symptoms will be caused only by abnormal enlargement of the lymphoid tissue so pronounced that, when sought for, it can hardly fail of being recognized.

The disease commonly met with in the lingual tonsil is a condition of general hypertrophy, in which the whole gland is increased to double the normal size or more, and its follicles themselves are considerably enlarged. This hyperplasia is very similar to the condition seen in chronic hypertrophy of the faucial tonsil. Associated with the hypertrophy there is often a dilatation of the blood-vessels. Sometimes but one or two vessels may be enlarged and sometimes many of them. It is not uncommon to see it in children.

The causes of the hypertrophy are, to a great degree, identical with those of chronic hypertrophy of the faucial tonsils. They may depend upon disturbances of the circulation due to renal or hepatic disorders, or upon cardiac disease. Among them acid indigestion plays a particularly important part.

The symptoms observed in these cases are many and, as a rule, well marked. They are more commonly observed in women than in men, and are in general such as commonly accompany hyperæsthesia of the parts. Thus, the patient complains of a sensation of pricking, or of the presence of a foreign body in the throat. The pain is usually localized, but sometimes radiates to other parts, these subjective phenomena being increased if the tongue be drawn backward. The explanation of the symptoms is simple. Normally, the margin of the epiglottis is free. When the lymphoid tissue of the tongue is so enlarged as to come in contact with it, then, two parts being in contact which usually do not touch each other, the subjective sensation of a foreign body results, accompanied or not by pain in proportion to the amount of irritation produced. Patients occasionally complain of pain shooting up to the ears, or refer their discomfort to the stomach, larynx, trachea, or intrascapular region. Pain is also present when the glands are in a state of subacute inflammation.

The effect of hypertrophy of the lingual tonsil upon the voice is marked and disastrous, for fatigue in speaking and singing is a common symptom. When the trouble is not severe the only complaint may be that the patient has pain while talking, without being hoarse, the neighboring parts of the throat being normal. In some cases the vocal fatigue can be traced to deficient innervation. In cases in which the difficulty is more pronounced, the voice may be entirely lost. In some cases the voice is uncertain, being sometimes good and sometimes poor. Sometimes it is unreliable or difficult to control, breaking during the effort to sing. Again, there may be a marked tendency to sing out of tune, and the timbre of the voice may be seriously impaired. In other cases the normal range of the voice is interfered with, the patient not being able to produce two or even three of the highest notes of which his voice is capable.

Some patients suffer from cough, which is observed in two different forms. It is either violent, spasmodic, and almost incessant, or of a hacking character, appearing at shorter or longer intervals. The spasmodic form, as a rule, occurs when the hypertrophied glands encroach upon the epiglottis, and is less frequent than the hacking cough. The latter often gives rise to great anxiety, as the patient fears it to be a symptom of developing pulmonary phthisis. This form of cough is often present when there is merely contact between the glands and the epiglottis, and it is probably due to the friction of the tongue and epiglottis against each other during their movements.

It is a question whether the so-called "globus hystericus," as seen in nervous women, is not often less a matter of the imagination than has been commonly supposed. In patients afflicted with this complaint, hypertrophy of the lingual tonsil has frequently been observed, while in patients of nervous temperament other reflex symptoms of the condition are often severe. On the other hand, the globus hystericus has been seen in patients in whom the base of the tongue was practically normal.

Finally, attacks of dyspnœa resembling asthma may occur in patients with enlarged lingual glands.

The prognosis is good, but the length of time required to effect a cure is not always easily determined.

Too radical measures for the relief of this condition are not indicated, and much harm has been done by the free use of surgical methods in cases in which simpler means would have answered the purpose. Thus, in cases depending upon hyperacidity of the stomach, correction of the indigestion will cure the tongue. When Bright's disease is present, or when there is disease of the liver or of the heart, the attempted removal of the enlargements or the obliteration of the dilated vessels can only result in harm.

In the congestive form of enlargement, especially when dependent upon indigestion, relief is often afforded by cleansing and astringent applications made to the base of the tongue by means of a good spray atomizer, attention being paid meanwhile to the constipation, or to the hyperacidity of the stomach, which may be present.

When the hypertrophic masses are permanent, requiring actual removal, surgical means are called for. Many special methods have been suggested for this purpose, from the use of various escharotics to actual ablation by means of cutting instruments. The latter are in general not to be preferred. On the whole, the most satisfactory means seems to be either the galvano-cautery applied by means of a flat electrode, the galvano-caustic snare, or the cold-wire snare. Under cocaine anæsthesia the operation is usually not very painful, and healing takes place in a few days.

Suppurative inflammation of the lingual tonsil is rare. When it is present it is necessary to determine the precise location of the lesion, and to remember that such attacks are sometimes accompanied by œdema of the larynx. Evacuation of the abscess during sleep may prove dangerous. Chronic abscess of this region and retention cysts have been observed. This condition is sometimes so severe as to suggest Ludwig's angina.

D. Bryson Delavan.

TOPEKA MINERAL WELLS.—Shawnee County, Kansas.

Post-Office.—Topeka. Hotel.

These wells, two in number, are located on Harrison Street, in the city of Topeka. We are informed that a good hotel has been established at the wells for the accommodation of persons requiring treatment. Turkish, Russian, electric, and steam baths may be obtained. The following analysis of the water was made by Messrs. Barnes and Sim, chemists. The estimate was presumably made in grains per United States gallon.

One United States gallon contains (solids): Magnesium chloride, gr. 11.76; sodium sulphate, gr. 19.26; magnesium sulphate, gr. 14.36; sodium nitrate, gr. 1.94; sodium bicarbonate, gr. 35.61; calcium bicarbonate, gr. 22.48; iron bicarbonate, gr. 28.06; ammonium sulphate, gr. 1.50; alumina, gr. 0.40; silica, gr. 10.28; organic matter, gr. 1.76; phosphoric acid, a trace. Total, 147.35 grains.

The baths have been in operation since 1879. They are highly recommended for obstinate cases of rheumatism. The water is also used commercially. The analysis shows a fairly strong saline-purgative water, and it should be useful in cases to which such waters are applicable.

James K. Crook.

TORMENTIL. See "*Rosaceæ*," under the heading *Roses*.

TORONTO, CANADA.—This city, of about 250,000 inhabitants, the metropolis of the Province of Ontario, is situated in lat. 43° 39' N., and long. 79° 23' W., on the northwestern shore of Lake Ontario. Meteorological observations made here can be taken to illustrate the special climatic features of the northern shores of Lake Ontario, known as that of the "Lower Lake Region." For the following description of the topography of this region, as well as of the city, the writer is indebted to Dr. P. H. Bryce, Secretary of the Ontario Board of Health.

"Lake Ontario is 240 feet above the sea level and lies in a depression produced by glacial erosion, being surrounded by five well-marked lake beaches, extending from the Oak Ridges escarpment on the north, to the Catskills to the south. Northwesterly, these heights form a central plateau stretching to Lake Huron, with a general elevation of 1,000 to 1,300 feet, thereby protecting the Lake Ontario region from the severe storms which move from the northwest plains over the upper lakes, and spend their force on the northwest slopes of the plateau as rain and snow storms. The annual rainfall of Toronto averages 31 inches, with usually a light snowfall. The soil underlying the city and neighboring shores of the lake is a tenacious Post-glacial clay—the Erie clays, geologically—capped, however, in the upper portions of the city with sands and gravels. The combined system of sewerage has converted Toronto from what was "Muddy York" to a paved city, famed equally for its well-kept streets and lanes and for its wealth of residential streets lined with forest shade trees, and its splendid central and suburban parks, with magnificent deep ravines, whose precipitous sides form valleys eroded through the clays by the Humber and Don rivers. Lying in front of the city is an island, which, when the city was founded, was a peninsula formed from the weather-worn cliffs of Scarboro Heights in the east, reposited as a sandbar five miles in length, which bounds a bay some two miles in width in front of the city. This island now forms the summer home of thousands of city dwellers, and on it there is also a lakeside park, visited daily by many thousands. In the midst of the lake, a mile beyond the island, and fully protected against the sewage which is poured into the bay, is the intake of the city water pipe. The breezes blowing over the deep waters, the temperature of which in even late summer seldom rises above 50° F., maintain a coolness which is typical of the whole northern shores of the lake, and which has caused these shores, from Hamilton to Kingston, to become yearly more and more the summer home of many thousands, especially from the Middle and the Southern States.

"The great depth of the lake keeps the waters open all winter, and gives to the climate of the surrounding region, during the winter and early spring, an unpleasant dampness and coldness similar to that which prevails in northern marine climates. The following table will enable the reader to compare the climatic conditions of Toronto with those of several other places where meteorological records have been kept."

ince of Ontario is between 30 and 40 inches. At Toronto the annual percentage of bright sunshine is 44, and for July at the same place it is 60. This is much higher than in England, for instance, where it is about 36, according to Stupart. The relative humidity, 77 per cent. for the year, indicates a moderately damp atmosphere.

As the metropolis, for over a hundred years, of the province, Toronto is adorned with a fine House of Parliament, a splendid City Hall, and a Provincial University, with lands set apart for educational purposes, in the first years of the province, and throughout which are distributed some ten colleges, which cluster around University College, probably the finest type of gothic architecture in America. Some three thousand students are enrolled in those colleges. There are, in addition, three

MEAN TEMPERATURES AND HUMIDITY.

Place.	Latitude.	Height in feet.	February.				July.				Relative Humidity.	
			Mean max.	Mean min.	Extreme max.	Extreme min.	Mean max.	Mean min.	Extreme max.	Extreme min.	February.	July.
Toronto	43° 39′	350	30.8°	18.2°	44.0°	1.0°	81.4°	63.5°	93.3°	53.3°	80	74
New York	39 57	185	39.9	23.8	55.0	3.0	85.5	63.6	90.0	55.0	77	70
Boston	42 21	125	37.1	11.5	56.0	− 4.0	77.4	60.1	89.0	51.0	71	68
Chicago	41 52	715	30.9	14.2	47.0	−18.0	80.7	64.6	94.0	56.0	76	68
Ottawa	45 26	330	26.1	8.5	40.0	−12.0	82.2	62.5	97.2	55.2	81	74
Winnipeg	49 53	760	13.3	11.4	41.0	−32.2	79.0	56.8	88.5	47.0	94	74
Calgary	51 2	3,389	24.9	7.0	40.3	9.7	72.4	46.0	86.3	39.0	73	61
Kamloops	50 41	1,193	35.5	22.0	44.6	11.5	78.9	54.8	98.0	46.0	79	67
Gravenhurst	44 50	770	25.0	8.8	40.0	−22.2	82.5	60.6	97.0	52.0	75	76

The table is interesting as showing that, while the relative humidity in winter is high, its mean minimum temperature in February is higher than it is either in Boston or in Chicago, though lower than in New York. On the other hand, its maximum mean is the same. Its two summer means are practically those of Chicago, although it is higher in both than it is in Boston.

The annexed chart, obtained through the kindness of Prof. R. F. Stupart, director of the Meteorological Service, Toronto, will show in detail the characteristic climatic condition of Toronto, and will also serve to illustrate the climate of the lower lake region. It will be observed that the winters are not excessively cold or the summers oppressively hot, this being due, as Professor Stupart remarks, to the tempering influence of the lakes. In May the mean temperature of the whole Ontario peninsula, says the same authority, is slightly higher than for the south of England. September and October are "generally delightful months." Much snow falls during the winter, but it seldom remains on the ground until March. The annual precipitation of the entire prov-

medical colleges, which have a four years' curriculum of study, with a fifth year of clinical work before a license to practise is given.

Toronto is naturally the centre of the larger charities in the province; all hospitals, refuges, and reformatories are located here under governmental supervision. There are seven large hospitals, general and special, with provision for 6,000 patients annually, and twelve homes and refuges provided for 1,000 inmates. It is thus apparent that the 400 physicians of the city, as well as the students of the colleges, have ample opportunities for developing medical practice into a high state of efficiency.

"DEATHS FROM CONTAGIOUS DISEASES IN TORONTO IN 1901.

Smallpox, 1—rate per 1,000	0.005
Scarlatina, 37—rate per 1,000	.18
Diphtheria, 174—rate per 1,000	.83
Measles, 8—rate per 1,000	.04
Whooping-cough, 25—rate per 1,000	.12
Typhoid, 37—rate per 1,000	.18
Tuberculosis, 489—rate per 1,000	2.30"

The City Health Department, acting under a health act common to the whole province, is well organized, and

CLIMATE OF TORONTO. LATITUDE, 43° 39′; LONGITUDE, 79° 23′.—PERIOD OF OBSERVATION, FIFTY-SIX YEARS.

Prepared by Prof. R. F. Stupart, Director of the Meteorological Service, Toronto.

	January.	March.	May.	July.	September.	November.	December.	Year.
Temperature—(Degrees Fahr.)								
Average or normal	22.4°	28.7°	52.1°	67.6°	58.6°	36.1°	26.3°	44.2°
Mean of warmest	28.9	35.6	61.3	77.4	65.5	42.0	32.2	
Mean of coldest	11.9	21.4	42.9	57.9	47.9	29.9	19.6	
Mean daily range	14.0	14.2	18.4	19.5	17.6	12.1	12.6	16.1
Highest or maximum	57.5	70.3	93.4	98.0	93.6	67.0	61.0	99.2
Lowest or minimum	−26.5	−15.6	24.6	38.7	27.9	− 5.0	−21.0	−26.5
Humidity—								
Average mean relative	83%	78%	70%	72%	77%	80%	82%	77%
Precipitation—								
Average in inches (rain)	1.16	1.44	3.05	2.99	3.27	2.67	1.60	27.35
Average in inches (snow)	17.4	12.3	.10	....	....	4.6	13.8	68.3
Wind								
Prevailing direction	W.	N. W.	N. W.	N. W.	N. W.	W.	W.	W. N. W.
Average hourly velocity in miles	11.4	11.5	8.9	7.6	8.5	10.5	11.1	9.6
Weather—								
Number of days without rain or snow	19	17	12	13	12	18	20	178
Number of days completely clouded	13	6	3	0	2	8	13	64
Number of thunder storms	0	1	3	7	3	0	0	29
Number of fogs	2	2	3	2	5	3	2	33
Percentage of bright sunshine	29	43	48	60	56	28	22	44
Percentage of sky clouded	74	63	57	49	50	75	78	61

the healthfulness of the city, with all the already mentioned charities centred in it, is illustrated by the fact that in 1901, the year of the last Canada census, the mortality was as follows: Toronto: Deaths per 1,000 population in 1901, 16.5; New York: Deaths per 1,000 population in 1900, 20.4."

One hundred and fifteen miles north of Toronto, near the town of Gravenhurst, is situated the Muskoka Cottage Sanatorium for the treatment of incipient cases of pulmonary tuberculosis. This institution is located in a beautifully wooded, sheltered park of some 80 acres, on the shores of Lake Muskoka. It has an altitude of about 800 feet, in the region known as the Highlands of Ontario.

The climate is a bracing one, and the air is dry and free from dust. The soil is dry, and of rocky formation, and the water very soft. The winters are cold, but there are no sudden changes of temperature. Snow remains on the ground from December to March. There is a very considerable amount of sunshine. The patients can remain out of doors from six to eight hours throughout the winter.

The buildings are constructed upon the cottage plan, with an administration building in the centre of the group. Each patient has a separate room, and the use of the sun parlors and piazzas. The accommodations at present allow for fifty patients, but the number of the cottages is to be increased.

Walking, sleighing, snowshoeing, and, in the summer, boating on the lake, are permitted for suitable cases. The cost to each patient is six dollars per week. The results so far have been satisfactory. This region also affords relief to those suffering from asthma and hay fever, and is much frequented as a summer resort by the people from the cities and towns farther south.

[For an excellent account of the climate of Canada as a whole the reader is referred to the paper of Professor Stupart, read at the meeting of the British Association, Toronto, 1897, and reprinted from the *Scottish Geographical Magazine* for February, 1888.] *Edward O. Otis.*

TORTICOLLIS.—(Synonym: Wry-neck.) Torticollis, as the name indicates, is a twisted neck, a distortion caused in most cases by active contraction or by actual shortening of one or more of the lateral muscles that control the head. Similar distortion may be present in Pott's disease, but in this instance the deformity is a symptom of a more important disease, while the term torticollis implies simple deformity.

Torticollis may be divided into two classes—the congenital and the acquired.

CONGENITAL TORTICOLLIS is a painless shortening of the tissues of one side of the neck of intra-uterine origin. Acquired torticollis is almost always accompanied at its onset by discomfort or pain. This afterward subsides, leaving the deformity; thus torticollis, from a therapeutic standpoint, may be divided into the acute and the chronic forms.

Whatever may have been the cause of the deformity, the sterno-mastoid muscle is most often affected, and typical torticollis implies contraction or shortening of this muscle. As an effect, therefore, the chin is slightly elevated and turned away from the contraction. The head is tilted toward the shortened muscle, and as a whole is displaced toward the opposite shoulder. There are also irregular forms of torticollis due to contraction of other muscular groups, to which attention will be called later.

Torticollis is a comparatively uncommon deformity, and the acquired form is far more common than the congenital variety. The sexes are about equally affected, and one side as often as the other.

CONGENITAL TORTICOLLIS.—In most instances the deformity is slight at birth, and it does not attract attention until the child is able to support the head, and in many cases not until a much later period. In exceptional instances, however, the deformity is well marked at birth and is accompanied by noticeable asymmetry of the head and skull. In cases of this character the contraction often involves all the lateral tissues of the neck, indicating that its cause must have been a fixed or constrained position in utero, an explanation that may be applied to the great majority of the milder cases also.

It may be stated in this connection that it was at one time generally taught that so-called congenital torticollis

FIG. 4738.—Well-marked Congenital Torticollis of the Left Side, showing the Effect of the Contraction in Displacing the Head toward the Opposite Shoulder.

was due to injury at birth, the sequence of events being somewhat as follows: The sterno-mastoid muscle was ruptured; rupture was followed by hemorrhage into the substance of the muscle, which in turn set up inflammation; this was followed by scar contraction and by deformity. This theory has now few supporters, for the following reasons: In the majority of cases of true congenital torticollis discovered in early infancy, there is no evidence of hæmatoma. Hæmatoma is in but few instances followed by torticollis, nor is rupture of muscle in later life or in other situations followed by such shortening. It is apparent, of course, that a congenitally short muscle might be injured at birth with a resulting hæmatoma, also that injury at birth might induce irritation or discomfort, and that deformity might follow the habitual attitude assumed by the patient for the relief of this discomfort.

Pathology.—In the ordinary type of congenital torticollis, as demonstrated at operations on children, the substance of the affected muscle or muscles is simply lessened in amount, and there is a disproportionate area of tendinous substance, as contrasted with the contractile tissue. In other instances the muscle may be traversed by fibrous bands or patches of scar-like tissue. Such changes are far more common in acquired torticollis, and they indicate primary or secondary inflammation of the muscular substance. In cases of torticollis in infancy, or when the distortion is slight, there is but little general effect of the local contraction; but, if the deformity persists, secondary changes appear. The face on the affected side is flatter, the nose, the corner of the mouth, and the eyelids may be drawn down toward the contraction, and the skull even may be markedly deformed. There is in all cases of this character lateral distortion of the cervical spine, the convexity being on the side opposite the contraction. Later, secondary curvature of the spine develops. Usually, there are also an increase of the dorsal convexity, "round shoulders," and a lateral compensatory curve in the direction opposed to the superior deformity.

If the deformity persists the neighboring muscles become eventually involved, together with the other tissues on the contracted side, the fascia presenting the greatest resistance to the correction.

Non-Operative Treatment of Congenital Torticollis.—If the deformity is discovered in early infancy it may be overcome, in many instances, by massage and stretching. In this manipulation one person holds the arm firmly, and another draws the head in the opposite direction, meanwhile vigorously massaging the contracted tissues. This treatment is carried out twice daily for about ten minutes each time. In holding the child and arranging the pillow during sleep, one should take advantage of postures that oppose the deformity.

Hæmatoma.—As has been stated, hæmatoma is not unusual after difficult labor. It forms a hard, resistant, ovoid swelling in the substance of the sterno-mastoid muscle. It is usually discovered about the second week after birth. Its absorption may be hastened by massage with some bland ointment. If there is a tendency toward contraction or toward a posture that might favor deformity, this should be prevented by manipulation and by posture.

Operative Treatment.—If the muscle or muscles are actually shortened, and if deformity cannot be overcome by manipulation in the manner described, operative treatment is indicated. This statement applies to practically all forms of torticollis, whether congenital or acquired, in which the deformity is persistent. The treatment of acute torticollis, and the prevention of deformity will be described later. The object of operative treatment is

FIG. 4739.—The Method of Applying the Plaster Bandage after Operation on the Left Side, to Hold the Head in the Attitude of Overcorrection. (From Whitman's "Orthopedic Surgery.")

to overcorrect the deformity and to hold the head in the overcorrected position until the parts are thoroughly adjusted to their new relations.

Forcible Correction.—The patient having been anæsthetized the shoulders are elevated upon a hard pillow, the arm is then held firmly by an assistant, and the operator begins a series of forcible movements, alternately stretching and relaxing the contracted parts and forcibly massaging them with the ulnar border of the hand. If the shortened muscles are very resistant, it is well to divide the tendinous insertions subcutaneously as a preliminary measure. In this operation the tendon being grasped between the thumb and finger, it may be divided without fear of injuring the deeper parts. One then proceeds with the forcible manipulation until all resistance has been overcome, and until the lateral curvature in the cervical region has entirely disappeared. The head is then fixed in the attitude of extreme overcorrection by means of a plaster bandage. This should include the upper part of the chest and shoulders, circular turns being made about the head. It should remain in position for at least three weeks, and for a much longer time if the appliance is comfortable, and if it is not considered objectionable. After removal of the supporting bandage the head should be turned forcibly from time to time into the attitude of overcorrection, for the purpose of preventing recurrence of deformity; and systematic exercises should be employed to strengthen the muscles and to re-establish the normal poise.

The Open Operation.—In many instances, and especially in cases of long standing in older subjects, the open operation is to be preferred to tenotomy and forcible stretching. An incision, parallel to the sterno-mastoid muscle and half-way between its two insertions, is made, running upward from the clavicle about an inch and a half. Through this incision all the resistant bands are divided as they appear under tension. When all resistance to overcorrection has been removed, forcible manipulation is carried out and the head is fixed in the manner already described. This fixation is not always necessary in the treatment of older subjects.

It should be stated that when the deformity is of long standing, it may be impracticable to fix the head at first in the overcorrected position, because of the impairment of the circulation or because of the discomfort that it causes.

ACQUIRED TORTICOLLIS.—As has been stated, acquired torticollis is far more common than the congenital form. At least eighty per cent. of the cases begin during the first ten years of life.

The deformity may be divided into two main groups, the common form or so-called acute torticollis and the irregular forms.

Acute torticollis is a painful contraction secondary to injury or disease of the muscles, or to irritation of the peripheral nerves. As a rule, the sterno-mastoid and trapezius muscles are involved, but occasionally other muscular groups are affected. A common form of torticollis is the so-called rheumatic or stiff neck, in which the muscles of the neck are stiff and sensitive to pressure; this form hardly requires consideration.

By far the most important form of acute torticollis is that which often follows irritation of the peripheral nerves in the naso-pharynx or its neighborhood; thus it is often a sequel of tonsillitis, measles, diphtheria, and the like. It may be preceded by toothache or earache, and it is often accompanied by enlarged or suppurating cervical glands. The onset of the affection is gradual, often preceded by fever, and the head gradually assumes the characteristic attitude of torticollis, and is fixed by the tonic contraction of the affected muscles. Attempts to overcome the deformity cause great pain, as do unguarded movements. It is particularly difficult to place the head in a comfortable position when the child lies down; thus "getting the child to bed" is a troublesome task.

The patients often become extremely nervous, and it would appear that the affection is more common among children of the nervous type. As has been stated, the deformity is usually typical, the muscles affected being the trapezius and the sterno-mastoid. In rare instances the contraction may affect both sterno-mastoid muscles, so that the head is drawn forward and downward between the shoulders; or the posterior muscles may be involved and the head is drawn backward, so-called posterior torticollis. The muscles and other tissues become shortened. The pain and discomfort finally disappear and the case becomes one of chronic torticollis, although in the milder forms spontaneous recovery is possible.

Treatment.—The treatment is symptomatic and preventive. Support is always indicated. As an immediate application the neck may be enveloped in a heavy muff-like collar of cotton; this should reach from the shoulders to the ears, and should be of such thickness as actually to support the head. It is held in position by circular bandages, and it may be stiffened by layers of adhesive plaster. This provides heat and fixation, and for the early cases it is often an efficacious remedy.

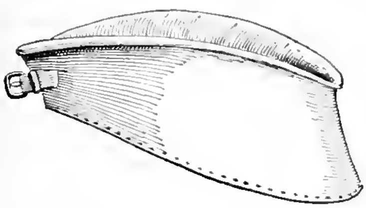


FIG. 4740.—The Thomas Collar. This apparatus is of service in the treatment of the milder cases of acute torticollis.

In most instances a more comprehensive support is indicated. Such a support is afforded by the plaster jacket and the jury mast; the elastic tension of the halter, if properly applied, will eventually overcome the spasm, and in great degree at least correct the deformity. This correction is further assisted by massage and by gentle manipulation of the head. When the spasm and deformity have been overcome, exercises to restore the ability of the weakened muscles may be employed. This treatment is particularly efficacious in those cases in which the muscular substance is involved by suppurating cervical glands. The duration of the treatment may be from several weeks to several months. If the deformity has persisted for more than six months operative treatment after the method described is, as a rule, indicated. It is evident, of course, that if acute torticollis is of secondary origin all sources of possible irritation should be looked for and treated if found; also that the general condition of the patient should receive attention.

IRREGULAR FORMS OF TORTICOLLIS.—*Spasmodic Torticollis.*—This is a form of convulsive spasm of the muscles of the neck resembling somewhat in its general characteristics writer's cramp. It is essentially an affection of adult life and is more common in individuals of a neurotic type. The onset is usually gradual, the first indications being sensations of stiffness and discomfort, drawing sensations, and twitchings of the head. When the affection is established there are at intervals spasmodic contractions of the affected muscles, which draw the head with a jerking motion into the attitude of extreme deformity. The spasm then relaxes, to recur at frequent intervals. These contractions may be painless, but in many instances the sensation is cramp-like. After a time deformity persists, the affected muscles becoming hypertrophied and structurally shortened.

Etiology.—Little is known of the etiology. Many of the patients present a neurotic family or personal history, and in certain instances constant or constrained attitudes in occupation, defective eyesight, and the like apparently induce the affection. There is little tendency toward spontaneous recovery.

Treatment.—The general condition of the patient should receive attention, and predisposing causes, such as occupation, should be avoided if possible. In mild cases massage, systematic exercise, and in some instances support in the form of a collar or light metallic brace may be of service. In confirmed cases resection of the nerves that supply the affected muscles seems to be the most effective remedy.

If the spasm is confined to the sterno-mastoid and trapezius muscles removal of a portion of the spinal accessory nerve may be sufficient. An incision is made along the anterior border of the sterno-mastoid muscle from the mastoid process to a point about one inch beyond the angle of the jaw. One then exposes by blunt dissection the transverse process of the atlas, which lies directly below the mastoid process. This is a valuable landmark because the spinal accessory nerve usually passes directly over it, or slightly in front of its most prominent part. Traction on the muscle will usually make the nerve prominent. If it is not readily found its position may be ascertained by drawing the finger nail across the bottom of the wound, a sharp contraction following pressure on the nerve. This having been isolated, a section, at least an inch long, should be removed. If the sterno-mastoid muscle is actually shortened, it should be divided and a portion of the trapezius also, if this resists the correction of the deformity. Fixation of the head is, as a rule, not required after the operation. In many instances the muscular spasm involves the other muscles of the neck. In such cases resection of the posterior branches of the upper cervical nerves, in addition to the complete division of the contracted parts, may be required.

In the ordinary operation an incision, about three inches in length, is carried downward from the occiput, parallel to and about one inch from the spinous processes. It is continued through the trapezius and complexus muscles, exposing the posterior branches of the nerves. Those of the three upper nerves are then resected. As has been stated, complete division of the muscles that are shortened accompanies the operation.

OTHER FORMS OF IRREGULAR TORTICOLLIS.—*Paralytic Torticollis.*—One or more of the muscles of the neck may be paralyzed, most often the result of an extensive anterior poliomyelitis. Isolated paralysis of the muscles is uncommon.

Diphtheritic Torticollis.—Paralysis of muscles may be a sequel of diphtheria, the trapezii muscles being most often involved. This allows a forward droop of the head. The diagnosis is usually apparent.

Posterior Torticollis.—The most common form of posterior torticollis is the so-called cervical opisthotonos which is often a symptom of cerebro-spinal or basilar meningitis. A slight degree of the same deformity is not uncommon in ill-nourished infants.

Rachitic Torticollis.—In the progressive stage of rachitis, in which the characteristic kyphosis is present in the lower part of the spine, the head may be tilted backward in compensation. Occasionally the attitude may be increased by slight spasm of the posterior muscle.

Ocular Torticollis.—In rare instances the head may be carried habitually in an attitude of lateral distortion to accommodate defective vision. This is, however, rather an improper attitude than a symptom of torticollis. The treatment of these uncommon and as a rule unimportant varieties of deformity does not require especial consideration.

Royal Whitman.

TOUCH. See *Skin, Functions of.*

TOXINS, TOXALBUMINS.—Toxins are poisonous synthetical products of bacterial growth.

The exact composition of toxins has not as yet been discovered, but it is believed that they are of proteid character. At first all the toxins were supposed to be albumins, but recently some of the most important, such as those produced by the tetanus and diphtheria bacilli, have been shown to possess characteristics which separate them from that class. Toxins are formed during the growth of bacteria in media containing no proteid, but more abundantly when it is present. Toxins are divided into extracellular and intracellular poisons. Thus, the toxins produced by the diphtheria and tetanus bacilli during their growth in the tissues or culture media are largely given up to the culture fluid, but little remaining in the bacterial protoplasm, while the toxins elaborated by the typhoid, tubercle, glanders, and colon bacilli, and indeed by the majority of parasitic and saprophytic bacteria, are largely retained in the bodies of the bacteria until their death and destruction.

Among the properties of the extracellular toxins are the following: They are so far as known uncrystallizable, and thus differ from ptomaïns; they are soluble in water and they are dialyzable; they are precipitated along with proteids by concentrated alcohol, and also by ammonium sulphate; if they are proteids they are either albumoses or allied to the albumoses; they are relatively unstable, having their toxicity diminished or destroyed by heat (the degree of heat, etc., which is destructive varies much in different cases). Their potency is often altered in the precipitations practised to obtain them in a pure or concentrated condition, but among the precipitants ammonium sulphate has little if any harmful effect. Regarding the intracellular toxins which are more intimately associated with the bacterial cell we know much less, but it is probable that their nature is similar, though some of them at least are not so easily injured by heat, *e.g.*, in the case of the product of tubercle bacilli. In the case of all toxins the fatal dose for an animal varies directly with the species, body weight, age, and previous conditions as to, *e.g.*, food, temperature, etc. In estimating the minimal lethal dose of a toxin these factors must be carefully considered.

The following is the method usually employed for obtaining concentrated extracellular toxins. The toxic fluid is placed in a shallow dish, and ammonium sulphate crystals are well stirred in till no more dissolve. Fresh crystals to form a bulk nearly equal to that of the whole fluid are added, and the dish is set in an incubator at 37° C. (98.6° F.) over night. Next day a brown scum of precipitate will be found floating on the surface. This contains the toxin. It is skimmed off with a spoon, placed in watch-glasses, and these are dried in vacuo and stored in the dark, also in vacuo, or in an exsiccator containing strong sulphuric acid. For use, the contents of one are dissolved up in a little normal saline solution.

The comparison of the action of bacteria in the tissues in the production of these toxins to what takes place in the gastric digestion has raised the question of the possibility of the elaboration by these bacteria of ferments by which the process may be started. It would not be prudent to dogmatize as to whether the toxins do or do not belong to such an ill-defined group of substances as the ferments. It may be pointed out, however, that the essential concept of a ferment is that of a body which can originate change without itself being changed, and no evidence has been adduced that toxins fulfil this condition. Another property of ferments is that, so long as the products of fermentation are removed, the action of a given amount of ferment is indefinite. Again, in the case of toxins no evidence of such an occurrence has been found. A certain amount of a toxin is always associated with a given amount of disease effect, though a process of elimination of waste products must be all the time going on in the animal's body. Again, too much importance must not be attached to loss of toxicity by toxins at relatively low temperatures. Many proteids show a tendency to change at such temperatures; for instance, if egg albumen be kept long enough at 55° C. nearly the whole of it will be coagulated. Such considerations suggest that the relation of toxic action to fermentation must be left an open question.

Similar Vegetable and Animal Poisons.—Within recent years it has been found that the bacterial poisons belong to a group of toxic bodies all presenting very similar properties, other members of which occur widely in the vegetable and animal kingdoms. Among plants the best-known examples are the ricin and abrin poisons, obtained by making watery emulsions of the seeds of the Ricinus communis and the Abrus precatorius (jequirity) respectively. The chemical reactions of ricin and abrin correspond to those of the bacterial toxins. They are soluble in water, they are precipitable in alcohol, but being less easily dialyzable than the albumoses they have been called toxalbumins. Their toxicity is seriously impaired by boiling, and they also gradually become less toxic on being kept. Both are among the most powerful poisons known, ricin being the more fatal.

It is also certain that the poisons of scorpions and of poisonous snakes belong to the same group. The poisons derived from the latter are usually called venins, and a very representative group of such venins derived from different species has been studied. To speak generally, there is derivable from the natural secretions of the poison glands a series of venins which have all the reactions of the bodies previously considered. Like ricin and abrin, they are not so easily dialyzable as bacterial toxins, and therefore they have also been classed as toxalbumins. While up to the present we have not been able to discover the exact chemical composition of any toxin, or even to obtain it in a pure state, many interesting facts upon the nature of toxins have been discovered by physiological methods.

From a large number of most carefully conducted experiments with the toxin and antitoxin of diphtheria, Ehrlich has formulated a theory concerning the constitution of the former. This theory has undergone several modifications since it was first proposed, and it is difficult to give an exact statement of it as it now stands. However, we will attempt to state in condensed form its essential points as follows:

Toxins and antitoxins neutralize one another after the manner of chemical reagents. The chief reasons for this belief lie in the observed facts: (*a*) that neutralization takes place more rapidly in concentrated than in dilute solutions; and (*b*) that warmth hastens and cold retards neutralization. From these observations Ehrlich concludes that toxins and antitoxins act as chemical reagents do in the formation of double salts. A molecule of the poison requires an exact and constant quantity of the antitoxin in order to produce a neutral or harmless substance. This implies that a specific atomic group in the toxin molecule combines with a certain atomic group in the antitoxin molecule.

The toxins, however, are not simple bodies, but easily split into other substances which differ from one another in the avidity with which they combine with antitoxin.

These derivatives Ehrlich calls prototoxins, deuterotoxins, and tritotoxins.

All forms of toxins are supposed to consist of two modifications, which combine in an equally energetic manner with antitoxin or with suitable receptors in the cells, but differ in their resistance to heat and other destructive agents.

The less resistant form passes readily into a toxoid substance which has the same affinity for the antitoxin or the cell receptors as the original toxin, but is not poisonous. The facts observed, Ehrlich thinks, are best explained on the supposition that the toxic molecule contains two independent groups of atoms, one of which may be designated as the haptophorous and the other as the toxophorous group. It is by the action of the haptophorous group that toxin unites with antitoxin or the sensitive cell molecule.

The toxophorous group is unstable, but after its destruction the molecule still unites with the antitoxin or the sensitive molecule through its retained haptophorous group.

Specific antitoxins can be produced not only with toxins but with toxoids.

Bordet believes, in contradistinction to Ehrlich, that toxin unites in different multiples with antitoxin, so that the toxin molecule may have its affinities slightly, partly, or wholly satisfied by antitoxin. Slightly satisfied, it is still feebly toxic; combined with a larger amount of antitoxin it is not toxic, but still may, when absorbed into the system, lead to the production of antitoxin. Fully saturated, it has no poisonous properties and no ability to stimulate the production of antitoxin.

The most important of the extracellular toxins are those produced by the diphtheria and tetanus bacilli. These are very powerful, 0.0000001 gm. of the dried filtrate of a tetanus culture will frequently kill a white mouse, while one-tenth of that amount of dried diphtheria filtrate has killed a guinea-pig.

According to Madsen and Ehrlich the specific tetanus poison consists of two toxins, tetanospasmin and tetanolysin. To the first of these the tetanic convulsions are due, while the second has a hæmolytic action.

When the tetanus toxins are placed in the blood tetanolysin largely combines with the blood, while the tetanospasmin combines with the nerve cells. Each of these substances produces in animals a specific antitoxin. To obtain diphtheria and tetanus toxins for injection in animals the bacilli are grown in slightly alkaline beef broth for from seven to ten days. The broth is then filtered and preserved. Tetanus toxin is produced under anaërobic conditions, diphtheria toxin under free access of oxygen.

The bacterial poisons which reside in the bodies of the bacteria are mostly extracted only after the death of the organisms. Here in the invaded animal the disease effects are more closely associated with the actual presence of the bacteria in the vicinity than in the case of the extracellular toxins. Antitoxic sera, prepared from injecting animals with the filtrates of these bacteria, do not produce marked immunity in injected animals to infection with the living bacteria.

Tuberculin and mallein are mixtures of the bacterial poisons produced by the tubercle and glanders bacilli. Tuberculin is prepared from a fully developed culture of tubercle bacilli grown on meat broth containing five per cent. of glycerin. This is evaporated to one-tenth of its volume over a steam bath. Injected into tuberculous animals it causes a marked reaction in the infected tissue with constitutional disturbances and a rise of temperature.

Mallein is prepared in the same way from old cultures of the glanders bacillus. Injected into animals infected with glanders, it causes swelling and heat in the healthy tissues into which the mallein has been injected. Marked general disturbance and a rise of temperature of 3° to 5° F. usually follow. Typhoid, dysentery, colon, and many other bacilli and cocci contain intracellular toxins.

William H. Park.

TRACHEOTOMY.—(*Bronchotomy, Laryngotomy, Thyrotomy*, etc.) The term tracheotomy is used in general to signify an opening made from without into the windpipe in any part of its course. The term bronchotomy, originally and more properly used in this sense, has gradually fallen into disuse, and is now rarely met with. The term tracheotomy, in its exact sense, is applicable only to an opening made into the trachea proper; while thyrotomy, cricotomy, and laryngotomy, singly or in combination, may be used to describe openings made into the larynx only, and laryngo-tracheotomy and cricotracheotomy those involving both larynx and trachea.

Indications.—The object of a tracheotomy may be either to furnish a new aperture for the respiratory current, when the natural one is no longer sufficient, or to afford access to the interior of the tracheal canal for local therapeutic purposes, or for the removal of foreign bodies lodged within it. In these cases it is a remedial measure. In addition, it may be indicated also as a preventive measure, as a preliminary to some surgical operations involving the cavity of the nose, pharynx, or larynx, to render possible tamponade of the larynx, and to facilitate the administration of anæsthetics.

Any affection, laryngeal or supralaryngeal, which is causing or threatening asphyxia, is an indication for remedial tracheotomy. These conditions may be classified into: (1) Traumatic conditions; (2) inflammatory conditions; (3) neuroses; (4) neoplasms.

Some consideration of each of these classes is necessary:

I. Traumatic Conditions.—The first under this head come *wounds of the larynx*. When, as the result of such a wound, blood is flowing abundantly into the trachea, and hæmostasis by ordinary means cannot readily and speedily be accomplished; also, when the wound has partially severed the epiglottis so that it falls upon and occludes the glottic orifice—in these cases immediate opening of the trachea is imperative. Tracheotomy may also become necessary later in the history of a wound of the larynx in consequence of infiltration of the submucous laryngeal connective tissue, and of the epiglottic folds, by blood, serum, pus, or air, causing the symptoms of œdema glottidis. Glottic emphysema, demanding tracheotomy, may be caused by extension of a general emphysema of the neck, when inadequate means to relieve such emphysema have been employed, but it is more frequently a localized air infiltration of the aryteno-epiglottic folds from a penetrating wound of the larynx with contracted external opening. Local scarifications of the tumefied tissues, whether caused by fluid or by air infiltration, practised through the mouth, may suffice to afford relief in some cases, when time and opportunity can be had for them; but in all cases in which the suffocative symptoms are urgent or the conditions are not favorable for making such local scarifications, immediate tracheotomy should be done. In these cases it would also be justifiable for a person provided with the necessary instruments, and skilled in their use, to try intubation after the method of O'Dwyer.

Burns of the larynx and pharynx, the result of swallowing hot fluids or caustic agents, or of the inhalation of steam, are liable to be followed by œdema sufficiently great to require tracheotomy.

Fractures of the larynx are likely to involve conditions making tracheotomy necessary. Displacement of the cartilages may in itself produce sufficient occlusion to become an indication. Consecutive œdema may result, as in the case of incised and punctured wounds of the larynx above considered; phlegmonous purulent infiltration is likely to develop; blood infiltrations are to be expected; in some instances paralysis of the glottic dilators, from injury to the laryngeal nerves or their compression by displaced cartilages or inflammatory effusions, may supervene—any of these conditions indicate tracheotomy.

Cicatricial contractions may result from loss of substance attending any of the above-mentioned traumatisms of the larynx, and may produce stenosis of a high degree. More or less occlusion may also result from adhesions between soft parts following the cicatrization of wounds of the larynx or trachea, and from the healing in abnormal situations of displaced cartilaginous fragments or flaps of soft tissue. In either of these conditions tracheotomy is indicated as soon as any considerable embarrassment in breathing is experienced; it serves both for the relief of the dyspnœa and to facilitate measures for the dilatation of the stricture. Intubation may, however, be substituted for tracheotomy in some of these cases.

In all cases of *foreign bodies in the air passages* in which suffocative symptoms persist, and are urgent or frequently recur, and in which the foreign body cannot be speedily and readily removed through the mouth, immediate incision of the trachea is imperative. In a very large proportion of cases the first violent spasms of dyspnœa provoked by the entrance of the foreign body soon subside and a period of calm follows, which may, indeed, last indefinitely. To be able to operate during such a period of calm is highly desirable, for it can then be done with deliberation and with proper attention to those precautions which will prevent the operation itself from adding any new dangers to those already present. The present absence of urgent symptoms should not induce the surgeon indefinitely to postpone operation, in the hope that spontaneous expulsion may occur, notwithstanding the frequent instances in which such spontaneous expulsion is finally effected, for the foreign body is a constant menace to life as long as it remains in the air passages, and is liable to produce sudden death at any time, even in the act of expulsion. Should the dangers of death by asphyxia be escaped, the later development of localized infective disturbances from the presence of the foreign body is inevitable.

Asphyxia from the abundant *entrance of blood, vomited matters, or fluids of any kind into the air passages* calls for tracheotomy and artificial respiration, together with the use of means to free the air passages from the foreign matter that embarrasses the respiration. Asphyxia from the entrance of blood is always to be guarded against in the course of operations about the cavities of the mouth and nasopharynx, when full anaesthesia is required, and every arrangement for immediate tracheotomy should be at hand in those cases in which a deliberate preliminary tracheotomy is not deemed advisable. A person attacked by vomiting while in a state of unconsciousness is in great danger that portions of the vomited material may enter the air passages. The accident of being drowned in one's own vomit is by no means infrequent. It is to be watched for in all cases in which general anaesthesia is induced, and when it occurs demands immediate incision of the trachea and the quick employment of energetic means to free the air passages from the obstructing material. The incision into the trachea not only supplies a new, more direct, and free opening for the entrance of air and facilitates the emptying of the air passages by the compressions used in carrying on artificial respiration, but it affords an opportunity readily to introduce instruments for cleansing the passages. Little can be accomplished in such cases by suction through tubes of any kind; but, by the forcible blowing of air into the lungs through a catheter or other suitable tube introduced through the tracheal wound, the ejection of fluids and semisolids from the air passages by the return current of air may be quickly and readily accomplished.

II. Inflammatory Conditions.—Stenosis of the larynx of such severity as to demand tracheotomy may arise in the course of any of the inflammatory conditions to which the larynx is subject.

In the course of an attack of *acute catarrhal laryngitis*, the rapid development of symptoms of severe dyspnœa, which are not relieved by an emetic or other antispasmodic treatment, indicates the supervention of œdematous infiltration of the aryteno-epiglottic folds and of the epiglottis. The suffocative symptoms produced by this condition may early become so immediately urgent that no opportunity for the use of ordinary therapeutic means is presented, and prompt surgical interference is the only possible thing that can avert a speedily fatal issue. In other cases a more gradual development of the œdema gives time for the employment of remedies, and many of these cases, though in great apparent danger for some time, ultimately end in spontaneous recovery.

Scarification of the supraglottic œdematous tissue has been successful in relieving some of these cases, and in yet others intubation has likewise sufficed to avert danger. But tracheotomy must remain the resource most frequently available to the practitioner who may neither himself have the special technical dexterity in throat manipulations required satisfactorily to practise the last-mentioned operations nor be able to call to his aid others who may have it.

The results of tracheotomy, when done for the relief of acute inflammatory occlusion of the glottis, are very encouraging, and, when the operation is done with the precautions and after-cares to be described further on, very little, if any, additional hazard is added to the case by its employment.

In acute laryngitis the parts below usually remain comparatively unaffected, and after the relief to the obstructed respiration has been afforded by the tracheal incision, the laryngeal inflammatory swelling so quickly subsides that the tube need be retained but a few days. The operation itself contributes to the shortening of the primary laryngitis by putting the affected parts at rest, and removing the source of irritation existing previously in the to-and-fro respiratory current.

The question of chief importance to the physician who is charged with the responsibility of the care of an acute laryngitis is, What degree of urgency must the suffocative symptoms attain to justify him in opening the trachea? He certainly should not wait until the patient is *in extremis*, nor should he be precipitate in action, for spontaneous recovery from very threatening conditions is not rare. At the same time, he is not to consider so much the idea as to whether the patient may not possibly recover without operation as he is to decide whether his chances of recovery will be made greater by the operation.

Tracheotomy is to be accepted as one of the therapeutic resources at the command of the physician for the relief of dyspnœa from laryngeal obstruction, and when the dyspnœa is sufficiently great and prolonged to produce serious suffering, or much exhaustion, the operation is justifiable. The personal element of the skill and experience in the operation of the physician himself must also come into the equation, for, if the dangers inherent in the operation are great, it would be improper to subject a patient to them unless the dangers that were to be averted by the operation were already unmistakably greater and more imminent. Tracheotomy, while often a simple procedure, at times develops conditions that tax to the utmost the coolness, adroitness, and command of resources of the most experienced surgeon. One who is thoroughly provided to control these difficulties would be justified in offering the operation as a means of relief in circumstances less urgent than one without these qualifications.

Loss of voice, frequent thin, metallic, muffled cough, difficult inspiration and prolonged expiration, the suprasternal and epigastric tissues sinking in at each inspiratory effort, great restlessness, suffusion of the face with bluish lips—these are symptoms that, if continued, will produce speedy exhaustion; but in many cases of acute catarrhal laryngitis much of this respiratory difficulty is due to glottic spasm, which may be controlled by treatment, or may spontaneously disappear. If the severe symptoms of dyspnœa are intermittent, if they are lessened in severity and in frequency by treatment, if the general prostration is not great, and if the lethargy denoting advancing defective oxidization of the blood is not marked, tracheotomy should be deferred.

When, on the other hand, the dyspnœa is continuous, and is gradually and steadily increasing despite treatment, especially when symptoms of exhaustion are developing—as shown by pallor of the face, with cold perspiration—and when the benumbing effects of defective aëration of the blood are manifesting themselves—as shown by a tendency to lethargy replacing previous restlessness—then tracheotomy should be resorted to without further delay.

Pseudomembranous Laryngitis.—Of all the causes which may possibly determine dyspnœa of sufficient gravity to require tracheotomy for its relief, the accumulation of a membraniform exudate upon the surface of the laryngeal mucous lining is the most frequent. When the accumulation of such a laryngeal exudate is secondary to, or synchronous with, the same formation within the pharynx or upon the tonsils, early recognition of the cause of the laryngeal symptoms is made; when the earliest manifestation of the exudate is within the larynx, a not infrequent occurrence, the condition cannot be distinguished with certainty from that attending acute catarrhal laryngitis in its severer forms; it is only when, in the progress of the case, membraniform fragments become detached and are expectorated, or a membraniform exudate forms in the pharynx or fauces also, or the presence of the exudate is demonstrated by incising the trachea, that an absolute diagnosis can be made. It is a common error to assume that severe and continuous dyspnœa arising in the course of acute inflammatory affections of the larynx is due to a membraniform exudate, and to denominate the case "membranous croup." This assumption has given rise to many erroneous conclusions as to the value of medicinal treatment in cases of so called membranous croup, for the catarrhal inflammation is much more amenable to medicinal agents than is the exudative. As long, however, as any doubt about the exact character of the case exists, it is wiser, from the standpoint of treatment, to assume that the more intractable disease is present and to guide the treatment accordingly. Such a principle of action will lead to an earlier resort to tracheotomy than would otherwise be the case. If the practitioner has positive evidence, or provisionally accepts the conclusion, that the larynx is becoming blocked by membraniform exudate, his course of action will also be likely to be influenced by his opinion as to the diphtheritic or non-diphtheritic character of the exudative process.

As to the possibility of the development, upon the surface of the laryngeal mucous membrane, of a membraniform exudate not due to diphtheritic infection, there is considerable evidence, consisting chiefly in the undoubted occurrence in localities of cases of membranous laryngitis at rare intervals during a long period of years before the prevalence of diphtheria in that locality.

If such non-diphtheritic cases formerly occurred they may doubtless still occur; but abundant observation has demonstrated that, clinically, it is impossible to distinguish such cases at the present time, and that the symptoms tabulated by systematic writers for establishing the differential diagnosis between the two classes of cases are entirely unreliable, and their importance quite imaginary. The occurrence of membranous laryngitis in any community at the present time is always associated with the prevalence of other forms of diphtheria.

Practically all considerations as to the treatment of pseudomembranous laryngitis resolve themselves into that pertaining to laryngeal diphtheria, and as such I shall consider them in what I may have to say further. The proportion of recoveries from laryngeal diphtheria, without tracheotomy, was exceedingly small, less than ten per cent., before the introduction of the use of diphtheritic antitoxin in the treatment of diphtheria. Present experience indicates that fifty per cent. of such patients may now be expected to recover under the antitoxin treatment without operative interference. The addition of intubation has still further reduced the mortality, so that now about two-thirds of intubated, antitoxin-treated cases end in recovery. The proportion of recoveries in tracheotomized-antitoxin-treated cases is about the same. Of 5,004 intubation-antitoxin cases gathered by Siegert from the records of hospitals for children on the continent of Europe for the period 1890–98 the mortality was 32.4 per cent.; of 6,942 tracheotomized-antitoxin cases the mortality was 32.5. Since, however, tracheotomy is usually resorted to in a more severe class of cases, and at a later date than is intubation, the therapeutic value of tracheotomy would seem to be distinctly greater than that of intubation, which should be preferred only in cases of slight intensity, in cases in which the special cares required after tracheotomy cannot be secured, as well as in those in which the consent of parents to tracheotomy cannot be gained.

The progress of a case from the first inception of symptoms of hoarseness and slight embarrassment of breathing to the termination in death is usually rapid. Out of 1,760 cases of fatal croup in the city of Brooklyn, in children less than five years of age, 57 per cent. died within three days from the onset of the croupy symptoms, 159 died within twenty-four hours, and 22 died within twelve hours. Much time for deliberation is therefore not to be relied upon.

In addition to the exhaustion produced by the unintermitting violent efforts to respire, the deficient blood oxygenation, and the continued depressing effect of the diphtheritic poison, the surgeon must also take into consideration the damage likely to be inflicted upon the lungs themselves during prolonged unrelieved dyspnœa. Pulmonary emphysema and œdema, and diffused capillary hyperæmia, with subsequent bronchial catarrh, result from prolonged dyspnœa, and from complications hindering recovery, should the dyspnœa finally be relieved by tracheotomy. Tracheotomy tends to prevent death in diphtheritic laryngitis by making possible free access of air to the lungs, and thus: (1) Relieving or preventing carbonic-acid poisoning and its sequelæ; (2) supplying the blood freely with the best of stimulants and tonics—oxygen—by which act it assists in the struggle to eliminate the special blood poison, and favors the limitation of the disease; (3) at once ending the cupping-glass action exerted upon the whole surface of the respiratory tract below the larynx by the inspiratory struggles, a result which lessens the danger of the occurrence of diffuse catarrh of the air passages, of pneumonia, and of pulmonary œdema, and promotes recovery from these conditions when not already too extensively developed; (4) rendering respiration free and easy, in consequence of which exhaustion from excessive muscular exertion is either prevented or—if already present—is in some measure relieved.

It tends to prevent death by eliminating from the possible causes of death œdema glottidis, and occlusion of the glottis by a piece of loosened membrane, through the establishment of an opening for the entrance of air at a point between the glottis and the lungs. It prolongs life, and thus gives increased opportunity for the action of remedies, and for a rallying of the powers of nature sufficient to throw off the disease.

By tracheotomy the surgeon is given ready access to the interior of the trachea, and is enabled to remove at once from it any masses of detached exudate that may be present, as well as the abundant pultaceous secretion formed by the mixture of membranous débris and muco-pus which often accumulates below the membrane proper, and is liable to be sucked back into the finer bronchial ramifications, blocking them up and carrying infection to the deepest parts of the lung tissue.

Through the tracheal opening local medication of the trachea and larger bronchia is facilitated, a more direct and accessible way being provided for the introduction of sprays and solutions, forceps and swabs, as the after-course of the disease may require.

The choice of the point at which the trachea is to be opened should also be controlled by the facility with which intratracheal examination and treatment may be carried on through the incision. Without question an incision at some point below the thyroid isthmus gives the surgeon the most advantage in this respect, and for this reason should be chosen, notwithstanding that it demands more care and anatomical knowledge for its safe performance than an incision above the isthmus.

When the one indication for tracheotomy is present, viz., laryngeal stenosis to such a degree as to be a source of danger either directly or indirectly, there can be no contraindication to the operation. Whatever the degree of septicæmia, if the stenosis is great enough materially to intensify it, the operation should still be done.

Coexisting pneumonia, bronchitis, exhaustion, even apparent death, instead of contraindicating, do the more distinctly indicate it. These and other complications render the prognosis more grave, but do not justify a refusal to operate. The literature of the subject abounds in instances in which, despite the gravest complications, recovery has been secured.

Laryngeal tuberculosis, syphilitic disease of the larynx, phlegmonous inflammation of the pharynx or of other structures in the vicinity of the larynx, and chronic hyperplastic laryngitis may each produce such a stenosis of the air passage as to necessitate opening of the trachea for its relief. More rarely spasm or paralysis of the muscles of the larynx may determine a dyspnœa so serious and prolonged as to become an indication for tracheotomy.

Neoplasms may become the cause of an indication for tracheotomy either by pressure from without, as in goitre, or by blocking up the air duct from within, as in carcinoma and papilloma.

Tracheotomy as Preliminary or Adjunct to Other Surgical Procedures.—The preliminary opening of the trachea, and the use of appropriate means to tampon the pharynx or the trachea, and thus to prevent the entrance of blood into the air passages in the course of surgical operations involving the cavities of the nose, mouth, and pharynx, commends itself as a device of great value, and worthy of being assigned an important place in the technique of bloody and prolonged operations in the regions stated.

For a full description of the anatomy of the anterior median region of the neck the reader is referred to the article on *Neck* in Vol. VI., and to that on *Tracheotomy* in the first edition of this HANDBOOK.

ANATOMICAL CONSIDERATIONS.—In the performance of the operation of tracheotomy it is highly important that the surgeon keep in mind the anatomical details of the region in which he operates, both as a guide to the successive steps of the operation and as a monitor to cause him to be prepared beforehand for the exigencies likely to arise during its course.

The vascular conditions in the pretracheal space vary so much that the greatest caution should be used in attempting to approach the trachea through it. There is no line of safety to be preserved. Whatever freedom from other complications may be present, the presence at least of an important venous plexus, covering the trachea in the middle line, will demand special precautions for its avoidance, except in occasional instances.

The loose character of the connective tissue which fills the pretracheal space permits great mobility to the trachea both vertically and from side to side. To this mobility is due the mischance, which has happened to some operators, to miss the trachea altogether, by reason of its having been pulled to one side from the line of incision, and to continue their dissection until arrested by the vertebral column. This lax connective-tissue envelope also permits the burrowing of the tube in front or at the side of the trachea when unskilful or hasty attempts at its introduction are made while the lips of the tracheal incision are not properly retracted, and the field of operation is covered with blood. This tissue also favors the burrowing of pus downward into the anterior mediastinum in certain cases.

The cricoid cartilage, being the most easily and certainly identifiable point along the laryngo-tracheal tube from the outside in children, becomes the most important landmark in the anterior median region of the neck by which to determine the first incisions for tracheotomy. If laryngo-tracheotomy, or tracheotomy through the upper rings by depressing the isthmus, is chosen, the cricoid prominence should fall midway in the incisions; if the low operation is to be done, the incision, beginning above over the cricoid, should extend downward from it to the sternum.

THE DIFFERENT LARYNGO-TRACHEAL INCISIONS.—According to the indications which a special case may present, the air tube should be opened at a higher or a lower point of its course. Operations which involve incision through some part or all of the larynx come under the general class of laryngotomy; those involving the trachea alone, under that of tracheotomy; those involving both, under that of laryngo-tracheotomy.

LARYNGOTOMY.—Incision of the larynx may be partial or total. If it involve only the thyroid cartilage, it is designated as thyrotomy; if the cricoid cartilage, cricotomy; if the cricothyroid membrane, intercrico-thyrotomy.

Laryngotomy is indicated whenever it is necessary to gain access to the cavity of the larynx for the relief of conditions that resist operative attacks through the mouth. These conditions include impacted foreign bodies, certain wounds of the larynx, strictures, some cases of acute perichondritis for removal of necrosed cartilages, and, lastly, tumors of the larynx. Intercricothyrotomy and cricotomy may be resorted to for the relief of urgent and sudden suffocative symptoms that demand haste. The extent and the superficial position of the crico-thyroid membrane in adults, and the ease with which its position may be recognized just above the rigid and prominent cricoid ring, render its opening by a quick plunge of a knife, in cases of emergency, easy and comparatively safe, even in inexperienced hands.

In general, it may be said that section of the thyroid cartilage is to be avoided if the necessary end can be gained by a section restricted to the lower structures of the larynx, because of the subsequent impairment of the voice which must follow the cicatricial agglutination of the anterior part of the vocal bands, which is inevitable to some extent after thyrotomy. The conditions of each case must, of course, determine the decision of the operator at the time as to the extent of the division of the laryngeal structures which he must make. Division of the crico-thyroid ligament and of the cricoid cartilage will be found sufficient for the removal of many laryngeal polypi and subglottic growths; dislocated fragments, in cases of fractures of the cartilages of the larynx, may be reached and manipulated into position through such an incision; necrosed cartilaginous fragments and impacted foreign bodies may likewise be removed thereby. If more room is desired than the partial laryngotomy affords, the prolongation downward of the incision through as many of the upper rings of the trachea as is necessary may suffice, and is to be preferred to total splitting of the thyroid. When, as the result of the condition for which the operation is to be performed, the vocal apparatus has already been irretrievably damaged, the surgeon may split the thyroid cartilage throughout its whole extent without hesitation, if it may seem desirable in order to render his work more facile and radical.

TRACHEOTOMY.—Incisions of the trachea are classified according to their relation to the isthmus of the thyroid gland. If above the isthmus, the incision is tracheotomia superior, or the high operation; if below, it is tracheotomia inferior, or the low operation; if behind the isthmus, it is tracheotomia media, or the middle operation.

Superior Tracheotomy.—The first ring of the trachea being the only one usually exposed above the isthmus, it is evident that sufficient room for a satisfactory opening into the air tube can be gained only by drawing the isthmus down so as to expose the rings behind it, or by extending the cut upward through the cricoid cartilage. In young children the softness and elasticity of the cricoid make easy its incision and the separation of the parts so as to admit of the introduction of a cannula. The high operation, therefore, is to be considered a crico-tracheotomy. Such an operation has a very considerable field for its employment. In general, whenever the air tube must be opened in haste, or by an inexperienced operator, the high operation is to be chosen. The operative difficulties are less, the parts are more superficial, there is less likelihood of the field being occupied by blood-vessels which would embarrass the operation by being wounded. In young children the cricoid cartilage is the most prominent and easily identified structure of the air tube, and presents a landmark which can be recognized quickly, and as quickly and certainly exposed by the knife of the surgeon. When the imminence of suffocation is such as to demand haste in opening the trachea, every other consideration must for the time be held in abeyance; the dangers of hemorrhage and the relative advantage in the after-history of the case of this or that point of incision into the trachea have to be disregarded. Crico-tracheotomy is the operation to be done under such circumstances, on account of the reasons just given.

Median Tracheotomy.—An incision into that part of the trachea usually covered by the isthmus of the thyroid gland constitutes median tracheotomy. The trachea may be exposed at this point either by pulling it down from above, after loosening its attachments, or by cutting directly through the overlying isthmus. In occasional instances the isthmus is wanting altogether, in which cases the median incision becomes a very simple matter. In cases in which, from the shortness of the neck, the existence of large blood-vessels overlying the trachea immediately below the isthmus, the unusual development of the isthmus, or from the persistence of the thymus gland, the exposure of the trachea below the isthmus is difficult or extra hazardous, the median incision is to be chosen.

Inferior Tracheotomy.—In most of the conditions for which tracheotomy is required the low incision is preferable. In stenosis from diphtheritic laryngitis, in cases of foreign bodies in the air passages (unless there is good evidence that the body is fixed in the larynx or high up in the trachea), in many cases of chronic laryngeal disease, in cases of stenosis of the trachea, and in cases of preliminary opening of the trachea to facilitate operations upon the larynx, it is desirable to make the opening into the trachea at some distance below the larynx. The recession of the trachea from the surface, and the plexus of blood-vessels in the deep pretracheal space overlying the trachea, make the operation more delicate, and one requiring more deliberation and experience for its proper and safe performance than the higher operations, but with care and attention to the special operative details which the particular conditions of the region demand, the trachea below the isthmus may generally be easily, expeditiously, and safely exposed.

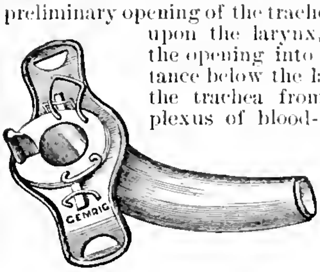


FIG. 4741.—Tracheal Cannula. Ordinary model.

OPERATIVE TECHNIQUE ; INSTRUMENTS.—The list of instruments which experience has shown me to be desirable to have at hand to facilitate the various steps of a tracheotomy comprises a small scalpel; a small, probe-pointed, curved bistoury; a director; a half-dozen pairs of hæmostatic forceps; two pairs of anatomical forceps; suitable retractors for depressing the suprasternal tissues and for elevating the isthmus; an aneurism needle for possible use in ligating the isthmus; a small, sharp, double hook for fixing and steadying the trachea when it is about to be incised; a pair of blunt double-hook retractors for dilating the tracheal wound; a pair of curved forceps for introduction into the trachea, and, finally, a tracheal cannula. Equipped with these instruments, the surgeon will find himself prepared to cope with any emergency likely to arise in the course of the operation, and by their proper use he can make himself to a great degree independent of assistants.

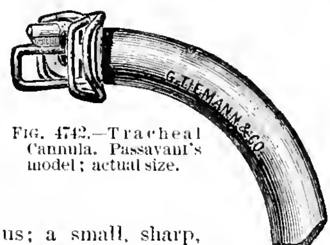


FIG. 4742.—Tracheal Cannula. Passavant's model; actual size.

The Cannula.—In most instances in which tracheotomy has been done, some kind of a cannula will be found indispensable in the after-treatment of the case, to prevent the premature closure of the new respiratory orifice. The model which in general gives best satisfaction is a curved double tube, approximating the quadrant of a circle, which is loosely attached at its outer end to an expanded shield-like plate, to which tapes may be fastened to secure it in place. When this plate is fixed, the tube in the trachea is allowed to move to a considerable extent, to accommodate itself to the movements of the parts. Fig. 4741 shows the cannula as usually found in the instrument shops.

The Material for the Tube.—Silver or aluminum is preferable as the material to use in making the tubes. Hard rubber is objectionable because of the necessarily greater thickness of the walls, which is secured at the expense of the lumen of the tube. Time and use also render the rubber brittle, so that the danger of the tube breaking away from the shield and slipping down into the trachea is created.

For general use four sizes of tubes are desirable, differing in their calibre and curve; and of each size, two different lengths. Let these sizes be denoted respectively by the letters A, B, C, and D, and their dimensions may be presented in tabular form as follows:

MEASUREMENTS FOR TRACHEAL CANNULÆ.

Number of size.	Outside diameter of the outer tube.	Length of the Tube Measured upon its Concave Side from Posterior Surface of Shield to Lower End. Short.	Long.	Radius of the concave side of the tube.
A	5.0 mm.	30 mm.	36 mm.	19 mm.
B	6.5 "	30 "	36 "	21 "
C	8.0 "	40 "	50 "	24 "
D	10.0 "	40 "	50 "	29 "

The shield of the tube should be as narrow as possible, that it may neither embarrass flexion and extension of the head, nor cover too much the wound. The form shown in Fig. 4741 is not so desirable as the one shown in Fig. 4742, in which the lock for securing the inner tube is set at the side instead of at the top, as in the ordinary model.

The lower end of the tube should have both its anterior and posterior walls slightly cut away, as shown in Figs. 4742 and 4743; and this lower end of the inner tube should project slightly beyond the outer tube when pushed fully down into its place. A suitable obtunder, slightly projecting from the lower aperture of the inner tube, is desirable for use during the after-treatment of a case of tracheotomy. Its use facilitates the reintroduction of a tube, and diminishes to a minimum the dangers of excoriations and lacerations which are often produced by attempts to introduce without such aid a tube through a partially collapsed channel.

The fenestra, which is commonly put at about the centre of the convexity of the outer tube, is usually undesirable and should not be present in the ordinary tube. Where it is commonly placed it lies partly outside of the lumen of the trachea and permits the soft tissues lining the cannula sinus to press into it whenever the inner tube is removed, so that often, when the inner tube is replaced, it shaves off a slice of the protruding granulations. Its supposed value in facilitating the early appreciation of ability to breathe through the glottis is fanciful.

ANÆSTHETICS.—Except in cases in which more or less complete insensibility is already developed from asphyxia an anæsthetic should be given. But little will usually be required, and it need not be pushed to the full degree considered desirable for most surgical operations. Chloroform is to be preferred, as less irritating to the air passages, and especially because its dosage and its effects can be more readily and exactly regulated.

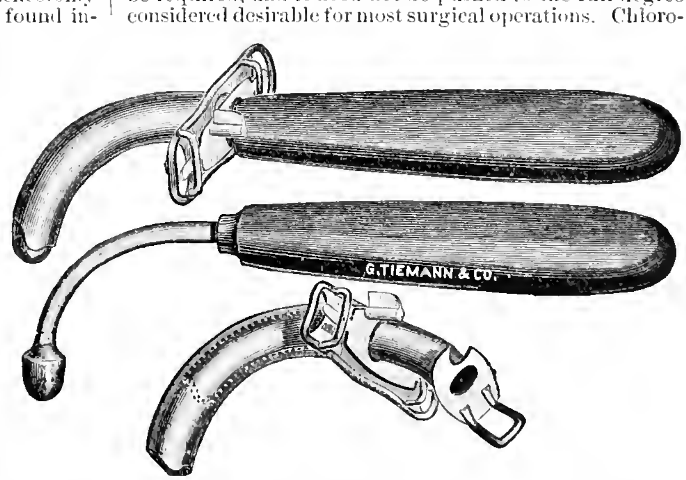


FIG. 4743.—Showing the Relation of the Inner Tube and of the Obtunder to the Tracheal Cannula.

PREPARATIONS FOR THE OPERATION.—*The Table.*—A suitable surface on which to place the patient is the first requisite. It should be high enough to make the surgeon's work convenient, and hard enough to keep the patient's shoulders from sinking down into it. Under no circumstances should the operation be undertaken with the patient lying in bed or in a crib. An ordinary dining or kitchen table answers well. The top of a bureau, if it is not too high, I have repeatedly made use of.

Light.—The more light the better; but usually the surgeon has no choice, and he must make use of what he can get. If the operation is by daylight, the table should be brought close to a window, so that it shall be between the latter and the operator. If the operation is in the night, the lamps and candles must be arranged and held so as especially to illuminate the field of operation. A single candle properly held will give light enough, and is preferable to several lamps placed at a distance. More than one light should, if possible, be provided, lest some mischance to the sole light should cause sudden embarrassment in the course of the operation.

Assistants.—Two assistants are desirable, but if the patient is already insensible, none is absolutely necessary. If an anæsthetic is to be given, one assistant is needed to administer it. He will stand at the head of the patient, and will also be able to render all the assistance needed to hold a retractor or ligate a vessel as the operation proceeds. He may possibly also assist with a sponge, but, as a rule, the operator himself can better do his own sponging. The second assistant is needed only at the feet of the patient to hold the legs quiet and prevent undesirable struggling in case the patient should recover sensibility and should resist before the operation is completed. Any nurse, parent, or friend is quite competent to act as this second assistant.

Sponges.—Small squares of old, soft, and absorbent cotton or linen material, which is always at hand in every household, suffice for sponges. A number of these pieces should be torn and wrung out in hot water, and made ready for use before the beginning of the operation. As fast as one becomes saturated with blood, it is to be thrown away and a fresh one taken.

Miscellanea.—Hot water should be at hand for use in arresting persistent oozing of blood which sometimes is met with; thread for ligating vessels, iodoform for application to the wound surfaces, tape for securing the cannula in position, and a soft catheter or piece of rubber tubing for purposes of insulation, if it should be necessary. A small piece of oiled silk and an ordinary sewing needle, armed with thread, will be needed to complete the final dressing.

THE POSITION OF THE PATIENT.—Everything being ready, the patient is to be placed in position for the

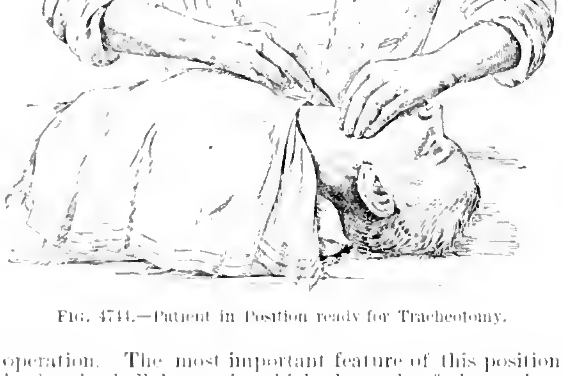


FIG. 4744.—Patient in Position ready for Tracheotomy.

operation. The most important feature of this position is that it shall be one in which the neck of the patient is strongly extended. Upon this point the facility with which the after steps of the operation may be done will greatly depend. A firm cushion should be placed under the shoulders—not under the neck—so as to lift them up and cause the head to fall back and thus extend the neck as the patient lies on the back (see Fig. 4744).

The desired cushion will usually have to be extemporized from articles to be found in the sick-room. A small pillow made into a firm roll; a bundle of clothing; a bottle with a towel wrapped around it; some books; other like materials may serve for the purposes of this cushion. The front of the chest as well as the neck should be made bare, and the field of operation and the adjacent skin should be cleansed with soap and water, if time permits.

THE OPERATION.—*Inferior Tracheotomy.*—The patient being in position and anæsthetized, and the instruments and sponges arranged on a table or chair within easy reach of the operator, he places himself on the right of the patient. The position of the cricoid cartilage is first identified, by the left index-finger, as the first landmark for the operation. The skin is then made somewhat taut, and the larynx steadied by the thumb placed on one side of it and the fingers on the other, as shown in the illustration (Fig. 4744), and at once with a scalpel in the other hand a free incision is made through the skin and superficial layer of the superficial fascia from the cricoid to the upper border of the sternum. Nothing will be gained but embarrassment in the further steps of the operation by making a less free external incision. If any superficial veins have been divided by this first incision, as is often the case, they are secured by hæmostatic forceps. The deeper layer of fascia is now exposed, and not infrequently upon its surface appear large and swollen branches of the anterior jugular plexus of veins, which so closely approximate each other in the middle line as to make it difficult to avoid them in pursuing the dissection further. The operator will be helped to avoid them by seizing the fascia at the lower end of the incision, just above the sternum, with a pair of forceps and nicking through it, and then, having passed a director underneath the fascia upward to the upper angle of the incision, lifting the fascia upon it. By this manœuvre he puts upon the stretch the tissue in the mid-line between the vein trunks, and can slit it up with much less danger of wounding the vessels than if he continued his incision free-hand. If, however, no vessels appear demanding this use of the director, the deeper layer of fascia may be divided without delay by a stroke of the scalpel to an extent corresponding with the cutaneous incision. A pair of hæmostatic forceps is now fixed in the free border of the incised fascia on either side and permitted to fall outward upon the side of the neck; this retracts the wound edges and freely exposes the connective tissue which joins the inner margins of the anterior ribbon muscles of the neck. The operator now seizes this connective tissue between two pairs of anatomical forceps, and, by causing them to pull against each other again and again, tears his way down to the trachea and freely opens up the pretracheal space. As the dissection deepens, the forceps which have been used as retractors are fixed in the deeper layers of tissue which have been opened up, until they are finally fixed in the tissue that ensheathes the trachea on either side, at the same time securing any bleeding veins that may be torn, while they continue to act as efficient retractors. The inferior thyroid plexus of veins will be identified, as its branches are exposed, and may usually be easily drawn aside and secured out of the field of the dissection by the retracting forceps. At the upper angle of the wound the lower border of the isthmus may encroach upon the field, especially if the isthmus is unusually broad. The clearing away of the pretracheal space should always be thorough enough to uncover and clearly define the lower border of the isthmus. If the breadth or low position of the isthmus is such as to hinder the ready and sufficient exposure of the trachea, it should be pulled up by a proper hooked retractor and held out of the way by an assistant If, now, all these precautions have been taken, the trachea will be found to be quite superficial and accessible, on account of the way in which the retracting forceps on either side lift it up from its bed and press back the wound borders. The anterior surface of the trachea should now be cleanly exposed by tearing through any connective tissue that may still cover it; any large vessels that may have been unavoidably wounded and temporarily secured by forceps should be tied; if possible all capillary oozing should also be stanched, although if the method described is adopted it will be rare that any troublesome hemorrhage will be met with. The anterior wall of the trachea is now to be hooked up in the middle line by a tenaculum, and held steadily by the operator with one hand, while, with the scalpel in the other hand, he pushes the point of the knife through the wall of the trachea into its cavity. The hiss of escaping air announces that the cavity of the trachea has been penetrated. The sharp-pointed scalpel is now laid aside, and the probe-pointed, curved bistoury is taken and, its point having been introduced through the opening into the trachea, the incision is carefully enlarged, either upward or downward, as may seem most judicious in the particular case, until the length of the incision is at least one and a half times as great as the diameter of the tube which is to be inserted. The incision should be made deliberately, with a full and exact knowledge of just where and to what extent tissue is being cut. Except in the most urgent cases, in which respiration has already actually ceased, there will be ample time to make the careful and systematic approach to the trachea which has been described. The doing of it takes by no means as much time as the description of it; for one who is at all experienced in the work, five minutes will not be required from the time the first incision is made till the cut in the trachea is accomplished and the new respiratory orifice is provided. As soon as the cut into the trachea has been made, the operator takes the tracheal retracting hooks, and, placing the hooks in the incision, from either side retracts the edges and dilates widely the new opening. One or both of these hooks may now be entrusted to an assistant, while the hands of the operator are set at liberty for the further cares which the case may demand. A tube should not at once be thrust into the opening, but it should be kept patent by the retractors, while a careful inspection of the interior of the trachea is made. In many cases in which the operation has been done on account of pseudomembranous disease, immediately upon the incision being dilated, there will occur a copious ejection through it of membranous débris and of muco-pus, and not infrequently of large membranous flakes, and even complete casts of the trachea. If the respiration has apparently ceased and artificial respiration is resorted to for resuscitation, firm compression of the thorax may cause the liquid contents of the trachea and the bronchi to well up out of the opening. Every care by immediate sponging should, of course, be taken to prevent the sucking back into the trachea of these materials.

In the cases in which tracheotomy has been done on account of a foreign body in the air passages, the exploration of the trachea for its detection and removal will follow as the next step after the trachea has been opened into. When the healthy trachea has been opened for the relief of laryngeal obstruction, or for preventive reasons, the immediate insertion of a cannula is to be made; in the cases, however, in which the trachea, when opened, is found to contain an exudate that is in process of exfoliation, every effort should be made to secure its removal before the cannula is introduced. For this purpose a chicken's feather may be passed down into the trachea and twisted about. This will often be efficient in detaching membranous bits and in provoking a spasm of coughing sufficient to expel them. Curved exploring forceps may be carried down into the trachea directly to seize and withdraw portions of exfoliating membrane. Their introduction will cause a strong expulsive cough, which will tend to loosen and drive between their open jaws any exudate not too firmly attached. I often fasten a small piece of sponge or soft rag in the jaws of the forceps, and introduce the forceps thus armed into the trachea, like a swab, more thoroughly to cleanse its interior. If, by any mischance, considerable blood should have entered the trachea from the operation wound, the same measures to secure its removal, as far as possible, should also be resorted to.

Before the cannula is put in place, while the tracheal opening is still kept patent by the hooks, the toilet of the external wound should be made. All hæmostatic forceps still in use should be removed, and final hæmostasis effected. The wound surfaces should be lightly dusted with iodoform or bismuth, after which the cannula, armed with its retaining tape, should be gently put in place, its tracheal portion being slipped into the trachea, while the edges of the tracheal wound are sufficiently separated by the dilating hooks to permit its entrance. If the cannula is so large as somewhat to distend the trachea, and it is necessary, or is deemed best, to use so large a one, it should not be crowded down the trachea; but if its end is once fairly engaged within the trachea, it will soon gradually work its own way down as far as it can get. The immediate effect of the introduction of the cannula is to excite a spasm of coughing, which, however, usually soon ceases. The cannula should be gently held in place by the fingers of the operator until this storm of coughing has subsided. The tapes should then be passed around the neck and tied so as to hold the cannula securely in place. Care should be taken, in tying the tapes, not to draw them too tight at first, but, while they are tight enough to prevent the end of the tube from slipping out of the trachea, still to have sufficient slack to provide for the swelling of the neck from infiltration of the borders of the wound, which always occurs within the first twenty-four hours after an operation. Otherwise the tapes will soon become too tight, and will cause much suffering to the patient if delay in frequent examination of them should occur.

The final dressings may now be applied. If the external wound has been made so freely upward as to extend considerably above the upper edge of the shield of the cannula a single suture may be applied so as to diminish the extent of the gaping here; but this will rarely be required. No attempt at suturing the lower portion of the wound should ever be made, lest retention of secretions and their burrowing downward behind the sternum be occasioned. A small compress should be made out of any thin, soft material, as an old pocket-handkerchief, or prepared gauze. It should be large enough to cover the wound and extend out on either side to the outer border of the flanges of the shield of the cannula. This compress should be slit down to its centre on one side so as to facilitate its application around the tube; it should then be smeared with an ointment of oxide of zinc and salicylic acid (oxide of zinc, gr. x.; salicylic acid, gr. iij.; vaseline, ℥ ss.), and, finally, should be applied around the tube and under the shield, so as to cover and protect the whole wound. Next, a bib made of oiled silk should be applied to the front of the neck and half-way down the front of the chest. It should be secured around the neck, having been cut away at the top so that its upper edge may easily be slipped under the lower edge of the shield, between it and the compress. The object of this is to protect the necessarily exposed parts of the chest from the air and from the secretions continually being expelled through the tube. Finally, a small veil made of two thicknesses of gauze or similar material, or a thin, flat sponge wrung out in hot water, should be adjusted over the external opening of the cannula to keep out dust and to moisten somewhat the inhaled air; the dressing is now complete, and the patient may be removed to his bed.

Superior Tracheotomy.—If the trachea is to be entered above the thyroid isthmus, the cricoid cartilage is again the landmark which is first to be identified. The skin and superficial fascia are to be divided by an incision at least one and a half inches long, the centre of which should fall upon the cricoid. The deep fascia may next be divided by free dissection, or upon a director. The thin connective-tissue layer which lies underneath is then to be divided carefully, or torn with forceps, so as to expose the surface of the cricoid. A careful transverse incision or tear of the fascia, which is attached to the lower border of the cricoid, is then to be made. This will loosen the isthmus from its attachment to the trachea, and now, with a suitable hooked retractor, the isthmus is to be pulled downward as far as possible. The upper two or three rings of the trachea are now exposed; the sides of the wound should be kept apart by the catch-forceps, as in the low operation, the fixation hook should be inserted into the cricoid, and a longitudinal incision, cutting from below upward, made through the exposed rings of the trachea after the manner already described. If the incision made into the trachea does not give room enough for the easy introduction of the cannula, the cricoid also is to be divided. The toilet of the trachea and of the wound, and the placing of the cannula, are to be done in the same way as already described for the low operation. In those urgent cases in which at every hazard an immediate opening must be made into the windpipe, the following method is to be followed: It is the work of but a moment to get the child upon a table, get a book or cushion under its shoulders, and tear away the clothing from in front of its neck. The larynx then being steadied and made prominent by the thumb and fingers of the left hand, with one free stroke of the scalpel in the other hand, all the superficial tissues are divided down to the cricoid and the isthmus; possibly the latter is also divided by this single cut. Does free bleeding follow the cut, the tissue from which the bleeding comes is seized *en masse* in the grasp of an hæmostatic forceps, with another stroke of the scalpel the trachea is opened, then the hook retractors are inserted, and the opening is dilated. There is always some one by to whom the dilating hooks can now be entrusted, while the surgeon institutes artificial respiration if needed, or seizes any vessels that may be bleeding, or removes any masses of exudate that may be blocking up the trachea. Free respiration having been re-established, haste is over, and all that is further required, including the introduction of the cannula, may be done with deliberation.

Complications of the Operation.—Varying conditions of pretracheal vascularity may embarrass the ready performance of any of the different methods of tracheotomy. It is by ignoring these conditions, by using too much haste in operating, by the lack of needed instruments, or by other imperfections in operative technique, perhaps unavoidable on account of emergency, that most of the serious accidental complications of tracheotomy are caused. The following list of complications is to be considered: Hemorrhage, asphyxia, displacement of the trachea, faulty incisions into the trachea, failure to introduce the cannula into the trachea, emphysema, and fatal syncope.

Hemorrhage.—The occurrence of hemorrhage is the most frequent of the accidents that complicate tracheotomy, and the one which brings in its train most of the other accidents enumerated. None of the precautions for the avoidance of hemorrhage which have been described in the section devoted to operative technique is unimportant. It is important that, if possible, bleeding should be arrested before the trachea is opened, but it may happen that delay for such a purpose may itself be fatal from the unrelieved asphyxia. When suffocation is imminent, therefore, the surgeon must, regardless of hemorrhage, boldly and rapidly proceed with his efforts to open the trachea. When the trachea has thus been opened through a pool of blood, the immediate introduction of the cannula is required, for the special purpose of preventing the flooding of the trachea with blood as well as for furnishing a conduit for the air. As soon as free respiration is again established, the bleeding will usually cease spontaneously, or may easily be controlled by pressure.

Hemorrhage from the vessels of the tracheal mucous membrane may also be a source of trouble. However perfectly bleeding may have been arrested before the trachea is opened, some hemorrhage from the divided vessels of the tracheal mucous membrane will follow the incision of the trachea. The blood flows into the trachea, but its flow usually ceases spontaneously, and the small quantity that has been effused is readily coughed out.

Cases of persistent internal hemorrhage from the tracheal vessels proper are fortunately rare. In such instances there will have been profound blood-poisoning antecedent to the operation. The method of operating, and of dealing with the trachea, which has already been advocated in the previous pages of this paper, will be the one best adapted for early discovering and successfully overcoming this complication.

Asphyxia.—The asphyxiative symptoms may be aggravated in some cases by the anæsthetic itself. Another source of aggravation, incident especially to the low operation, is liable to be present in very young children whose tracheal rings are not very resistant. When the deep fascia is incised and the deep pretracheal space is opened up, an important protection to the trachea from external pressure is lost, so that the soft tube is exposed to the full effects of atmospheric pressure at every attempt at respiration. A certain amount of collapse of the trachea may thus be caused, with speedy asphyxia unless the tube is quickly opened. This will occur, of course, only when the laryngeal obstruction is already very great, and therefore is more likely to complicate those operations that are deferred until the suffocative symptoms have already become extreme. This is the cause of the marked increase in the asphyxiative symptoms which so often develop during an operation, and alarm the surgeon lest the patient die before the trachea is opened. It is just at this crisis that, in his haste and solicitude, the operator is most likely to wound a vessel and add to the existing perils the dangers and difficulties of a sudden flooding of the wound with blood. To delay to stanch the bleeding would be fatal, to find the trachea through the deep, narrow wound filled with blood is difficult, and to incise it thus obscured is hazardous; but nevertheless, in such an emergency, it must be done as the only resource. The surgeon may properly protest against the delay in operating which should expose his patient to such perils, but in many cases the time of operating is not a matter of choice, for he may not arrive at the bedside of the patient until extreme symptoms have already developed. As soon as the trachea is opened, if done under such circumstances of hemorrhage, the patient should be turned over on his face to prevent the flow of blood into the trachea; if breathing has already ceased artificial respiration must be instituted; if the trachea has been flooded with blood it must be forced out by compression of the thorax, and by blowing air into the bronchi through a tube, as a catheter, so as to excite expulsive cough. It should be noted, however, that in any case the amount of time required for such a careful and systematic exposure of the trachea as would suffice to guard against operative mischance is so short that the surgeon need rarely feel himself compelled to depart from the cool, safe, and regular prosecution of his work. The preservation of a dry wound, and the obtaining of a clear, unobstructed opening into the trachea are the very best safeguards against the occurrence of uncontrollable asphyxia, and to secure these he may well disregard for the moment threatening asphyxia, relying on his ability to re-excite respiration by artificial means if it should actually cease before the opening in the trachea is made. Fatal asphyxia may be caused by a plug of false membrane crowded down into the trachea before a hastily introduced tube. A thick and loosely adherent lining of membrane may be pushed before the point of the knife which cuts the more resistant tracheal wall, and a hastily introduced tube, pushing its way between the membrane and the wall of the trachea, may find itself within the trachea, but still shut off from its cavity by this membranous layer. Death from asphyxia may occur before the cause is recognized and remedied. In general, as to these dangers, it may be said that prevention is better than cure. If care is taken to have the trachea clear of loose exudate before the cannula is inserted, such accidents cannot happen. If, however, as the result of circumstances beyond his control, the surgeon finds himself confronted by this accident, as indicated by increased embarrassment to the breathing or its total cessation upon the introduction of the cannula, the latter must be at once withdrawn, the tracheal opening dilated, perhaps enlarged, and, by the use of forceps, swabs, syringes, inflating tubes, or feathers, the cavity of the trachea must be quickly cleared, and artificial respiration resorted to.

Displacement of the Trachea.—The trachea may have been dragged or pushed away from its proper position in the median line by tumors. A more frequent cause of displacement of the trachea is unequal retraction of the borders of the wound in the course of the dissection to expose it, or unintentional departure from the midline of the neck by the surgeon. The result is that the operator strikes the trachea laterally, or misses it altogether. Cases are recorded in which the operator, having thus missed the trachea, has continued his dissection until the vertebral column was reached. Such mischances are most likely to occur when the field of operation is obscured by blood, and an inexperienced operator is under the pressure of symptoms demanding haste.

To guard against such accidents it is important that the landmarks for the operation which have been described in earlier sections be identified at the outset of the operation, and that, when haste in operating is imperative, the larynx should be steadied and the tissues evenly retracted by the fingers of one hand, while the incisions are made with the other.

Faulty Incisions into the Trachea.—These include lateral incisions, multiple incisions, too short incisions, too long incisions, and complete transfixion of the trachea with penetration into the œsophagus. They are generally the result of haste and hemorrhage. A lateral incision will make the cannula stand awry upon the surface of the neck, and increase the dangers of irritation to the tracheal mucous membrane from its extremity. Multiple incisions are the result of repeated ineffectual stabs at the trachea when the first incision is lost beneath shifting tissues or in a pool of blood.

When a puncture has been made and lost, so that it cannot quickly be found again, time should not be wasted in searching for it, but a new incision should be made. Too short an incision interferes with the ready introduction of a tube; too long an incision leads to difficulty in retaining a tube in the trachea. The length of the incision should not exceed one and a half times the diameter of the tube that is to be inserted, and when the tracheal cartilages are too rigid to permit ready separation of the edges of the incision to a sufficient extent, exsection of a portion of them should be done.

Complete transfixion of the trachea may easily be done in young children in whom the tracheal walls are quite soft, and possibly already somewhat collapsed. It is to prevent this accident that the recommendation is made to hold up and steady the anterior wall of the trachea by a fixation hook or tenaculum before it is carefully pierced by the point of the knife. Attempts to open the trachea by quick thrusts of the knife should never be made.

Failure to Introduce the Cannula into the Trachea.—Death before the cannula is introduced, on account of delay from some of the accidents already mentioned, has occurred many times. There can be no excuse for leaving a cannula thrust down by the side or in front of the trachea. Such an accident can happen only when the incision in the trachea is imperfectly exposed and retracted, perhaps hidden by blood, or when the trachea has been missed altogether. The rush of air through the tube when it enters the windpipe is unmistakable, and the operator should never be satisfied until the free current of air in and out of the tube clearly demonstrates that it is properly in place.

Emphysema.—When emphysema follows a tracheotomy, it must be produced by some operative mischance whereby the peritracheal connective tissue is opened up deeply without corresponding external wound, or lateral or multiple incisions into the trachea have been made, or an incision into which the cannula either has not been introduced at all or has slipped out of, so that the expired air is forced into the connective tissue. Though the cannula may have been properly introduced at first, it may slip out of its place later, either because too loosely tied in, or because the tracheal incision is too long, or because the tracheal cannula is too short from the first, or the subsequent tumefaction of the tissues lengthens the track so that it becomes too short later.

The appearance of the emphysema may be first noted during the operation, or it may not be noted until some hours have passed, depending upon the time when the causes of it become active. It may be limited to the region of the wound, or may in extreme cases become generalized. As soon as its cause is removed, it will rapidly subside.

Syncope.—A transient syncope occurs in some cases immediately upon the incision into the trachea being made, caused by the sudden free in-rushing of an abundant stream of air. For a moment further inspiratory efforts cease, and the child appears as if it would never breathe again. There is no cause for anxiety, however, since the momentary shock is quickly rallied from and regular respiration begins again. Compression of the thorax and dashing cold water into the face of the patient may be resorted to, if the syncope is prolonged.

Fatal syncope may occur at any stage of the operation in children who are the subjects of diphtheria, from heart failure determined by agitation, hemorrhage, or possibly the anæsthetic.

After-treatment.—Much difficulty is often experienced in inducing children to take the needed amount of food, not necessarily because it hurts them to swallow, but because of their general state. Not infrequently, also, such paralytic weakness of the pharyngeal and laryngeal muscles develops that, at every attempt to swallow, more or less food will enter the larynx and provoke violent coughing. Rectal enemata, or feeding through an œsophageal tube, must be resorted to in such cases. The general principles of dietetics which are recognized in other cases attended with exhaustion will find their application in the after-treatment of tracheotomized patients. The air should be pure and abundant, as well as warm and moist. I can see no advantage to be gained from shutting up the patient in a close tent, or in maintaining the temperature of the sick-room at a very high point and having it filled with steam, which cannot be equally well obtained from simple and less depressing measures. A temperature of from 72° to 75° F. is high enough. The floating dust of the air should be strained out, and additional moisture given to the in-going current of air by keeping the orifice of the tube covered with a moist veil or sponge. The fact must not be lost sight of that the pre-existing condition of congestion of the pulmonary and bronchial capillaries induced by prolonged dyspnœa predisposes to the development of pneumonia and bronchitis—of which the entrance of blood into the air passages, the aspiration of portions of food and of necrotic bits of exudate, or unhealthy secretions from the larynx and trachea, may frequently be the final determining cause. It is important, therefore, to keep from the respiratory tract as far as possible every depressing influence; hence the importance of the injunction that the air supplied should not only be warm and moist, but also abundant and pure. In no class of cases is the value of intelligent and careful nursing more marked, and it would be greatly to the advantage of the little unfortunates in large cities, where diphtheritic croup prevails, if all such cases could be kept after tracheotomy in special wards of hospitals, equipped with every facility for their proper care. Traumatic fever, to some extent, is unavoidable from the character of the wound. If no complication in the course of the wound healing takes place, the fever will demand no special treatment; if it is excessive and prolonged, the cause for it is to be sought in some complication to which appropriate treatment must be directed.

In addition to the general cares above outlined, special care will be required for the management of the wound, of the trachea, and of the cannula.

THE WOUND.—In general, the cares which the wound will demand are very simple; while it remains open, its secretions, together with any tracheal secretions that are ejected upon it, readily flow away. No dressing should ever be applied which would favor the retention of secretions in the wound. Twice daily, the wound should be lightly dusted with iodoform or bismuth to prevent septic changes, while the wound, as a whole, should be kept protected from external irritation by a small square of linen or similar material laid over it, smeared with an emollient, like the salicylated zinc ointment, already mentioned. The removal of dried crusts and the general cleanliness of the adjacent parts must be looked after on general principles. After the cannula has been dispensed with, the wound rapidly contracts, the cannula fistula collapses, its walls quickly adhere, and a simple superficial granulating surface is left, the treatment of which is conducted on general principles. The rapidity with which these reparative changes take place will depend on the amount of the previous disturbance of the wound and on the general vigor of the patient. When much loss of substance has taken place, or the cannula has been worn for a long time so that its sinus has become lined by a well-organized membrane, a permanent fistula may remain, the obliteration of which may require a plastic operation.

Phlegmon of the Wound.—Some phlegmonous inflammation of the borders of the wound is common. They become tumefied and indurated, and a zone of redness extends to a variable extent outward upon the skin of the neck, and downward upon the thorax. Little tendency seems to exist to the formation of abscesses—at least I have never observed it; the necrotic changes which it determines in its more intense forms take place on the surface, and may range from slight ulceration to extensive sloughing. If erysipelas or diphtheria is engrafted upon it, these necrotic changes will be aggravated. This wound inflammation is septic in character, and aggravated by the irritation of the cannula. It begins to manifest itself more especially during the third day; if life is prolonged and the case does well in other respects, it will begin to subside after three or four days, especially if the cannula can be dispensed with. An efficient antiseptic treatment of the wound from the first, as already advised, is the best preventive of this phlegmonous invasion, and the best curative, if the invasion has already taken place. The inflamed integument should be kept anointed with carbolated oil (carbolic acid, three per cent.), or an ointment of ichthyol (ichthyol or ichthyolate of ammonia, ten per cent.). The cannula should be kept out of the wound as much as possible. Even though the condition of the larynx may not permit of the permanent removal of the cannula, still the stiffness of the wound borders will suffice to keep the track of the cannula patent enough for respiration for quite a while after the tube has been taken out, so that the patient may be able to get along without the latter for from fifteen to sixty minutes or more at a time, before it becomes necessary to replace it. After the tube has been in place for an hour, it may be removed again, and so on as long as the persistent wound inflammation may require such help. In such cases as this the use of a suitable obturator to facilitate the reintroduction of the tube (see Fig. 4743) is especially needed. With the help of such an obturator any intelligent nurse can carry out this procedure. Erysipelas of the wound is characterized by a more extreme spreading of the skin inflammation, is simply a more severe form of septic disturbance of the wound, and is to be antagonized by the same kind of treatment.

Diphtheria of the wound demands no special treatment different from that given to the phlegmonous inflammation which attends it. If the case does well in other respects, the exudate exfoliates spontaneously in due time, and cicatrization proceeds.

Gangrene of the Wound.—This may manifest itself either in a progressive ulcerative process that converts the wound into an ill-conditioned spreading ulcer, or in the formation of distinct sloughs of necrosed tissue. Its causes are the same as those of the less severe forms of septic infection already noted, and indicate a more intense form of infection and less local and general resisting power on the part of the patient. A black discoloration of the cannula, caused by the disengagement of sulphureted hydrogen, indicates the beginning of the gangrenous process. The treatment consists in the use of local stimulants and antiseptics, and general tonics, and the suppression of the cannula as much as possible. If the gangrene is superficial, the sloughs are soon cast off, the wound assumes a healthy appearance, and its cicatrization proceeds without any permanent damage having been occasioned. Every degree of disorganization may, however, occur, even to the invasion of the larynx and trachea. An extreme loss of substance, if ultimate cicatrization should be accomplished, would entail stenosis of the windpipe requiring permanent wearing of the cannula.

Secondary Hemorrhage.—Bleeding may take place at any time during the after-history of a case until all ulcerative tendencies have been arrested. It may be due to the reopening of a vessel wounded during the operation, to the erosion of the coats of a vessel through the pressure of the cannula, or to the falling of a slough. Not infrequently the expectoration becomes tinged with blood from time to time. This is due in most instances to slight erosions of the tracheal mucous membrane by the cannula, most frequently at its point, and calls either for greater gentleness in the manipulations about the cannula, or for a change in the tube itself, so that, by having one of a different length or different curve, the ulcerating point may be relieved from pressure. Many cases of profuse and fatal secondary bleeding have been reported. Such hemorrhages are due usually to eroded tracheal vessels, but may be due to the opening by ulceration of some vessel in the external wound. In a number of reported instances the innominate artery has been the source of the bleeding. The possibility of serious secondary hemorrhage should always be borne in mind, and every care should be taken to prevent or limit the ulcerative processes upon which it depends. When a large vessel is the source of the bleeding, the immediate inundation of the air passages with blood will cause speedy death. If the bleeding is less overwhelming in its onset, the bleeding point must be sought for, and the flow stanched by the use of the ordinary means available for hæmostasis.

THE TRACHEA.—*Pseudomembranous Exudate.*—The extent and character of intratracheal exudations is one of the most important conditions upon which the success of tracheotomy depends, especially in cases in which the operation is performed in the course of diphtheria. The amount of the tracheal mucous surface that may become involved in the pseudomembranous exudate varies much, and it is generally impossible to determine, previously to the opening of the trachea, whether the exudate extends below the larynx or not; in a large proportion of cases it remains limited to the larynx throughout; in others, if life is prolonged by tracheotomy, it afterward extends to the trachea and to the bronchi; in many the trachea is involved from the first; of these, in some, after the exfoliation of the exudate already formed, no further deposit occurs; in others its progressive formation leads irresistibly to death. When the trachea already contains an exudate at the time of operation, more or less extensive particles of it, accompanied by much muco-pus, will often be ejected through the incision when made. In other cases, in which the exudate is still adherent, it may be possible to secure the detachment and expulsion of portions of it by the introduction through the wound into the trachea of suitable instruments, as already advised in a previous section.

The readiness with which exfoliation of the membranous exudate takes place, depends upon the degree to which its elements adhere to and penetrate the mucous membrane beneath, which again is a very fair index of the intensity of the local inflammation. The cases marked by a ready exfoliation are those in which the depth and intensity of the local disease are slight, and which give a ready hope for recovery, provided that the special dangers incident to the location of the deposit be overcome.

In many of the cases in which the loosened exudate is ejected upon the first opening into the trachea, or is easily removed at once, unimpeded and speedy recovery will ensue if only the simplest precautions be taken to protect from hurtful extraneous influences.

Much more frequently, however, the detachment of the membrane is delayed, and it takes place in smaller masses, of varying size, that appear from time to time in the expectoration during the after-progress of the case. These loosened pieces of membrane, usually mingled with viscid mucus or muco-pus, are often expelled with difficulty; they provoke suffocative crises that for a time seem to threaten the utmost peril; and in not a few instances, when skilled and instant assistance is not rendered, they produce death by blocking up the lumen of the trachea, or of the cannula that may be in use. In any case in which there has taken place a membranous exudate within the trachea below the point of incision, such a suffocative crisis is likely suddenly to arise at any time during the period of its exfoliation. These are the cases in which the ultimate result depends directly upon the completeness with which the indications presented by the presence of this loosening membrane are appreciated, and the faithfulness and thoroughness with which they are carried out.

Catarrhal Inflammation.—Some catarrhal inflammation of the tracheal mucous membrane always accompanies a membranous exudate, and frequently causes conditions that complicate greatly the after-treatment. It is liable to be excited *de novo*, in cases not associated with membranous exudate, by the inhalation of unmodified air—cold, dry, and dust-laden—through the new respiratory aperture. It may extend to the smaller bronchi; it is the immediate cause of death in a considerable proportion of cases after tracheotomy.

Even in cases in which the catarrhal inflammation does not extend beyond the trachea or the primary bronchi, the secretion may be so copious and so viscid that the air passage can be kept clear with difficulty; where there is membrane also present, it is by the catarrhal secretion that the membrane is lifted up and disintegrated; this secretion mingles with the membranous shreds that are expectorated and may cement them together in masses too large to be expelled without assistance; it clings to the interior of the cannula, where it readily dries in the air current and forms incrustations that rapidly diminish its lumen. The greatest trouble from this catarrhal secretion is usually experienced within the first three or four days after tracheotomy. It then either diminishes greatly in quantity, or becomes muco-purulent and diffluent. In many cases the character of the secretion has already become muco-purulent before the incision into the trachea is made, in which case its copious and ready expulsion through the opening then takes place.

The indications for treatment of catarrhal inflammation of the trachea are to limit its extent, to modify its intensity, and to obviate dangerous accumulation of its secretions.

The first two indications may be fulfilled by the same measures. Whatever remedial measures have been recognized as of value in the treatment of inflammations in general of the respiratory mucous membrane, will be of equal value in these cases, and will be applied according to the experience of the individual practitioner. Calomel, antimony, and muriate of ammonia each possess a positive influence in promoting free secretion and rendering it less viscid, but in the majority of cases dependence will be mostly placed on local applications.

The air inspired must be warm, moist, and pure. The use of the moist sponge or gauze veil over the mouth of the cannula, advised in a previous section, should be kept up. If necessary they may be held in place by tapes fastened at either side, and tied over the head or around the neck. In addition to this precaution, whenever difficulty is being experienced by the patient in fully coughing out the tracheal secretions, inhalations of vapor, instillations and injections of liquids may be practised. Inhalations of steam, of steam charged with vaporized Peruvian balsam, with atomized lime water, or with solution of muriate of ammonia, may be used with benefit. Instillations and injections are also of great advantage. When the symptoms are not urgent, three or four drops of warm water and chloride of sodium, of lime water, or of dilute lactic acid, may be made to run down through the tube into the trachea as often as seems to be necessary to keep the secretions diffluent and the expectoration free. Whenever this is not sufficient to prevent the continued marked accumulation of secretions, whether of tenacious and inspissated mucus or of muco-pus and membranous débris, injections of the solvent liquid, to the amount of a drachm or more, are to be made by means of a syringe introduced deeply into the cavity of the trachea. For this purpose a small syringe, as a hypodermic syringe, having a tube attached to it of suitable size and curve to pass through the cannula, terminating in a perforated bulb, as shown in the illustration (Fig. 4745), is desirable. In making the injections, the bulb is quickly passed down through the cannula, or through the wound after the cannula has been withdrawn, for an inch or more into the trachea, and the liquid is injected with some force. A violent expiratory paroxysm follows, the diluted and loosened mucus is dislodged and expelled; after a minute or two the injection may be repeated, and will be followed by still greater relief. These injections may be repeated from time to time, as often as the reaccumulation of viscid mucus in the air passage is evident.

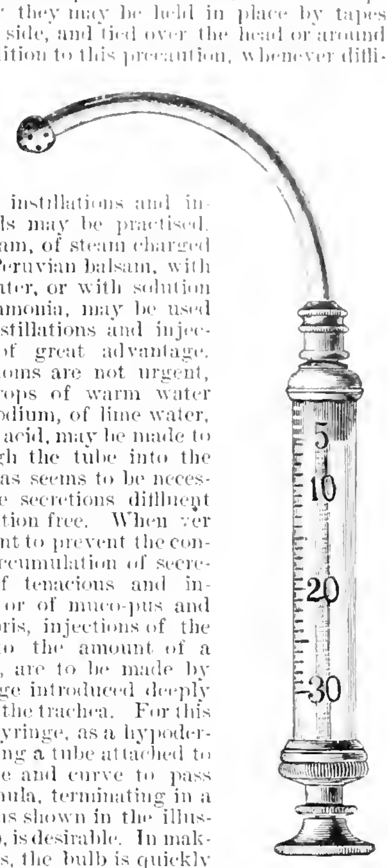


FIG. 4745.—Syringe for Intratracheal Injections.

Pressure Sores.—The possible erosion and ulceration of the tracheal walls from the pressure and friction of the cannula is always to be borne in mind. The mere pressure exerted by the cannula does not seem to be the only thing at fault in the development of ulcerations of the trachea, as the prolonged wearing of a cannula after tracheotomy for conditions other than diphtheritic croup, and even in many of these cases, without unpleasant pressure effects ever being experienced, is sufficient to prove. The vitality of a tissue which has been the seat of a diphtheritic exudation is diminished; it naturally tends to necrosis; the more intense the diphtheritic process, the greater the necrotic tendency. In such cases the slight additional irritation afforded by the pressure of the cannula suffices to determine a slough. That in the movements of the neck, and in the manipulations of the tube, frequent antero-posterior tilting of the cannula should be done is unavoidable; and it would be expected that the striking of the anterior edge of the inner end of the cannula against the anterior wall of the trachea in these frequent tiltings would cause that point to be the one at which ulceration should most frequently take place.

Many cases of mere erosion or of slight ulceration undoubtedly pass unnoticed. The most important symptoms which indicate the existence of ulceration are two —namely, the appearance of bloody streaks in the expectoration some days after the operation and a black discoloration of the lower end of the tube.

It is on account of the danger of these pressure effects that so much stress has been laid in a previous section on the use of such a form of tube as shall in its construction provide as perfectly as possible against friction and pressure while it is worn. For the same reason efforts to dispense with the cannula should be begun very early, and whenever evidences of pressure effects are detected, its removal, if but for a short time at any one trial, should be frequently practised. In cases of the high operation the cannula may possibly sometimes be dispensed with altogether.

Granulation Vegetations. — Exuberant granulations, forming polypoid excrescences projecting into the trachea, have been noted by many observers; they may be sessile or pedunculated, single or multiple; they most frequently occupy the superior or inferior angle of the wound, at which points a small space exists not occupied by the cannula, which is early filled by granulation tissue and is constantly subject to the irritation of the tube thereafter.

Whenever vegetations are discovered protruding into the trachea from the angles of the tracheal wound, they are to be treated as exuberant granulations would be in any other locality. They are to be destroyed by the application of caustics, or if they can be torn away their bases should be cauterized. Whatever operative procedure may be necessary to make them accessible to the required applications must be done, as their presence is always a source of danger. Whenever a prolonged use of the cannula is necessary, a watch should be kept for any signs of their development and their growth repressed from the first.

Chronic Hypertrophic Subglottic Laryngitis.—A chronic thickening of the soft parts between the vocal cords and the lower border of the cricoid cartilage is an occasional sequel to laryngeal diphtheria, and by the stenosis which it causes makes necessary the prolonged retention of a tracheal cannula. Attempts to relieve the obstruction by laryngotomy and excision of the obstructing tissues have been uniformly unsuccessful.

Care of the Cannula.—A constant watch over the cannula should be had from the moment of its introduction until either it is possible to remove it altogether, or the trachea has become accustomed to its presence and the tracheal secretions are normal. The surgeon must see that the nurse is thoroughly familiar with the mechanism of the double tube and knows how to remove and replace the inner tube with the least possible disturbance to the patient. It is especially desirable that the care of the cannula be entrusted to a judicious person who will not neglect it on the one hand, nor needlessly torment the patient on the other by useless fussiness over it. The inner tube should be removed only when there is a manifest occasion for it, as shown by some interference with the free passage of air. If the toilet of the trachea has been carefully made before the tube is introduced, the amount of expectoration will often not be very great during the first twenty-four hours; but if rapid breaking down of membrane, or a copious tracheal or bronchial catarrh coincides with the introduction of the cannula and occasions profuse expectoration, the tendency to clogging of the tube will be so frequently manifest that the removal of the inner tube and its cleaning will be required at comparatively short intervals. Even in cases which are not giving much trouble, obstructive crises are likely to develop suddenly at any time, caused by clumps of inspissated mucus, or pieces of exfoliated membrane, being driven into the tube by cough, or being brought up against its lower end so as to occlude more or less completely its opening. The extreme dyspnœa caused by such an accident, if not quickly relieved, will soon end in death. If the removal of the inner tube does not relieve the symptoms, the whole tube should be removed, and the needed measures to clear out the trachea be carried on through the unobstructed wound. When the inner tube is to be removed, the shield of the outer tube should be steadied by the thumb and forefinger of one hand, while the inner tube is disengaged and withdrawn with the other hand. The withdrawn tube should then be dropped into a cup of warm water, in which it should be left for a short time in order to soften the more or less inspissated mucus within it. Then a small mass of cotton-wool or a piece of sponge should be pushed through it, so as to clear it out. A splint from a broom will always be available for the purpose of pushing the cotton or sponge through, and is to be chosen rather than a wire or hairpin; for the latter, if not very carefully used, may scratch and mar the soft metal of which the tube is made. The tube having been cleaned out, it should then be rinsed in the water and replaced. The inner tube ought not to be left out any longer than is necessary to clean it, lest, when it is replaced, it push before it a possible mass of inspissated mucus, gathered on the inside of the outer tube while the inner one has been out, which by the time the tube is down in place may become a plug sufficient entirely to occlude it.

The outer tube may usually be left in place, without being disturbed, for the first two days. At the end of this time, that is, at the close of the second or the beginning of the third day, it will be desirable to remove the whole apparatus for the purpose of cleaning up. By this time the wound borders will have become somewhat firm, so that the opening down to the trachea will remain patent for a while without the tube, and sufficient time can be had to clean up the wound and the parts about, as well as to cleanse the tubes and arm them with fresh tapes. When the cannula is ready to be replaced, it will generally easily slip back into the trachea along the track which it has already made for itself, the walls of which are firm enough to guide the advancing end of the tube, if it is gently pushed along with proper regard to the direction which it should take. A hitch may occur when the end of the cannula reaches the entrance into the trachea, owing to the resilient cartilages having sprung back and partly closed the opening. If the tube has been kept out some time this obstacle is more likely to arise. Usually a little gentle pressure will overcome it, but care must be taken lest the tube be thrust down in front or at the side of the trachea instead of into it. The use of a conical-pointed pilot obturator (Fig. 4743) will always prevent any difficulty of this kind, and the surgeon would do well to be provided with one. The three-bladed dilator of Laborde is also very serviceable in overcoming such a difficulty. If the cannula track has not become quite well defined and firm, the hook retractors may be used to advantage for dilating anew the tracheal wound sufficiently to permit the cannula to pass.

If the walls of the wound are still so soft at this period that they fall together at once after removing the cannula, the wound must be kept open by a dilator while the necessary cares are given to it and a fresh tube is made ready for insertion. When this first change of the cannula is to be made the patient should be placed upon a table with the same arrangement as in the original operation, otherwise the surgeon may find himself at a very great disadvantage in his efforts to give the needed attention to his patient.

The further care of the cannula will differ according to the nature of the case for which tracheotomy has been done. If the tube is to be worn permanently, or until some cause of obstruction has been removed by subsequent operation, it will be left in place, with but rare changes. If the tube is one whose size and shape are adapted to the case, the trachea soon becomes accustomed to it so that it is borne without discomfort; the superficial wound heals rapidly, and the track of the cannula becomes a fistula with well-organized walls. If the operation has been done for the relief of temporary obstruction from inflammatory or diphtheritic disease of the larynx, it will be desirable to dispense with the cannula as soon as the obstruction shall have cleared away sufficiently to permit air again to pass through the larynx. To determine this the tube should be removed at the end of thirty-six or forty-eight hours, with great gentleness, so as to alarm the patient as little as possible, and the wound opening should be occluded with two or three folds of moist muslin placed over it, so as to test the ability of the patient to respire through the larynx. Frequently, even as early as this, it will be found that the obstruction has cleared away and that the cannula can be permanently dispensed with. If, however, respiration through the natural channels be found still impossible, the cannula must be replaced. Each day the permeability of the larynx may be again tested for a time. If by the eighth day it shall appear that easy respiration through the larynx is not yet possible, it will rarely be due to the persistence of obstructive exudate or œdematous swelling, but will be caused in the most cases either by temporary paralysis of the glottic dilators, diphtheritic in origin, or by glottic spasm of emotional origin; less frequently it will be due to persistent submucous inflammatory swelling or to inflammatory infiltration of the laryngeal muscles. More rarely yet, the inability to do without the tube will be due to the tracheal conditions already described, viz., in-turned cartilages, collapse of the trachea, or polypoid granulation excrescences. Cicatricial contractions causing stenosis of the trachea, following upon extensive destruction of its walls by ulceration or gangrene, may also oblige the patient permanently to retain the cannula. Whatever the cause, it will be well now to suspend for a time the efforts to do without the tube. A week may be allowed to pass during which the larynx is left at rest, and efforts are made to improve the general condition of the patient by iron and strychnine, and the local paresis by faradization. At the end of this time the efforts to dispense with the cannula should be renewed. All the manipulations should be made with gentleness, accompanied by manner and voice tending to reassure the patient, who has learned to rely on the cannula for breath, and who regards its removal with apprehension. As soon as any marked distress is caused by the absence of the tube it should be replaced, and further attempts deferred until another day. If after three or four trials suffocative crises continue to follow quickly after every attempt to remove the tube, these efforts should be desisted from again for some time, a week or more. In the vast majority of cases a time will finally come when the tube may permanently be dispensed with.

Emotional laryngeal spasm is a condition which has frequently to be encountered in the effort to remove the cannula in nervous, excitable children. It may coexist with and thus aggravate the difficulties caused by other conditions, or may be the sole trouble.

This emotional condition is to be overcome by tact, patience, and time. Many artifices have been resorted to for conquering the nervous fear upon which the spasm depends. Gradual shortening of the cannula, even down to the point of a mere button resting upon the closed external wound, and gradual narrowing of the cannula until it is no longer a pervious tube, have each been resorted to successfully. The confidence of the patient in his ability to breathe without the tube must be awakened; how to do this must be left largely to the ingenuity of the attendants and the inspiration of the occasion.

Lewis S. Pilcher.

TRAGACANTH.—(*Tragacantha*, U. S., Br., P. G.; *Gomme adragante*, Cod. Med.) A gummy exudation from *Astragalus gummifer* L., and from other species of *Astragalus* (fam. *Leguminosæ*). The species yielding this gum are straggling, spiny shrubs of southwestern Asia, some of them extending into southeastern Europe. The gum is a product of the mucilaginous degeneration of the cell walls of the pith. At certain seasons it is subjected to a great pressure within the stem, by which it is forced out, in the manner indicated in the accompanying illustration, through any opening reaching to the surface. Many such openings occur from natural causes, while others are made for the purpose by the gum collectors. The form of the exudate varies somewhat with that of the opening, so that cylindraceous ("vermicelli"), ribbon-like ("flake"), tear forms, etc., occur. Most of the flake form is obtained from artificial incisions. The gum is gathered promiscuously by the collectors, and is carefully assorted by professional pickers after being

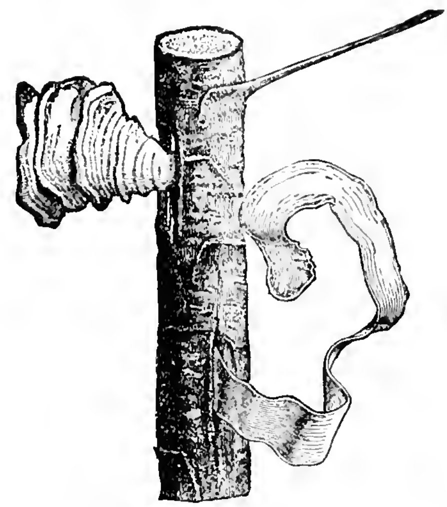


FIG. 4746.—Gum Escaping from Incisions in a Branch of a Tragacanth Shrub. (Baillon.)

marketed. There are numerous commercial grades, primarily designated by number, and depending upon the purity, solubility, and whiteness of the article.

DESCRIPTION.—In narrow or broad bands, more or less curved or contorted, marked by parallel lines or ridges, white or faintly yellowish, translucent, horn-like, tough, and rendered more easily pulverizable by a heat of 50° C. (122° F.).

On treating tragacanth with water, it swells and gradually forms a gelatinous mass, which is tinged blue by iodine T.S., and the fluid portion of which is precipitated on the addition of alcohol, but is not colored blue by iodine T.S.

Tragacanth consists of from one-third to one-half its weight of *bassorin* ($C_6H_{10}O_5$), an insoluble gum common to a number of commercial products (bassora gum, simaruba gum, cherry-tree gum, etc.) and of extended occurrence in the vegetable kingdom. It is capable of absorbing a good many times its weight of water, when it becomes transparent, soft, and jelly-like, but will not dissolve clearly when more water is added. Bassorin can be seen reasonably pure by putting a piece of tragacanth in a tumblerful of water and letting it remain, say, twenty-four hours until the soluble gum is dissolved out. About half of tragacanth consists also of a *soluble gum*, of the arabin series. Water, mineral substances, and impurities constitute the remainder. Tragacanth has no medicinal, and very little nutritive value. It is very largely used in the arts for sizing, mucilage, etc., and has considerable employment in pharmacy, where it is used as a basis of emulsions, for the suspension in liquid of powders and insoluble substances in "mixtures;" as a body for troches, etc. It appears in the following official preparations: *Trochisci Acidi Tannici*, *Trochisci Ipecacuanhæ*, *Trochisci Potassii Chloratis*, *Trochisci Santonici*, *Trochisci Zingiberis*, all of them belonging to the United States Pharmacopœia. There is a Mucilage of Tragacanth (*Mucilago Tragacanthæ*, U. S. P.) consisting of six parts of tragacanth, eighteen of glycerin, and enough water to make a hundred; this, diluted with about as much more water, will emulsionize cod-liver or castor oil sufficiently well; the usual strength is to make the emulsion one-half oil. It may be flavored with peppermint, almond, or other fragrant substance. For desk purposes, as an adhesive mucilage, tragacanth, softened with thymol water and kept from evaporation, will not decompose or sour in the least, even after years.

W. P. Bolles.

TRAINING, PHYSICAL.—The word *training* has two applications in common use. Its more general application is to a system of exercises intended to develop the neuromuscular system. In this application physical training is used in the literature of the subject as synonymous with "*physical education*" and "*physical culture*." The other application of the word *training* is to a specially devised daily programme of exercise and diet preparatory to an athletic contest.

I. PHYSICAL TRAINING.—Physical training in its general sense is an educational system supposed by many to signify the development of muscle alone, but it became apparent very early in the study of muscular development: (1) that there could be no extensive development of muscles without brain development; and (2) conversely no extensive development of the brain as a rule without at least a moderate muscular development. As soon as educators became cognizant of the intimate relation between brain development and muscular development, the far-reaching importance of a carefully worked out system of physical education became generally recognized. Germany, Sweden, and England as a result of the efforts of Jahn, Ling, and Maclaren, respectively worked out in those countries systems represented at the present time by the German method in the Turn Verein, the Swedish gymnastics, and the English modification of the German system.

Somewhat later, Dr. Dio Lewis started a movement in this country through his lectures and writings on hygiene, muscular exercise, and gymnastics. The general interest aroused led to the gradual development of a system which embodies some of the better features of the European systems, while introducing many features which are particularly adapted to the conditions that exist in America.

The system of physical training, now used in this country, may be classified under the heads: (1) Developmental or educational; (2) corrective or therapeutic; (3) recreative or hygienic.

1. *Developmental* or *educational* physical training is a progressive series of physical exercises designed to cultivate in the growing child or the youth muscular strength and the ability to command the muscles singly or in groups to act gracefully and accurately. Both grace and accuracy depend upon co-ordination. Such a series of exercises is adapted not only to the development of the normal child, but also of the child whose mental and physical development has been retarded or arrested.

2. *Corrective* or *therapeutic* physical training consists of a series of specially devised exercises prescribed by a physician to correct special pathological conditions.

3. *Recreative* or *hygienic* physical training consists of a series of calisthenics, gymnastic floor games, field sports, and athletics intended to maintain the physical vigor, to divert the mind from its regular channel, and to increase the power of resistance to disease.

II. ATHLETIC TRAINING.—1. *Definition.*—To produce in an individual by a definite régime a condition of strength, agility, skill, and courage; with ability to endure pain, to maintain self control, to resist or quickly to recover from fatigue.

2. *The régime* of training consists in a course of carefully arranged exercises or tests which gradually bring the muscular strength and agility to their highest point of perfection. The exercises are of a threefold character: (*a*) General exercises to increase general strength, and particularly the strength of heart and capacity of lungs, as upon a vigorous circulation and an ample respiration depends much of the success of the athlete in these contests. (*b*) Daily practice in the event or particular exercise in which the athlete is to contest. The object of this part of his training is to give him skill and courage in that particular exercise or sport. (*c*) A carefully arranged system of diet, baths, and general hygiene, the object of which is to keep his system in the best possible hygienic condition.

Winfield S. Hall.

BIBLIOGRAPHY.

I. GENERAL.

Kroh: Gymnastics: The German System, St. Louis, 1897.
Euler: Handbuch des gesammten Turnwesens, Pichler & Sohn, Wien, 1894–96.
Posse: The Swedish System of Educational Gymnastics, Lee & Shepard, Boston.
Johnson: Swedish System of Physical Education, Wright & Co., Bristol, 1897.
Stecher: Gymnastics; German-American System, Gay and Bird, London, 1897.
Stebbins: Delsarte System of Expression, Werner, New York, 1894.
Treves: Physical Education, vol. i., pp. 537–613, in Stevenson and Murphy's Treatise on Hygiene and Public Health, London, 1896.
Laspée: Calisthenics, Darton & Co., London, 1856.
Thomas, Julia and Annie: Psycho-physical Culture, Werner, New York, 1892.
Graf: Gymnastic Competitive and Display Exercises, Bell & Sons, London, 1897.

1. Educational.

Lennox and Sturrock: The Elements of Physical Education, Blackwood & Sons, Edinburgh, 1898.
Bowen: A Teacher's Course in Physical Training, Wahr, Ann Arbor, 1899.
Tsanoff: Educational Value of Children's Playgrounds, Philadelphia, 1897.
James, Alice: Girls' Physical Training, Macmillan, London, 1898.
Colburn: Graded Physical Exercises, Werner, New York, 1901.
Ballin, Hans: Physical Training in the School-Room, Little Rock, Kansas, 1901.
Bancroft: School Gymnastics, Kellogg & Co., New York, 1896.
Anderson: Methods of Teaching Gymnastics, Flood and Vincent, Meadville, Pa., 1896.
Hartwell: Physical Training in American Colleges and Universities, United States Bureau of Education, Circular No. 5, Washington, 1886.
Barrows: Report of Conference on Physical Training, Boston, 1890.—American Physical Education Review, Quarterly, Boston.

2. Corrective and Therapeutic Physical Education.

Wide: Handbook of Medical Gymnastics, Low, Marston and Company, London, 1899.
Durgin: Medical Inspection of Schools, Boston, 1897.
Denison: Exercise and Food for Pulmonary Invalids, Chain and Hardy, Denver, 1895.
Ostrom: Massage and the Original Swedish Movements: Their Application to Diseases of the Body, Blakiston, Philadelphia, 1902.
Schreber: Medical Indoor Gymnastics, Williams and Norgate, 1899.
Herschell: Cycling as a Cause of Heart Disease, Baillière, Tindall & Cox, London, 1896.

3. Recreative and Hygienic Physical Training.

Lagrange: Physiology of Bodily Exercise, D. Appleton, N. Y., 1896.
Green: Healthy Exercise, Harper & Brothers, New York, 1900.
Blaikie: How to Get Strong and How to Stay So, Harper, New York, 1899.
Sandow: Strength and How to Obtain It, Gale & Polden, London, 1897.
Sampson: Strength, Rand, McNally, Chicago, 1895.
Schmidt: Physical Exercises and their Beneficial Influence, St. Louis, 1894.
Alexander: Healthful Exercises for Girls, Philip & Son, London, 1887.
Harney: Physical Exercises and Gymnastics for Girls and Women, Longmans, Green & Co., London, 1896.
Butts: Manual of Physical Drill, United States Army, D. Appleton, New York, 1897.
Chase: Physical Drill for Foot Troops, Chapman, Washington, 1897.

II. ATHLETIC TRAINING.

Thornton: Training for Health, Strength, Speed, and Agility, Excelsior Publishing House, N. Y., 1890.
Rolfe: Exercise and Training, D. Appleton, New York, 1894.
Faries: Practical Training for Athletics, Outing Publishing Company, New York, 1897.
Schmidt: The Training of the Body for Games, Athletics, etc., Dutton & Co., New York, 1901.

TRANCE. See *Consciousness, Disorders of.*

TRANSFUSION.—Under this title are included the various processes of introducing into the veins of a patient the blood of another person or of an animal. The term is often used more broadly to include also the procedures already described under the titles *Hypodermoclysis* and *Intravenous Injections.*

The possibility of transfusing blood was known to the ancients and was occasionally practised during the Middle Ages. A famous instance is that of Pope Innocent VII., mentioned by Savonarola. The pope was bled and his blood injected into two young men. They were bled in turn and their blood was introduced into the veins of the pope. All three died.

After the discovery of the circulation by Harvey in the early part of the seventeenth century a number of experiments on animals and on man were done with the object of treating various diseases by the transfusion of blood. Attempts were made to cure leprosy, insanity, and other diseases in this way, as well as to combat hemorrhage and shock and to rejuvenate the aged. The names of Libavius, Lower, and Denis are prominent in this connection. They had more or less success In consequence of the death of one of Denis' patients, treated for insanity by the introduction of lamb's blood, the operation was forbidden in France. It was revived in the early part of the last century. It then steadily gained ground as its value became obvious. Only quite recently has it been displaced by the safer, simpler, and equally efficacious method of saline infusions.

The blood of animals and of man has been employed. Many of the early operators used the blood of lambs. The introduction of the blood of an animal of one species into the veins of an animal of a different species is, however, a dangerous procedure, as the blood of one animal destroys the corpuscles of another. Moreover, in man marked toxic symptoms are produced. Even with small doses dyspnœa, sensations of heat and distention, especially in the face and head, backache and headache may come on during the administration. Increased peristalsis with abdominal pain, vomiting and catharsis may occur. In the course of an hour chills and fever are almost always observed. Subsequently hæmoglobinuria, albuminuria, and urticaria are sometimes present.

Defibrinated human blood has also been used. This is objectionable because the process is somewhat complicated and time-consuming, and it is difficult to keep the blood aseptic. A more important objection arises from the fact that the fibrin ferment is formed in the process of defibrination, and is present in the blood injected. There is good reason to fear that intravascular clotting might result.

The immediate transfer of blood from donor to patient without intermediate manipulation is probably the best method. Even this, however, is not free from the dangers of air emboli and of clot formation in the tubes. It is possible, too, that serious diseases might be transmitted. Another objection is the difficulty of securing a donor. These objections are not, however, insurmountable, and the operation has been developed to such a point of safety and convenience that, had not safer and simpler, but almost equally efficient means been devised for accomplishing the same end, there can be no doubt that the operation would be of great value to-day.

Operative Procedures.—These have varied greatly, but in the present status of the operation a detailed description is not necessary. For further details the reader is referred to the excellent article by Dr. Howe in the first edition of this Handbook. For direct transfusion the apparatus of Aveling is perhaps the best. This consists of a rubber tube eighteen inches long, with a small bulb in the middle and a cannula and stopcock at each end. The instrument is boiled, filled with warm, sterile decinormal salt solution (sodium chloride, six-tenths of one per cent.), and every care taken to expel all the air from it. It is kept, while the patient is being prepared, in a basin of the same solution. The arm of the patient is rendered surgically clean, and the most prominent vein near the bend of the elbow is exposed by a short incision and slight dissection. The vessel is opened and one of the cannulæ inserted. The assistant in the mean time has inserted in exactly the same manner the other cannula in a vein of the donor. The latter should be in good health, of strong mental equanimity, and preferably not an anxious relative of the patient. As in phlebotomy the veins may be made more prominent by applying about the arm above the elbow a bandage tight enough to obstruct the venous outflow without stopping the pulse. During the transfusion the bandage should of course be removed from the patient, but may with advantage be left upon the donor.

The cannula in the donor should point toward the fingers, that in the patient toward the shoulder. They

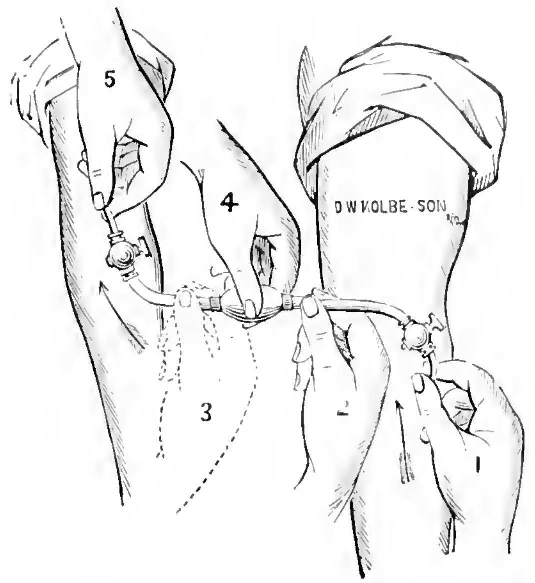


FIG. 4747.—Aveling's Transfusion Apparatus. 1, 5, Hands of the assistant holding the cannulæ in position; 4, hand of the operator compressing the bulb; 2, 3, hand of the operator compressing alternately the afferent and efferent tubes.

need not, as a rule, be tied in. The operator now pinches the tube between the bulb and the donor (*2*, Fig. 4747), and with his other hand opens both stopcocks. He then compresses the bulb, thus driving its contents into the patient's arm. Keeping the bulb compressed, he removes the first hand and pinches the tube on the patient's side of the bulb (*3*, Fig. 4747). Now, the pressure on the bulb itself being released, the apparatus fills with blood from the donor, which, on repeating the process, is forced into the patient's vein. Five to ten ounces of blood should be transfused. The quantity can be calculated from the capacity of the bulb, ordinarily two drachms.

It is said that the bulb is unnecessary as, by properly bandaging the arm of the donor, his intravenous blood pressure may be made sufficient to bring about the transfer.

For the use of defibrinated blood various methods were devised. The simplest way is as follows: The donor is bled into a clean vessel. The blood is then whipped with glass rods till the fibrin is all removed. It is then strained through muslin and kept warm until needed by setting the container in warm water. An ordinary glass funnel with a rubber tube ending in a cannula and guarded by a stopcock may be used for the injection. Syringes of various sorts have been used both with whole and with defibrinated blood. Full aseptic precautions should of course be observed and every care taken to exclude air bubbles.

Peritoneal transfusion, the injection of blood into the peritoneal cavity, is of no practical value and should not be used. *Autotransfusion* consists of increasing the supply of blood to the essential organs at the expense of the limbs. It is accomplished by the application of tight rubber bandages to the legs, beginning at the toes and going upward. It is of undoubted value for temporary use in emergencies where large amounts of blood have been lost, until the volume of the circulation can be made up in other ways. A somewhat similar procedure has been recently advocated for the purpose of maintaining the blood pressure in cases in which the vaso-motor centre has been exhausted by shock—the pressure being applied to the abdomen and extremities by inflating a pneumatic rubber suit.[1]

The principal indication for transfusion is severe hemorrhage. It may be said that in most cases the introduction of salt solution under the skin will be sufficient. Occasionally, where the absorption of such an injection does not take place or where every instant of time is of value, the intravenous route is to be selected. Rarely, if ever, will there be enough advantage in the use of blood to overbalance its greater dangers and difficulties, and the greater delay in administering it.

The repeated intravenous injection of small quantities (5–25 c.c.) of defibrinated lamb's blood has been advocated by Bier[2] for the purpose of bringing about the reactions described in a previous paragraph in cases of old, chronic tuberculosis. Some of his cases were encouraging. *Ralph C. Larrabee.*

[1] Crile: Boston Med. and Surg. Journ., March 5th, 1903.
[2] Bier: Munch. med. Wochenschr., 1901, Bd. xlviii., S. 569.

TRANSPORTATION OF THE DISABLED ON LAND.—The first systematized methods for the care of the wounded in battle and their removal from the field date from 1792, when Baron Larrey, chief surgeon of the French army under Napoleon I., established his system of *ambulances volantes*, or flying field hospitals. Shortly after, in 1800, Percy, another distinguished surgeon of that army, organized companies of *brancardiers*, or stretcher-bearers, whose duty it was to remove the wounded from the battlefield to a place of safety, where they could receive proper care.

Since that period increasing attention has been paid to this subject, until at the present day more or less elaborate systems of military hospitals, and means for transporting the sick and wounded to these hospitals are maintained by all civilized armies.

It should be explained in this connection that in foreign armies by the term "ambulance" is understood the entire movable field hospital, including medical and surgical supplies, the means of transportation, the animals and harness, and the personnel of the hospital officers and men of the sanitary force. In our army the term is restricted to the *ambulance wagon*, in which the sick and wounded are carried. The term ambulance corps in the United States Army comprehends the ambulance wagons, litters and other appliances for transporting the disabled; the baggage and subsistence wagons; the harness and animals, as well as the officers and men who are charged with their control and management. In this article the terms will be used in the same sense in which they are understood in the United States.

In our service the means of transportation, which usually accompany a moving command, are its ambulances

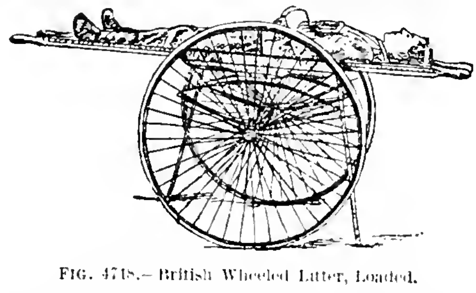


FIG. 4748.—British Wheeled Litter, Loaded.

and hand litters. At times, owing to the character of the country in which the troops are operating, as in regions without roads, the ambulances cannot be employed; in such cases other means must be resorted to. When, owing to excessive casualties or other exigencies, sufficient ambulances are not available, army wagons, wagons or carts of the country, saddle, pack, and draught animals may supplement the ambulances. When rail or water transportation is available and practicable, railroad trains and boats are employed, especially when large numbers of sick and wounded are to be removed to a considerable distance, as in the service of evacuation. It is a military principle that the operating force should not be embarrassed by the care of its sick and wounded any longer than necessary; this enables the field hospitals, which always accompany the moving army, to travel light, makes room for the wounded from an impending engagement, and diminishes the danger of infecting the well by those already diseased. Besides, base and general hospitals being more or less permanent institutions, are better supplied with the necessities and comforts for the care of the sick than would be possible in a hospital which accompanies a moving force.

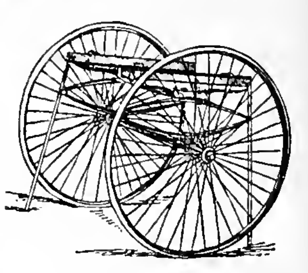


FIG. 4749.—British Wheeled Litter, without Litter.

Ordinarily patients from the battlefield will have to be carried on litters to the dressing station, from which point they are again carried by litters to the ambulance stations; here they are loaded into the ambulances for removal to the field hospitals. Other specially devised means that are used for the transportation of the disabled in the military service are the wheeled litter, cacolet, single or double-horse (or mule) litter, and the travois.

The hand litter has already been described in this work in the article on *Army Hospital Corps* by Major Bushnell, and will not be considered here.

The Wheeled Litter.—The wheeled litter is simply a litter mounted upon wheels, usually two in number, designed to be propelled by a single bearer. Numerous different patterns of such appliances have been devised, varying in design with the character of the service required of them. In some forms the bed for supporting the patient is removable, permitting of its use as a hand litter; in others, it is fixed permanently to the carriage; some are made to fold into a compact bundle to permit of ready packing or shipment; in another form, the litter is mounted between two bicycles, which are joined to the litter frame and to each other by interlocking bars; tricycles arranged "fore and aft" with reference to the litter have also been adapted to form the carriage. The simplest and most practical form consists of two light wheels and an axle, supporting a frame for the litter with a device for holding it in the horizontal position when at rest without the bearer's help. This device consists of two hinged bars of proper length fastened to each end of the frame or carriage, which are swung up and secured by suitable fastenings when the litter is in motion. Usually litters of this class are covered with a removable hood and are mounted upon springs. An excellent type was used by the British military surgeons in the recent war in South Africa, and is shown in Figs. 4748 and 4749. The wheels have steel spokes and rims, rubber tires, and ball bearings; the bed is made to take the British regulation litter, and is mounted upon elliptical springs; the litter is securely held in place upon the bed by means of two buttons with tightening screws. The great object of this carriage is said by its designer, Major McCormack, R.A.M.C., to have been "to obtain mobility, strength, and lightness combined with efficiency and a ready and easy means of transport for sick and wounded, no matter where a patient has to be transported from." Nevertheless, wheeled litters have but a limited range of usefulness. They were extensively tried during our Civil War for the purpose of removing the wounded from the battlefield, but did not meet with favor from our surgeons; they proved to be practically useless over the rough ground upon which battles were fought. In moving patients from one part of a hospital to another, and in villages and towns where ambulance systems do not exist, their utility is undoubted; but in the military service their sphere of usefulness will be largely confined to work in and about hospitals, and in loading and unloading trains; they will here prove economical of men and comfortable to patients.

Horse-litters.—One form of horse-litter is the *cacolet*, which consists of a pack saddle, from each side of which

FIG. 4750.—British Crimean Cacolet. (After Weir.)

is suspended a seat or chair; in this seat the patient is carried in the sitting posture. This form of litter was extensively used by the English in the Crimean war, and by the French in Algeria and Mexico, apparently with satisfactory results. In our service trials were made during the Civil War with this form of litter, but the consensus of opinion of our medical officers, who had experience in its use, was decidedly against this method of transportation for sick and wounded. No doubt this unfavorable opinion was largely due to inability to secure properly trained animals, and perhaps also to the fact that other more satisfactory means were available.

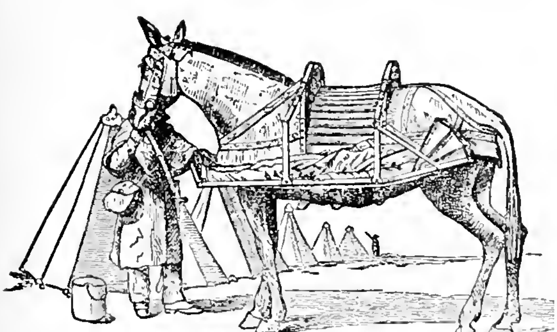


FIG. 4751.—British Crimean Mule Litter. (After Weir.)

Its sphere of utility should properly be confined to work over country that is inadmissible to wheeled transportation. Its successful employment requires strong, docile and well-trained animals, and a comparatively open country; it cannot be employed on a narrow trail running through a heavily wooded region. Fig. 4750 represents the cacolet used by the British in the Crimea.

During the same war the British also made successful use of a mule-litter in which a litter is slung horizontally from each side of a pack-saddle. Like the cacolet, this form of litter has not been favorably considered by our medical officers, and the same objections hold good with reference to it. An additional objection is its weight, which, with its pack-saddle and bedding, is placed at one hundred and sixty-seven pounds; this, added to the weight of two patients, makes a formidable load for the average-sized horse or mule. Fig. 4751 illustrates the arrangement and general appearance of this kind of horse-litter.

In another form of horse-litter a single patient is carried in the recumbent or semirecumbent position upon the back of the animal, either upon a specially devised saddle and litter, or upon an improvised arrangement made by securing the ordinary hand-litter to a pack or riding saddle. An example of the former is the McElderry single mule-litter (Figs. 4752 and 4753), devised by the late Major Henry McElderry, Surgeon, U.S.A., with a view to its employment in operations against the Modoc Indians in the lava beds of California. In this, the frame is hinged, allowing its adjustment at different angles; the hinges also permit it to be folded compactly

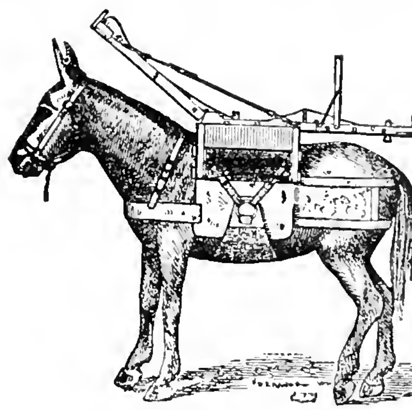


FIG. 4752.—McElderry's Single Mule-litter.

together for facility in its transportation. The saddle to which it is attached when in use is that known as the Mexican *aparejo*, now universally used in pack-trains. Some of the advantages claimed for it by its inventor are that "it is especially adapted for use in broken and mountainous country; long narrow and winding defiles, abounding in sudden and abrupt angles; and in places and under circumstances generally where no other kind of litter could be employed. A wounded man can be transported on this litter with entire safety on the back of any steady pack-mule or horse, taken indiscriminately out of the pack-train; the animal not requiring any special training before he will pack it, otherwise than that already received in the pack-train."

In the improvised form two stout wooden traverses are strongly lashed to the pommel of a riding or pack-saddle, preferably a pack-saddle; upon the outer ends of these traverses two wooden poles or bars are fastened in a longitudinal direction and parallel to each other, forming a framework upon which the litter rests and to which it is securely bound by ropes or other lashings.

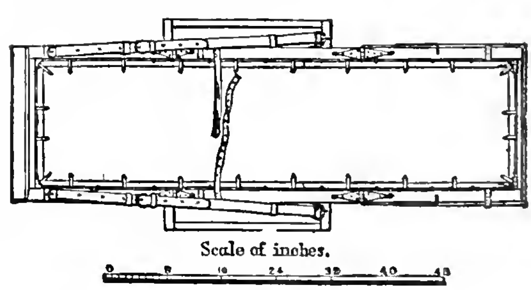


FIG. 4753.—Plan of McElderry's Single Mule Litter.

The patient is carried in the recumbent posture with head toward the head of the animal. In this form of transportation but little lateral oscillation is experienced, though the jolting must be considerable. It is espe-

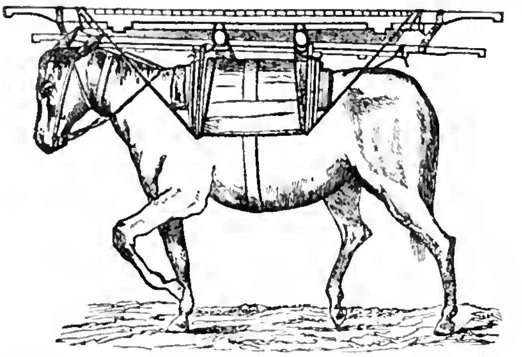


FIG. 4754. Single Mule Litter used by the French in Mexico. (After Gouchet.)

cially adapted to mountainous regions where trails are narrow and the surface of the ground is broken. It is not economical of attendants, as in addition to the man who leads the animal one is necessary to keep the patient from slipping off in going up and down steep places. This method was used by the French in Mexico, through a mountainous country over long distances, and it is reported that the patients bore the journey very well, though complaint was made of the pressure of the forward bow of the saddle upon the patient's back. This was remedied by shifting his position or by using some kind of padding to increase the thickness of the bed at that point. Fig. 4754 represents the method then used. This adaptation is admirable in principle, and can usually be improvised from materials at hand.

The transport of sick and wounded by means of the *two-horse-litter* has commended itself to our military surgeons, and has been frequently employed in campaigns against Indians in the United States and in operations in the Philippine Islands. In this method a litter is suspended between two horses or mules in tandem; it is easily extemporized where suitable materials are at hand. In its construction two stout poles about sixteen feet and a half in length are required, and two cross pieces, about three feet long, which serve as traverses to keep the poles apart. The traverses forming the ends of the litter bed are fastened five feet from the front and rear ends of the poles; between them a piece of canvas, a blanket, or other suitable material is stretched and securely fastened to the sides of the poles and cross pieces. Sick and wounded men can be safely and comfortably carried over long distances by this form of litter. The objections to it are that two animals, and at least two attendants, are required for one patient, and that it cannot be employed upon narrow paths with short turns and steep declivities. At one time (1861) horse-litters of this pattern were regularly issued in our army to "posts whence they may be required for service on ground not admitting the employment of two-wheeled carriages." In these the poles were hinged to permit their packing on pack-animals; the complete litter with straps and girths weighing 88 pounds. These litters are still recognized as means of transport; paragraph 1614, Army Regulations, 1901, authorizes their issue upon recommendation of the chief surgeon, though the writer is not aware that they have been so issued in recent years. In the improvised form they have been recently employed in the Philippine Islands (see Fig. 4755).

Another form of horse-litter, more economical of men and animals, is the Indian travois. This contrivance was in universal use by the North American Indians for the transportation of supplies and other property as well as for carrying their disabled. In this form the front ends of the litter poles are fastened to the sides of the animal like the shafts of a wagon; the rear ends drag upon the ground. One pole is slightly shorter than the other, in order that in passing an obstacle the shock may be received successively by each end and the motion be equably distributed. The travois is now recognized as a regular means of transport for the disabled in our service. The Medical Department Regulations for 1902 direct that ambulances Nos. 1 and 5 in each ambulance company shall carry a travois. Paragraph 148, Drill Regulations for the Hospital Corps, 1902, gives the following instructions for improvising this kind of litter:

"A travois may be improvised by cutting poles about 16 feet long and 2 inches in diameter at the small end. These poles are laid parallel to each other, large ends to the front, and 2½ feet apart; the small ends about 3 feet apart, and one of them projecting 8 or 10 inches beyond the other. The poles are connected by a cross bar about 6 feet from the front ends and another about 6 feet back of the first, each notched at its ends and securely lashed at the notches to the poles. Between the cross pieces the litter bed, 6 feet long, is filled in with canvas, blanket, etc., securely fastened to the poles and cross bars, or with rope, lariat, rawhide strips, etc., stretching obliquely from pole to pole in many turns, crossing each other to form the basis for a light mattress or improvised bed; or a litter may be made fast between the poles to answer the same purpose. The front ends of the poles are then securely fastened to the saddle of the animal. A breast strap and traces should, if possible, be improvised and fitted to the horse. On the march the bearers should be ready to lift the rear ends of the travois when passing over obstacles, crossing streams, or going uphill."

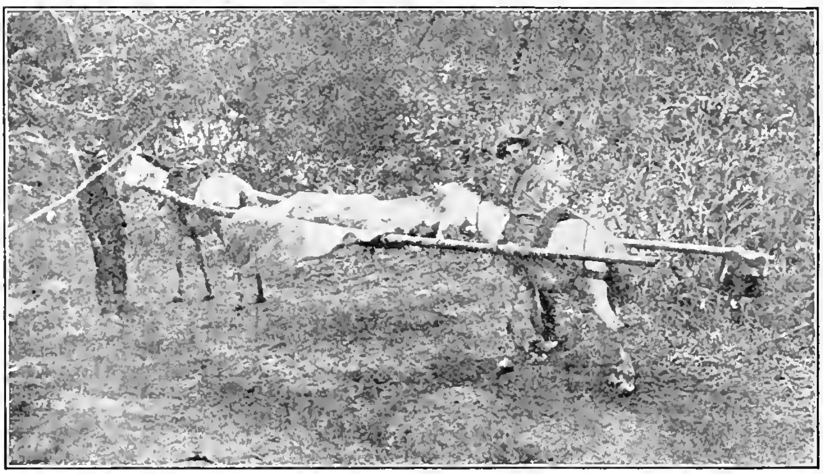


FIG. 4755.—Improvised Two-horse Litter, as used in Philippine Islands.

Colonels Greenleaf and Cleary, of the Medical Department of the United States Army, have each devised a travois which can be used either as a hand-litter or as a horse-litter. In both the shafts are made detachable, being attached to the side poles of the litter proper by means of collars and pins; both can be rolled up, making them easy to transport in wagons or upon pack-animals. Lieutenant-Colonel Havard, Deputy Surgeon General,

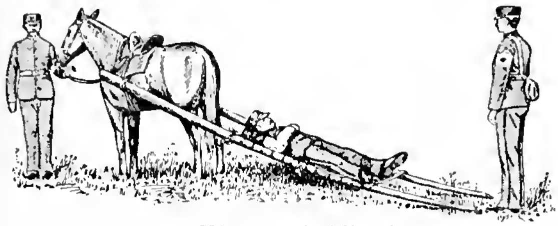


FIG. 4756.—Improvised Travois.

U.S.A., has more recently suggested that this form of litter could be further perfected by making the rear ends of the poles rest upon a narrow two-wheeled truck instead of dragging upon the ground.

The travois, in the absence of ambulances or other wagons, has proved to be a very satisfactory method of transportation by animals. It is comfortable, safe, easily improvised, and can be employed over rough and mountainous country where other methods of animal transportation are not feasible, as well as over level country. Upon a fairly level road the two-horse litter is probably preferable, and in the case of a fractured limb, there is less liability of disturbance of the fragments, as in this mode of transport the patient is carried in a horizontal position. For general utility and especially where economy in men and animals has to be considered, the travois will be found superior. Medical officers who have had experience with them look upon them with favor, and Havard has wisely suggested that two, to be carried by pack-mules to the front, be provided for each regiment in the field under circumstances where ambulances are not available. Fig. 4756 shows an improvised travois in its simplest form. In all these forms of litters intended to be drawn or carried by animals mules are generally to be preferred to horses, in that they are patient, more quickly trained, surer-footed, and accustomed to carry burdens.

Devices intended for attachment to the saddle, with the object of supporting a sick or wounded man upon a

FIG. 4757.—The Improved Army Ambulance, Pattern of 1900.

horse, have been suggested at various times; but on trial all such arrangements have been found to be impracticable. If necessary to support a disabled man on a horse, a comrade mounted behind him will answer the purpose, or a lean-back made of a blanket-roll, a bag stuffed with grass, or a sapling bent into an arch over the cantle of the saddle, may be secured to the saddle and the patient bound to it.

The Ambulance.—The requirements of a good military ambulance are that it shall be of sufficient structural strength, due regard being had to lightness, to withstand the rough usage to which it is liable in active service; so constructed as to permit its turning in a space equal to its length; it should be able to travel over rough, sandy, or muddy roads; comfortable to its occupants when partially as well as when fully loaded; capable of carrying patients both in the recumbent and in the sitting position; it should have provisions for carrying small quantities of dressings, food, stimulants, water, and patients' effects, without intruding upon its carrying capacity for patients; also so designed as to permit rapid loading and unloading. The present pattern of the United States Army ambulance (Fig. 4757, pattern of 1900), known as a Munson's modification, has been evolved from the older types and fulfils these requirements. It is an excellent wagon and possesses features that are found in no other military ambulance. It is a four-wheeled vehicle intended to be drawn by either two or four horses; the body is 9 feet long and 4 feet 7½ inches

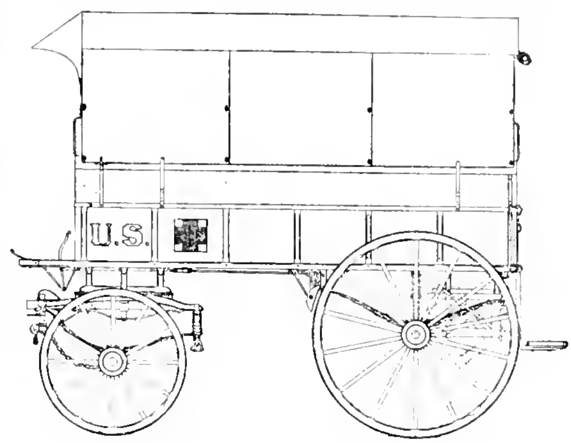


FIG. 4758.—Side View of Improved Army Ambulance.

wide, outside measurements; the height of the floor is 3 feet 8 inches above the ground. The space for patients is 7½ feet long and 4 feet 4½ inches wide; in front of this space is the driver's seat, wide enough for three occupants; under the driver's seat is a box 4 feet long, 10 inches wide and 16 inches high, for storing extra parts and other articles. The body is covered by a wooden roof supported by wooden bows; the height of the roof in its centre is 5 feet from the floor; the sides and rear end are provided with curtains, which can be rolled up; a division curtain, which also is made to roll up, extends across the wagon just back of the driver's seat; all curtains are made of pantasote; the roof is likewise covered with this material. At the rear is attached a step 2 feet above the ground; the rear of the body is closed by a tail-gate. The body is swung on

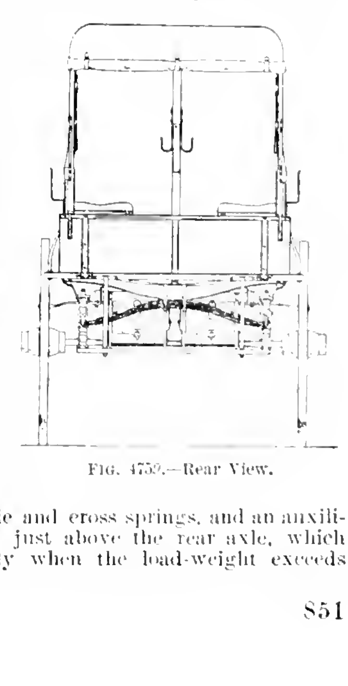


FIG. 4759.—Rear View.

the axles by both side and cross springs, and an auxiliary spring is placed just above the rear axle, which comes into play only when the load-weight exceeds

400 pounds. The ambulance is provided with an efficient foot brake, operated by the driver; the brake lever passes through the centre of the footboard and is furnished with a ratchet which engages in a rack

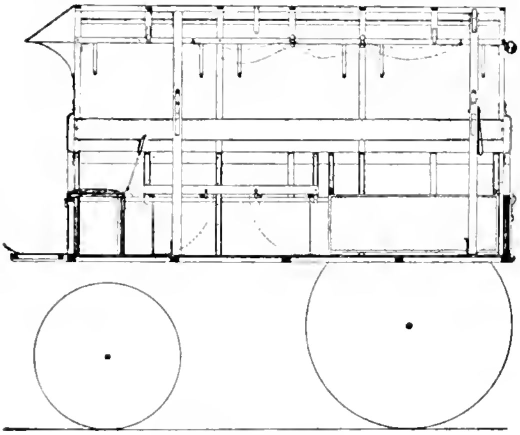


FIG. 4760.—Vertical Section.

in the footboard. The diameter of the hind wheels is 4 feet 2 inches, of the front wheels 3 feet, exclusive of the tires; tires are of steel, 2¼ inches wide and $\frac{7}{16}$ of an inch thick; the track of the vehicle is 5 feet 2 inches over rims. Two cylindrical water tanks, 15¼ inches long, 10¼ inches in diameter, made of No. 22 galvanized iron, each provided with a compression bibcock, are suspended in stout wooden frames from underneath the body, just behind the rear axle; each tank has a capacity of 40 litres. The interior of the ambulance is fitted with four removable seats, two on a side, which, when not used as such, are hung against the sides. The cots are regulation hand-litters, four of which are carried by each ambulance. When used to carry recumbent cases two litters rest upon the floor; the other two are suspended by hooks and straps from the litter-supporting posts and the curtain rails respectively, 27 inches above the floor. The use of the hand-litter, instead of a special cot, allows the patient to be loaded into the ambulance without being transferred from the litter, upon

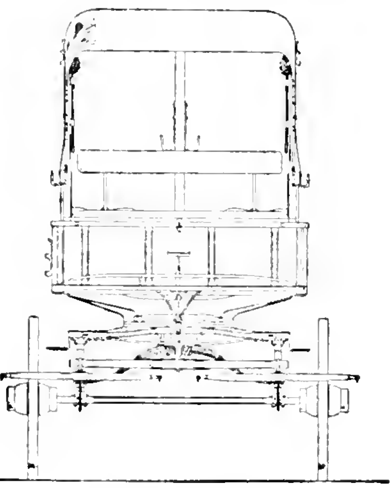


FIG. 4761.—Front View.

which he is carried to the wagon. The litter-supporting posts are wooden uprights, 3 inches square, placed 73 inches apart; the front post is placed 1 foot behind the driver's seat, and is stationary, being secured to the roof and floor; the one at the rear is hinged at the top; when the upper berths (litters) are not to be used, it is strapped to the roof. When the upper berths are to be used, it is unstrapped, swung into a vertical position, and its lower end is secured to the floor by means of an iron shoe and bolt. Upon each side of the litter-supporting posts is a hook for the support of the inside handles of the litter, and opposite each hook, fastened to the inside of the curtain rail, is a strap to hold the outside handles. A hammock net is also fastened by hooks to the inside of the curtain rail on each side; these are for carrying clothing or equipments of the patients. This ambulance will carry patients either recumbent or sitting up, or both classes of patients together, viz., 12 sitting, or 2 recumbent and 6 sitting, or 4 recumbent. Figs. 4758, 4759, 4760, and 4761, show the general plan of construction of this vehicle.

In most of the European armies ambulances are accompanied by light carts, which carry dressings, drugs, foods, etc.; in our service these articles are carried by each ambulance as follows:

CONTENTS OF AMBULANCE BOX OF HOSPITAL STORES.

(In metal box, packed in rectangular galvanized-iron boiler with lid, enclosed in iron fire grate, carried under body of ambulance.)

Arrowroot	pounds,	2
Beef, soluble liquid, or extract, in 100 c.c. containers	containers,	6
Brandy, in 500 c.c. bottle	bottle,	1
Can opener	number,	1
Chocolate, sweetened	pounds,	3
Condensed milk, unsweetened, in commercial tin	tins,	6
Malted milk	pounds,	2
Matches, safety in waterproof tin	boxes,	2
Pepper, black, ground, in dredge with screw cap	ounce,	1
Salt, in dredge with screw cap	ounces,	3
Sugar, white, granulated	pounds,	3
Tea, black or green	pound,	½

CONTENTS OF AMBULANCE BOX OF SURGICAL DRESSINGS.

(In metal box, packed in rectangular water boiler with lid, enclosed in iron fire grate, carried under body of ambulance.)

Antiseptic tablets, 125 in 125 c.c. bottle	bottle,	1
Bandages, plaster of Paris, two-inch	number,	6
Bandages, roll, sterilized, gauze, two one-half-inch	number,	24
Chloroformum, in 125-c.c. bottle	bottle,	1
Cotton, absorbent, in 30-gm. package	packages,	12
First-aid packets	number,	24
Gauze, iodoform, sterilized, 0.5 metre in package	packages,	12
Gauze, plain, sterilized, two 0.5 metre pieces in package	packages,	20
Morphinæ sulphas, 8-mgm. hypodermic tablets	tubes,	8
Pins, safety	dozen,	4
Plaster, adhesive, in roll 30 cm. wide	number,	2
Strychninæ sulphas, 1-mgm. hypodermic tablet	tubes,	8

SPARE PARTS AND ADDITIONAL ARTICLES CARRIED BY EACH AMBULANCE.

Axle grease	pot,	1
Boilers, galvanized iron, with lid	number,	2
Bolt, king, extra	number,	1
Brush, horse	number,	1
Bucket, galvanized iron	number,	1
Color, camp	number,	1
Comb, curry	number,	1
Dressings, surgical, in metal box	box,	1
Grates, fire, iron	number,	2
Guidon, ambulance	number,	1
Hatchet	number,	1
Hospital stores in metal box	box,	1
Lamps, ambulance	number,	2
Lanterns, extra, one white, one red, in space under seat	number,	2
Lantern wicks, extra	number,	6
Link, split	number,	1
Litters, hand	number,	4
Oil, mineral, in space under seat	tin,	1
Tanks, water	number,	2
Whip	number,	1
Wrench, monkey	number,	1

NOTE.—In addition to the above, ambulances Nos. 1 and 5 will carry an extra pole and a travois.

The allowance of ambulances for troops in active service in the United States Army is estimated upon a basis of one ambulance to 400 men of the effective force. Three ambulance companies, usually one company to each brigade, are ordinarily attached to each division of normal strength; nine ambulances is the number prescribed for each company. For a battery of artillery, detachment of infantry, or squadron of cavalry, operating independently one ambulance is allowed. The strength of the armies of the United States in time of war is not fixed either by statute or by regulation; hence a division may be composed of a variable number of troops. Usually it has consisted of three brigades of two or three regiments to the brigade, varying accordingly between 12,000 and 18,000 men; upon a basis of one ambulance to 400 men, the division ambulance corps should contain 30 to 45 ambulance wagons. Havard recommends as a basis 3 ambulances to 1,000 combatants, and in his scheme of organization provides for 12 ambulances to each ambulance company, assuming the strength of the division at about 11,000 men. Reynolds recommends 15 to each company,—the division strength being assumed at about 13,000 men. It is difficult to estimate even approximately how much ambulance transportation should be provided for wounded after a battle of magnitude between forces equally well-armed with modern firearms. Recent experiences have shown that the ratio of wounded to the strength engaged is not far from 12 per cent. With a division of 12,000 to 18,000 men this would give 1,440 to 2,160 wounded; probably one-third of this number would not require ambulance transportation, while about 1 in 12 would be so seriously wounded as to make their immediate transportation beyond the dressing station inadvisable; excluding these, there would remain 880 wounded for a division of 12,000, and 1,320 for a division of 18,000, for whom ambulance transportation would be required. The present model of regulation ambulance would probably average 8 men per trip, and with the field hospitals situated near enough to permit each ambulance to make 4 trips, 28 to 40 ambulances would be needed for a division of the strengths mentioned. It must not be understood that the allowance laid down by Medical Department regulations is inflexible; it simply serves as a basis, and may be changed as the exigencies may require.

The following regulations for ambulance drill are those prescribed for the present pattern of ambulance, as laid down in the "Drill Regulations and Outlines of First Aid for the Hospital Corps, United States Army, 1902":

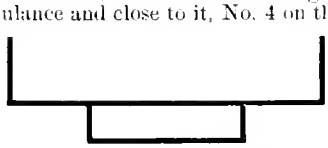
AMBULANCE DRILL.—The litters are said to be *packed* when they are strapped and placed upon the brackets. The seats are said to be *prepared* when they are horizontal, supported by the legs; and *packed* when they are hooked against the sides of the wagon.

To take posts at ambulance.

Being in line:

1. *At ambulance;* 2. POSTS.

The designated squad marches in a column of files to the ambulance; when No. 1 takes post on the left, No. 2 in the centre, and No. 3 on the right of the rear of the ambulance and close to it, No. 4 on the right of No. 3.



1 2 3 4

In the case of a litter lowered in rear of ambulance preparatory to loading, head of patient toward it, at the command *posts*, each number faces about and proceeds directly to his post.

This is the invariable position of the squad *at ambulance posts;* it may be taken from any position (the litter, if any, being *grounded* or *lowered*), and when disarranged, from whatever cause, the squad may be reassembled by these commands for service at the ambulance.

The ambulance having seats *packed* and the squad being *at ambulance posts:*

1. *Prepare;* 2. SEATS.

Nos. 1 and 3 raise the curtain, if necessary, and open the tail-gate; Nos. 2 and 3 enter the ambulance, No. 2 facing the front and No. 3 the rear seat of their respective sides. Each man seizes the lower edge of the seat about six inches from the ends with both hands and lifts it; he lowers the legs and adjusts them to the floor and tries the seat for firmness before leaving it. He then prepares in like manner the opposite seat. No. 3 unfastens the litter-supporting post and swings it to the front of the ambulance, where it is grasped by No. 2, who lifts it to its place and straps it. Nos. 3 and 2 now resume their positions *at ambulance posts.*

The ambulance having seats *prepared*, and the squad being *at ambulance posts:*

1. *Pack;* 2. SEATS.

Nos. 1 and 3 raise the curtain, if necessary, and open the tail-gate; Nos. 2 and 3 enter the ambulance and face the front and rear seats of their respective sides; each man releases the legs and secures them against the seats, then, seizing the front of the seat with both hands, lowers it to the side of the ambulance, and then makes in like manner the opposite seats. No. 2 then unfastens the strap which holds the litter-supporting post to the roof of the ambulance, swings the post to a vertical position, and places it firmly in its socket. Nos. 3 and 2 now resume their positions *at ambulance posts.*

Seats can be prepared or packed on one side only, leaving room on the packed side for two recumbent patients by the commands:

Prepare (or *pack*) *seats, right* (or *left*).

The litter being *lifted* at the commands:

1. *Take post to load ambulance;* 2. MARCH.

the squad proceed to the ambulance. No. 4, starting ahead in double time, lays the arms and accoutrements of the patient (which he carries) on the ground by the right rear wheel; he then raises the curtain, if necessary, opens the tail-gate, observes the condition of the ambulance, and (resuming his post at the litter) reports it to the squad leader. Upon approaching the ambulance the litter is wheeled about so that the head of the patient is toward the rear of the ambulance and two paces from it, when the litter is halted and lowered. If it be necessary to prepare the ambulance before loading, the squad takes posts at ambulance, No. 4 remaining in charge of the patient; if ready for the reception of the lower litter (or berth) the commands are given:

1. *Prepare to load;* 2. LOAD.

(*a*) At the first command No. 2 faces about, No. 3 steps around his left handle and takes post at the patient's left shoulder; No. 1 takes post opposite No. 3; all facing the litter stoop, No. 2 grasping his handles, and Nos. 1 and 3 their respective poles; No. 4 watches the patient and otherwise renders any needful assistance. At *load*, the bearers slowly raise the litter to the level of the floor of the ambulance and advance to it, being careful to keep the litter in a horizontal position; the legs are placed on the floor by Nos. 1 and 3, and the litter pushed in by No. 2, assisted by the others. When this is accomplished, Nos. 1, 2, and 3 are in position *at ambulance posts.* No. 4 places the arms and accoutrements of the patient (if any) under the litter, and then takes his position on the right; Nos. 1 and 3 close the tail gate and, if necessary, lower the curtain. The squad may then be faced to the left or about and marched in any desired direction.

(*b*) 1. *For upper berth, prepare to load;* 2. LOAD.

At the first command the bearers face about and Nos. 2 and 3 stoop and grasp their respective handles.

At *load* the litter is lifted and advanced to the rear of the ambulance, when Nos. 1 and 4 face the litter and grasp their respective poles opposite the patient's shoulders; No. 3 relinquishes hold of the front handles, mounts the step (see Fig. 4762, loading upper berth, No. 1) and enters, when he resumes hold of the handles, as in passing obstacles. The litter is raised and passed into the ambulance, care being taken to keep the litter in a horizontal position (see Fig. 4763, loading upper berth, No. 2); No. 3, inside at the front, and No. 2 on the rear step, place the left (or right) handles in the receiving sockets and slip the straps over the right (or left) han-

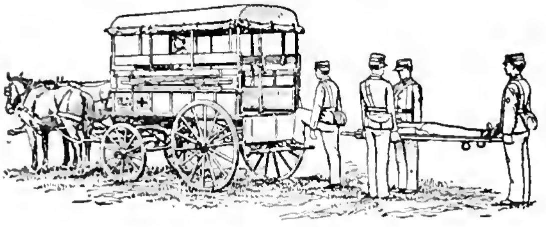


FIG. 4762.—Loading Upper Berth, No. 1

dles. Nos. 1 and 4 assist in loading by supporting the litter on their respective sides until the handles have been secured; No. 3 steps over the front seat, jumps to the ground, and the squad takes position at ambulance posts. No. 4 places the arms and accoutrements of the patient, if any, in the hammock, and then takes his position on the right; Nos. 1 and 3 close the tail-gate and, if necessary, lower the curtain. The squad may then be faced to the left or about and marched in any desired direction.

(*a*) The squad being *at ambulance posts:*

1. *For lower berth prepare to unload;* 2. UNLOAD.

At the first command, Nos. 1 and 3 raise the curtain, if necessary, open the tail-gate, and No. 2 takes hold of

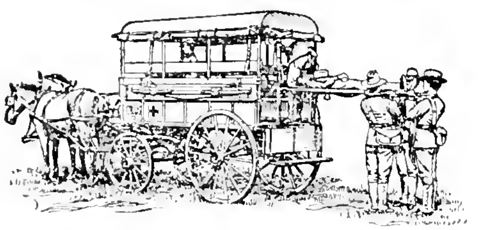


FIG. 4763.—Loading Upper Berth, No. 2.

the protecting handles of the litter; at unload, No. 2 draws out the litter, assisted by Nos. 1 and 3, who, facing inward, support the poles until the inner handles are reached. The litter, carefully supported in a horizontal position, is then lowered with the head of the patient two paces in rear of wagon; No. 4 closes the tail-gate, and all take posts at the litter.

(*b*) The squad being *at ambulance posts:*

1. *For upper berth, prepare to unload;* 2. UNLOAD.

At the first command Nos. 1 and 3 raise the curtain, if necessary, and open the tail-gate; No. 3 runs to the front of the ambulance, climbs in, stepping over the front seat, and faces the rear, grasping the front handles. No. 2 mounts the step and grasps the rear handles. Nos. 1 and 4 face the litter (see Fig. 4764, unloading upper berth). *At unload,* the handles are lifted and freed from their fastenings by Nos. 2 and 3; the litter is carried out, Nos. 1 and 4 on their respective sides supporting the litter, first at the foot and then at the head, as Nos. 2 and 3 step down from the ambulance. The litter, carefully supported in a horizontal position, is then lowered, with the head of the patient two paces in rear of the wagon; No. 4 closes the tail-gate and all take posts at litter.

(*a*) To load lower berth with two bearers, the litter being lowered in position for loading, at *prepare to load,* the bearers take posts on their respective sides, mid-length of the litter and facing it; they stoop and grasp each pole firmly with both hands. *At load,* they lift the litter and push it into the ambulance.

At *unload,* each bearer grasping his handle, they partly withdraw the litter, then shifting their hands to their respective poles and facing each other, they continue to withdraw it until the head reaches the rear of the ambulance, when they lift the litter out and lower it to the ground.

(*b*) To load the upper berth with two bearers, the lower berth is first loaded, as here described, and the litter is then lifted to its position and secured, one bearer inside the ambulance at the front handles and the other on the step at the rear handles. To unload, this movement is reversed.

The right side of the ambulance is always loaded or unloaded first, unless otherwise ordered. With more than one recumbent patient, the upper berth should be the first to be loaded and the last to be unloaded. The lower berth is the last to be loaded and the first to be unloaded.

When necessary to load the feet first at the commands: *By the feet, take post to load ambulance, march,* the litter is lowered with foot toward the ambulance, when the loading proceeds as above described, excepting that No. 3 remains between his handles, No. 2 takes post opposite the right ankle, and No. 4 opposite him.

At the conclusion of the drill with ambulances the detachment is reformed in line.

Two-wheeled ambulances designed to be drawn by a single animal have met with favor in nearly all the European armies, and during the Civil War were supplied to the United States troops. They are usually made to accommodate two recumbent or four sitting-up cases. Their principal advantages lie in their lightness and ability to cover ground which is impracticable for a four-wheel vehicle. They proved to be unsatisfactory in our Civil War, and were generally unfavorably reported upon by the medical officers who had had experience with them. They were found to be uncomfortable to their occupants on account of the jolting, and, being of light construction, were easily broken. The reason they have met with more favor in Europe than in the United States is no doubt due to the fact that our roadways are generally inferior to those of Europe. There can be little economy in their employment, as their carrying capacity is less than half that of our present service ambulance. Theoretically, a light two-wheeled vehicle should be admirably adapted to the removal of the wounded from the battlefield; but practically this can be done more expeditiously and with greater comfort to the wounded and safety to the injured and their bearers by hand-litters. The British in the South African War made use of the Indian "tonga," a light two-wheeled vehicle drawn by two ponies, for the transportation of wounded: it accommodates two recumbent patients. It is reported as having given satisfaction, and is described as being "so well arranged and padded that the occupants are seldom hurt by striking against the sides with rough jolting, unless quite helpless."

In cities the motor ambulance has almost entirely superseded the horse ambulance in the transportation of the disabled. However satisfactory this vehicle has proved to be for urban use and in regions where good

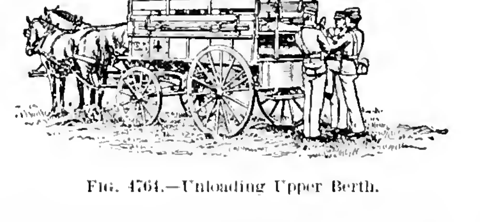


FIG. 4764.—Unloading Upper Berth.

roads exist—and its superiority under such conditions is unquestioned—it is doubtful whether it can ever entirely replace the present service ambulance in the transportation of the sick and wounded of the military service. A military ambulance must be able to go over any ground practicable for wheeled vehicles—over steep grades, through mud, sand, and ruts. Its construction must be simple, so that it can be managed by the average enlisted man, and when disabled must be capable of being readily repaired with the materials at hand and by the men who accompany it. The motor wagon does not as yet fulfil these requirements. About the base and at times perhaps along the lines of communication a motor ambulance would prove a satisfactory substitute for the present service wagon; but only exceptionally could it accompany the field hospitals or reach the ambulance stations. In several of the European armies motor vehicles are used for hauling wagon trains and transporting staff officers, couriers, and supplies, and recent trials have demonstrated that, within certain limits, this means of transportation is feasible for military purpose. Perhaps the future will develop a motor ambulance which can be used under all military conditions. The advantages of such a vehicle would not be inconsiderable; there would primarily be a great saving in the transportation of animals and forage; the fuel, if it be a fuel motor, would probably be of small bulk; and the increased speed of such a vehicle would extend its operations and increase its carrying capacity. So far as known to the writer, a motor ambulance which fulfils all the requirements of the military service has not yet been produced.

Circumstances must often arise when ambulances are not available for the transportation of the disabled, and after an important engagement with excessive casualties the number of ambulances, even with a most liberal allowance, will hardly ever be sufficient in number to remove promptly all the wounded; so, too, in the service of evacuation from the field into base and general hospitals, rarely will it happen that additional transport will not be required. Recourse under such conditions must then be had to other means. If railroad trains are impracticable, there will usually be army wagons, and the wagons and carts of the country; at times artillery caissons, though poorly adapted to this purpose, have been so employed. Where cots or litters are at hand, they should be used for the recumbent patients; the army wagon, with cover, which can carry two recumbent patients on litters or cots, or three recumbent without litters, or eight sitting-up cases, has often proven a satisfactory substitute for the ambulance.

When litters or cots are not available, the bottom of the wagon should be covered with a bed of hay, straw, leaves, or other material. Wagons with springs, for obvious reasons, are always to be preferred. Elastic rods of wood, properly covered with canvas and hay, laid across a wagon box, make a very good springy bed, or such a bed may be made by interlacing straps or ropes across a wagon body. Hay wagons with a thick layer of hay in the bottom make fairly comfortable conveyances for the disabled. Sleighs and sleds suggest themselves as excellent means for the transportation of the sick and wounded; the advantages of their employment under favorable conditions are so evident that further remarks regarding them are unnecessary.

In the service of evacuation, by which is understood the transportation of the sick and wounded from the field or division hospitals to the more permanent hospitals at the base and beyond, the means of transportation already mentioned will usually be inadequate, even if these means were available for such service. General and base hospitals are usually located with a view to their accessibility of communication with the operating force; if roads do not already exist, they are constructed as the troops move on. So, too, if the exigencies of the campaign require railroads or lines of steamboats, these will be constructed or established. Thus the means of transportation that carry forward troops and supplies to the front may be utilized in bringing back the disabled. The service of evacuation is of importance, as by it the field hospitals are emptied, enabling them to move promptly and expeditiously with their respective commands, holds them ready for the reception of the sick and wounded from subsequent military operations, and removes centres of disease from the active army. Besides, at the more permanent hospitals the sick and wounded can be better cared for than would be practicable in a moving hospital.

In some of the European armies hospital trains, made up of cars especially constructed and equipped for carrying sick and wounded, are maintained as part of the transportation of the army. In such trains the hospital cars are fitted up as wards, the beds being either fixed berths or litters are used as berths, upon which patients may be carried to and from the cars. The regular hospital car of the German hospital train has twelve beds with hair mattresses, bedside tables, two reclining chairs, hammocks for clothing, lavatories and lockers. The beds can be lifted off and used as litters, and are arranged on a system of springs, allowing universal motion. A kitchen car is attached to each train, and is equipped with ranges, refrigerators, cooking utensils, and crockery, etc., sufficient for three hundred sick. A freight car is also attached, for carrying baggage and stores. Hospital trains are more often improvised from such rolling stock as may be available, and for this purpose sleeping-cars, passenger coaches, baggage and freight cars may be used.

During the War of the Rebellion in the United States many thousand wounded were transferred from the front to general hospitals by rail; after the battle of Chancellorsville, for instance, 9,000 men were moved from the army in three days; and after the battle of Gettysburg 15,425 wounded were moved in fifteen days. In several cases more than a thousand patients were reported as having been carried upon a single train. It is manifestly impracticable to have at hand sufficient regularly fitted and equipped hospital cars to transport such large numbers of disabled men, and in the instances above cited the trains were composed almost entirely of freight cars, both box and open cars; the floors of the cars were covered with a thick bed of hay, grass, straw, or leaves, upon which the patients were laid; the open cars were covered with an improvised roof of canvas.

Ordinary passenger coaches are also used for carrying sick and wounded; in some cases the seats are removed and the patients laid upon the floor, either upon litters, or upon bedsacks, or loose hay or straw. Where the seats are not removed, berths may be made by laying boards across from seat to seat or over the backs of the seats. During the war just referred to our hospital trains were usually composed of freight cars and passenger coaches, which had been converted into hospital cars by placing two rows of stout stanchions on each side of the car at distances corresponding to the length and breadth of the litter. From pins or hooks fastened to the stanchions the litters were suspended in two or three tiers, depending on the height of the car. In some cases india-rubber rings were employed for suspending the litters, on the theory that the elastic action of the rings would minimize the vibration and jolting; experience demonstrated, however, that if the rings were thin enough to permit their elasticity to come into play the jolting was increased; while, on the other hand, if the rings were thick and strong, there was no elastic action, and any other method of suspension acted as well. In another plan, fixed berths were constructed in the cars by means of boards and stanchions arranged as described above. Upon these the patients were placed either upon the litters which brought them to the train, or upon mattresses or bedsacks filled with straw. In the recent Boer War in South Africa the British converted freight cars into hospital cars by this method; the berths were arranged in two tiers (Fig. 4765). Makin says of these cars that they "seemed to offer little scope for improvement except in minor details. To them much of the success in the treatment of the wounded, who had to traverse the immense distances incident to South Africa, must be attributed." A train of hospital cars fitted up in England and sent to South Africa, in which the berths were arranged in three tiers, was reported upon as having been less satisfactory.

In the German army the regular hospital trains are supplemented, when the necessity therefor arises, by improvised trains composed of freight cars. For this purpose "knock-down" lockers for carrying the required equipment, and springs which reach across the bottom of the car, each of which will support four litters, are held in readiness.

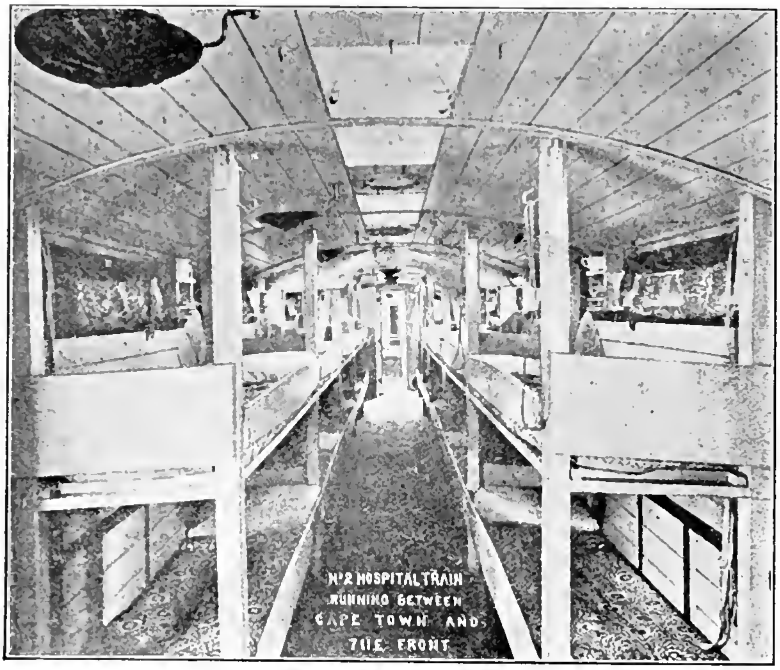


FIG. 4765.—Interior of British Hospital Car. (After Makin.) (Boer War in South Africa.)

In another arrangement litters are suspended from supports by means of chain slings with spiral springs.

In the English, French, and Norwegian services freight cars are converted into hospital cars by a system in which the litters are supported in two tiers in hinged frames, suspended from ropes running across the top of the cars. In this system, which is known as Zavodovski's (Fig. 4766), the frames in which the litters rest are not rigidly fixed, thus permitting a slight swaying motion, which to a certain extent relieves the vibration and jolting.

During the Spanish-American War a regularly equipped hospital train was in operation transporting sick and wounded from the different division hospitals to the general hospitals. This train was composed of ten hospital cars, a kitchen and dining car, a combination car, and a so-called "private" car, which latter was used as quarters for the officers of the train. The hospital cars were of the type known as Pullman "tourist" sleeping-cars, chartered from the Pullman Company. In these cars the seats, which are arranged in pairs facing each other, may be converted into beds; above these seats is a tier of beds, secured by hinges to the side of the car; when not in use these beds are swung up to the roof and locked there by suitable fastenings. The space under the seat is enclosed, forming a box in which the bedding is kept when not in use; the upper berth, when closed, contains its bedding likewise. Each car has lockers for bed linen and clothing, fixed wash basins, water tanks, and closets. In this train each berth was supplied with mattress, sheets, pillow, and pillow case, and a pair of blankets, and each car was provided with the usual appliances needed in a hospital ward, such as bed pans, urinals, basins, etc. The cars were without carpets or curtains, for obvious reasons; the seats were of woven cane, a point of some moment where sick and wounded are to be carried. Some of the cars had twenty-four berths, others twenty-eight, making the capacity of the train about two hundred and forty. If only convalescents were to be carried and the journey was of short duration, the train could accommodate double that number without crowding. The dining and kitchen car was of the pattern used in the passenger service of our railroads. It contained a compact and complete kitchen, with range, refrigerators, cooking utensils, and appliances sufficient for the full carrying capacity of the train. In this kitchen were prepared all meals for patients, including special diets, as well as those for the entire personnel of the train. The combination car contained a baggage and a passenger compartment; the baggage compartment was the train storeroom, in which were carried patients' effects, stores, tools, bedding, tents, litters, etc.; the passenger compartment, from which most of the fixed seats had been removed, was used as the train office, dispensary, and operating room, and was equipped with desk, medical and surgical chests, and a folding operating table.

In loading the train with patients it was "broken" after every second car, sufficient space being allowed between the cars to permit of easy handling of the litter; this was passed upon the platform by two bearers, one end reaching through the doorway; from here it was taken by another squad of two men who carried it into the car, and with the assistance of a third bearer transferred the patient to the bed. Patients requiring special attention or who were helpless were placed in lower berths, where they could be more conveniently attended. Upon the arrival of the train at its

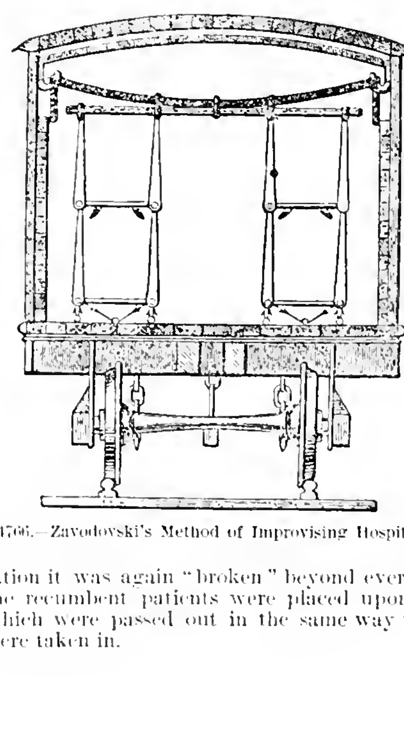


FIG. 4766.—Zavodovski's Method of Improvising Hospital Cars.

destination it was again "broken" beyond every second car; the recumbent patients were placed upon the litters, which were passed out in the same way in which they were taken in.

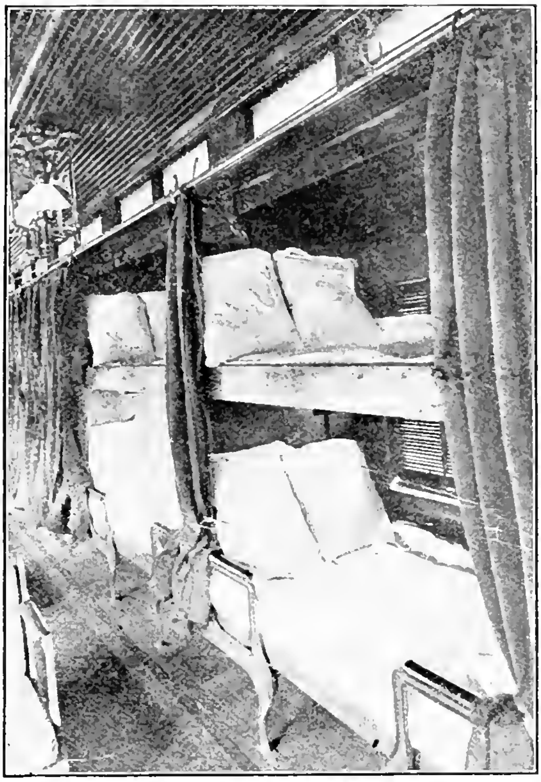


FIG. 4767.—Interior of Tourist Sleeping-Car, with Beds Prepared. Used during Spanish-American War, 1898. (This illustration should be without curtains or carpet.)

Stress has been laid by military surgeons upon the advantage of transporting patients (especially wounded) on trains upon the litters which bring them; this advantage is more fancied than real, as with trained men patients, even though severely wounded, can be safely and comfortably transferred from litters to beds and from beds to litters.

In the instances where the receiving hospitals were situated at a distance from the railroad track, electric street cars were used to transfer patients from the train to the hospital. In these, recumbent patients were placed upon mattresses laid upon the seats and upon litters resting on the floor. When the hospital was near the railroad track, patients were transferred to it by hand-litters or ambulances.

This train was not merely a railroad ambulance, but a moving hospital, organized and equipped to treat sick and wounded as well as transport them. Its personnel was quartered and subsisted upon it during the entire period that it was in operation, and the usual hospital routine and discipline were observed. It made many journeys of more than a thousand miles in length and of two days' duration. Patients were examined and prescribed for on admission, and their diagnoses were recorded; while en route regular morning and evening visits were made, and the more seriously ill were visited as often as was deemed necessary; wounds were dressed and minor operations performed. Cases of all kinds, except contagious diseases, were carried, and it is worthy of note here that they generally bore the journey well in spite of the heat and dust which prevailed during the summer months. Even typhoid fever cases in the first week and during early convalescence were not unfavorably affected, though those in the height of the disease, as might have been expected, did poorly.

Cars of the type constituting this train are heavy in weight and construction, and are mounted upon six- or eight-wheel trucks; they are supported upon the trucks by an efficient system of springs; these factors tend to lessen the vibration and jarring incident to all railroad travel, a matter of consideration where sick and wounded are to be carried. Such cars have ample window space, are readily ventilated, and easy to keep clean; the aisle running through the car lengthwise from door to door between the beds permits of convenient and expeditious loading and unloading of the litter cases, while the facility with which the seats can be converted into beds and *vice versa*, enabling patients to sit up or lie down as the necessity of their cases might require, is a valuable feature possessed by no other improvised hospital car. Fig. 4767 shows the interior of such a car with beds prepared; Fig. 4768, with seats prepared.

Undoubtedly the best type of railroad car for the improvised transport of sick and wounded over long distances—in the United States at least—is the Pullman tourist sleeping-car, or a car similar to it in construction and arrangement.

Hospital trains composed of cars especially devised and constructed for the transportation of the sick and wounded of the military service would possess many valuable features, which are either impracticable or impossible in any improvised arrangement, and would be most desirable adjuncts to an army. Few governments, however, find it expedient or necessary to maintain such trains on hand ready for use; consequently such means as are available or can be speedily made so will have to be employed. For short hauls and in sudden emergencies almost any kind of rolling stock can be used, and will prove satisfactory. Baggage, freight, and ordinary

FIG. 4768.—Interior of Tourist Sleeping-Car, with Seats Prepared. Used during Spanish-American War, 1898.

passenger cars are usually at hand, as they will have brought troops and supplies to the front, and under these conditions may be used without making any changes in them. But for systematic work, as in the service of evacuation, and where sick and wounded are to be transferred over distances requiring more than three or four hours of travel, better arrangements should be provided. Under such circumstances, in the absence of specially devised and equipped hospital cars, sleeping-cars of the type described above are desirable. When these cannot be secured, such cars as may be available must be so arranged as to permit the transportation of the sick and wounded with the least discomfort. Fixed berths or supports for litters must be erected; a water-supply, water-closets, lockers for linen, seats for attendants and for patients who are able to sit up, should be provided. If box cars are converted into hospital cars, special provisions must be made for heating, lighting, and ventilation. One car will be fitted up as a kitchen and dining car, with range, cooking utensils, refrigerators, dishes, tableware, etc., sufficient for the full carrying capacity of the train. Another car will be arranged as office and dispensary and storeroom, with desk, medicines, medical and surgical chests, and medical stores.

The necessary personnel of a hospital train will depend upon the capacity of the train, the character of the patients carried, and the length of the journey.

The Manual for the Medical Department of the United States Army, edition of 1902, gives as the personnel required for a hospital train of nine cars, seven of which are used for patients with a capacity for two hundred men, the following:

Two Medical Officers.—One captain, assistant surgeon, commanding. One lieutenant, assistant surgeon.

Three Non-Commissioned Officers of the Hospital Corps.—One sergeant, first-class. Two sergeants.

Twenty-four Privates of the Hospital Corps.—Twenty nurses. Two cooks. Two medical officers' orderlies.

The number of non-commissioned officers here prescribed will prove adequate, but the medical officers and privates are not sufficient in number. One medical officer will usually be detailed as quartermaster and commissary of the train, and would only occasionally be free to attend patients, leaving but one other officer to look after the professional needs of two hundred patients and attend to the numerous other duties incident to a service of this character; three medical officers would be more satisfactory. If the journey to be performed be twenty-four hours or more in duration, and if it be assumed that each hospital car carries at least twenty-four patients, three nurses will be needed to each car—two for duty during the day and one for night duty; two additional men would also be required for work in the dining car. There is no economy apparent in limiting the number of cars for patients to seven; ten cars could be as easily hauled and administered; this would increase the capacity of the train by one-third, and would only necessitate an increase of three nurses to each car.

The problem of the transportation of the disabled in the military service is one which confronts the military surgeon under varying conditions and circumstances, and is no less a question of importance to the military commander. In many wars lives have been lost which might have been saved had adequate means of transportation been at hand. Even at the present day the means at our disposal are often crude and still limited; advance has been made, more yet remains to be done. War can never be waged with comfort to its participants. Nevertheless it behooves us as military surgeons to mitigate its horror and suffering as best we may. Improvements in both means and methods of transportation for the disabled will contribute to this end. *Charles Richard.*

TRANSPOSITION OF THE VISCERA.—(Synonym: Situs Viscerum Inversus.) DEFINITION.—In this condition the relations of the various organs of the body are exactly reversed: right and left are changed about like the reflection in a mirror. As applied to the heart, this organ is on the right side of the chest, with the apex directed outward, giving the anomaly known as dextrocardia. The lungs may take part in the transposition, the left having three lobes and the right two. The position of the aorta and its branches may be reversed. The spleen is located in the right hypochondrium and the liver in the left. The stomach may also be affected in this change, the fundus lying to the right of the median line and the pylorus to the left. The sigmoid may lie on the right side of the abdomen and the cæcum and appendix vermiformis on the left. Transposition of the viscera may be *total* or *partial*. The heart alone may be transposed; or the transposition may be limited to one or more of the abdominal organs. Complete transposition is much more common than partial. The congenital transposition, which is under consideration in this article, must be carefully distinguished from acquired displacements of organs, such as the dextrocardia due to traction or pressure from disease in the thoracic cavity.

HISTORY.—Gruber made a remarkable collection of all cases found in literature up to the year 1865. Of the 79

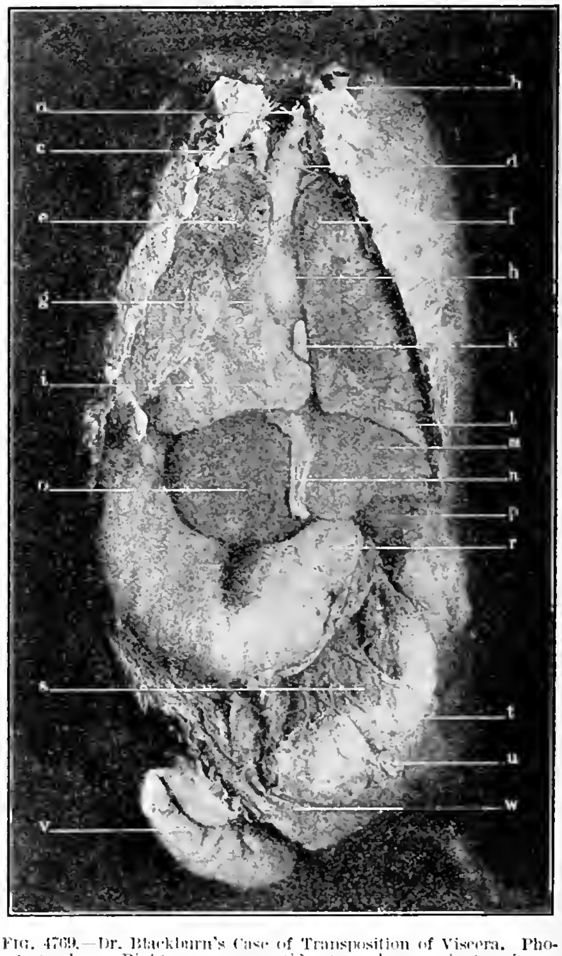


FIG. 4769.—Dr. Blackburn's Case of Transposition of Viscera. Photograph. *a*, Right common carotid artery; *b*, innominate vein; *c*, left common carotid artery; *d*, innominate artery; *e*, left lung (?); *f*, right lung (?); *g*, pulmonary artery; *h*, aorta; *i*, right ventricle of heart; *k*, appendix of right auricle; *l*, diaphragm; *m*, right lobe of liver; *n*, suspensory ligament of liver; *o*, left lobe of liver; *p*, gall bladder; *q*, cardiac end of stomach, and situation of spleen; *r*, pyloric end of stomach; *s*, gastro-colic omentum; *t*, transverse colon dragged downward; *u*, situation of cæcum; *v*, sigmoid flexure; *w*, omentum.

cases which he reports, only 5 or 6 were discovered during life. This fact seems rather remarkable since his report covers a period of more than two centuries. In 1643

Petrus Servius reported the first case as occurring at Rome.

Küchenmeister, up to the year 1888, collected 149 cases. The majority of these were discovered in the anatomical

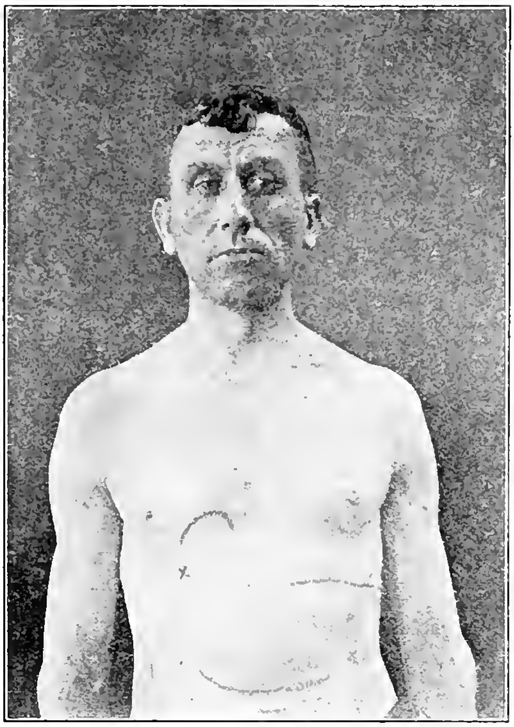


FIG. 4770.—Photograph of Schüppel's Case of Transposition of the Viscera. The X below right nipple indicates the position of the apex beat. The curved line above shows the absolute heart dulness. The straight line below the left nipple indicates the upper border of the liver dulness. The X below this line indicates the lower border of the liver dulness. The curved line above the navel indicates the greater curvature of the stomach. The curved line low down on the right side indicates the splenic dulness.

laboratory and on the post-mortem table. Pic in 1895 increased the number of reported cases to 190. Lochte up to the year 1894 collected 13 cases of partial transposition of the viscera. In more than half of these very poor descriptions were given.

An attempt to collect all the cases of situs viscerum inversus is extremely difficult and unsatisfactory, because they are reported in the literature under numerous headings. Perhaps something like 300 of these cases have been reported.

Until recent years cases of transposition of the viscera have been discovered, studied, and reported chiefly by anatomists and pathologists. Judging from my own personal experience with these cases, and from that of a large number of prominent clinicians and anatomists to whom I addressed letters of inquiry regarding their experience with transposition of the viscera, it would seem that the pendulum has swung about of late years, and that now a much larger percentage of cases of transposition is discovered by the clinician. This fact is a natural result of the much more frequent and careful physical examinations that are now being made. However, even with this improvement, all physicians know that a very small percentage of even sick people submit to careful physical examination, and that the percentage of the entire population who are thus examined is extremely small.

Since the spring of 1897 I have seen in hospital and private practice six cases of transposition of the viscera. It is rather a remarkable fact that three of these cases were seen within the short period of six months. I am also personally familiar with three other cases of situs inversus, discovered in the living subject by members of the internal medical staff of the University of Michigan, two by Dr. Warthin, and one by Dr. Cowie.

These cases have been reported in detail in the *American Journal of the Medical Sciences*, November, 1902, and in the *Vaughan Festschrift*, 1903.

In reply to my letters the following facts were gleaned: Five well-known internists and four professors of anatomy had never seen a case of transposition of the viscera. In the remaining letters 37 cases were reported. All save 6 of these were discovered during life. In this country, at least, cases of transposition are nowadays much more frequently discovered during life than after death. Note the contrast between Gruber's report and my own. Of his 79 cases only 5 or 6 were discovered during life. In my collection, which simply covers the cases reported in the letters referred to, together with those with which I am personally familiar, are 46 cases, of which 40 were discovered during life.

Method of Examination.—Careful inspection, palpation, percussion, and auscultation of the chest are of course prime essentials. The failure to find the heart apex and heart dulness on the left side most often puts one on the right track. A careful examination of the right chest may then reveal a dextrocardia. This is at once a key to the physical condition. An absence of liver dulness is then detected in the right hypochondrium. It is sought for and discovered in the left hypochondrium; the splenic dulness will then be found in the right midaxillary line.

The position and outline of the stomach may be demonstrated by inflation or by the use of the gastrodiaphane; the same is true of the sigmoid. x-Ray examination of the heart with the fluoroscope easily demonstrates the right-sided position of this organ. (See Fig. 4771.)

Theories Explaining the Development of Transposition.—These are chiefly of interest to the embryologist and anatomist, and will hardly be understood except by those who have devoted special study to embryology. The following are some of them.

Von Baer explains transposition by the turning of the embryo in the opposite direction; that is, the embryo normally lies on the left side of the umbilical vesicle; but if it lies on the right side, then we have transposition. According to him this occurs at the beginning of the developmental period.

Förster considers situs inversus a malformation in which the transposition of the anlagen takes place in the

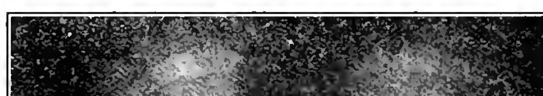


FIG. 4771.—Radiograph showing Transposition of the Heart to the Right Side. (Schüppel's case.)

first embryonal formation. In the double monster the fœtus of the right side shows a complete transposition, while the fœtus on the left side shows a normal situs.

Rindfleisch believes that a spiral turning of the blood column is responsible for the displacement of the heart. Normally it flows from left to right, but in situs inversus an opposite direction must obtain. The asymmetry of the heart is made responsible for all asymmetry in the animal body.

Virchow emphasizes the influence of the umbilical cord. In situs inversus it is wound spirally to the right; in situs solitus to the left.

Küchenmeister thinks that the location of the fertilized germinal disc at the surface of the egg is the essential thing. The normal situs in single birth probably depends upon growth of the germ from below upward, instead of from above downward. He says that from this it must be self-evident that the turning of the embryo has been inverted. This must also affect the later spleen side and the side of the arterial heart. Concerning the congenital partial situs viscerum, solito inversus, which shows itself either in the chest or in the belly, but not in both places at the same time, he believes that the growth on the whole follows the type for the situs inversus. The rarer partial situs is an inhibition formation which grows according to the type of the normally projected embryo.

Martinotti in the situs transversus of the single born emphasizes the condition of the vena omphalo-mesenterica, first mentioned by Dareste. The direction which the heart loop takes depends upon the dissimilar growth of the two halves of the vascular area. Under normal conditions a dissimilar formation of the two halves exists. The left omphalo-mesenteric vein is more developed than the right; the right gradually disappears. The heart reacts in a very sensitive way toward the cause of situs transversus.

Marchand says that the loop formation of the vena omphalo-mesenterica about the intestines under normal conditions prevents the intestines from slipping toward the right. So a right turning takes place if the loop formation is absent. He considers a left-sided persistent vena omphalo-mesenterica the cause of the right position of the stomach. In a more recent monograph Marchand states it as his belief that the development of the vena omphalo-mesenterica can have no influence upon the rotation of the stomach.

Lochte advances the view that the growth of the organ considered in the sense of situs solitus is associated with a persistence of left-sided omphalo-mesenterica and umbilical veins, while those of situs transversus totalis, on the other hand, are associated with corresponding right-sided veins.

To the clinician transposition of the viscera presents many interesting problems in differential diagnosis. The displacement of the heart to the right makes it necessary to examine the lungs and pleura carefully, in order to exclude acquired displacement. The discovery of an enlarged area of dulness in the left hypochondrium suggests a number of possibilities. It is most likely an enlarged spleen—either of leukaemia, malaria, splenomegaly, or some other disease. This point is illustrated by actual cases in practice. In Munson's case the diagnosis of an enormously enlarged spleen had been made; and the displacement of the heart was thought to be due to dilatation.

In the normal patient it is a very common experience to find an entire absence of liver dulness in the right hypochondrium. It is also common to find that the apex beat is neither seen nor felt on the left side, especially if the patient is quiet and in the horizontal position. Heart dulness is also frequently absent. So it is easy to understand how these cases of transposition often are overlooked.

It is possible to mistake an aneurism of the arch for a dislocated heart. This fact was recently brought to my attention.

Gruber refers to the following errors in diagnosis. In one case of transposition a pain in the right hypochondrium led to the diagnosis of a chronic inflammation of the liver. In another case a soldier was wounded in a duel, in the right hypochondrium; from the position of the wound and the vomiting of green fluid it was thought that the liver had been penetrated. In a third case, in the Würzburg clinic, the transposed liver was diagnosed as a spleen tumor. In a fourth case, one of cancer of the pylorus, in a transposed stomach, the hard tumor felt deep in the left hypochondrium was thought to belong to the left part of the stomach or the pancreas.

In appendicitis developing in a patient with transposition of the viscera the signs and symptoms would of course be located on the left side instead of on the right side. The surgeon would choose Monroe's point instead of McBurney's point for the site of his incision.

Gruber arrived at a number of interesting conclusions from a study of 79 cases. "Concerning the sex there were 49 men, 19 women, and 11 in which sex was not mentioned. These individuals lived as long as those with normally placed organs. Five of the 19 women lived to an age between seventy and eighty-four.

The women were normally fruitful. One gave birth to twelve children. Among the 79, 4 died an unnatural death, and only 4 were extremely malformed. There was transposition of *both* chest and abdominal organs in 71; of the abdominal organs alone in 8. In the first kind the transposition was complete, in the latter incomplete.

The lungs were transposed in 35 of 71 cases; the right had two lobes, and the left three. In 2 cases they were not transposed; in 2 both lungs had two lobes; in *one* the right had one lobe, and the left two lobes.

Curvature of the dorsal portion of the spine is mentioned in only 11 cases. In 7 of these it was to the left, in 4 to the right as normally.

We cannot draw the conclusion that persons with transposition are more likely to be left-handed than those with normally located viscera.

The position of the testicle was mentioned only 7 times. In 4 the right was lower, in 1 the left. In 1 the left had not descended.

The lower position of the right testicle is unimportant as a sign of situs inversus.

In only 9 cases were there notes on the position of the kidneys. In 7 the left was lower, in 2 the right.

In 32 cases in which the vessels arising from the arch of the aorta are mentioned, these were transposed 29 to 30 times.

H. Steinhauser mentions the fact that in the operation of œsophagotomy, it is well to know that the œsophagus lies over the right trachea in persons with transposition.

In situs partialis the transposition of the abdominal organs may be very irregular. In one case the stomach and duodenum were normally located, while the other organs were transposed. In another case the liver alone was transposed.

In 1888 a case of pure dextrocardia with congenital pulmonary stenosis, without malposition of the viscera in general, was shown to the Vienna Medical Society by Dr. Gruss. In discussing the case, von Bamberger concurred in the diagnosis, and remarked that Professor Schrötter had lately stated that no single case of pure dextrocardia had ever been proved, whereas all anatomists of experience, for example Rokitansky, Friedberg, Förster, *et al.*, had mentioned such cases, and he himself had seen two.

The above quotation emphasizes the fact that partial situs is a much rarer condition than complete. If the transposition is located in the abdominal cavity, it will most likely be overlooked in the physical examination.

James Rae Arneill.

TRAUMATOL—iodocresol, orthocresol iodide, $C_6H_3.CH_3.OI$—is a reddish, odorless, insoluble powder which is used as an antiseptic substitute for iodoform in wounds and ulcers. It is an efficient drying powder and deodorizer. *W. A. Bastedo.*

TREMATODA.*—The class Trematoda, or Flukes, constitutes one of the prominent subdivisions of the

* A general discussion of parasitism and its effects is to be found under the heading *Parasites*.

branch or phylum Plathelminthes, the characteristics of which were outlined under the Cestoda. The group was recognized as distinct in 1800 by J. G. H. Zeder, a practising physician in Germany, who with great clearness of vision separated the then accepted class of Helminthes or intestinal worms into five groups of closely related forms. These groups received in 1809 at the hands of K. A. Rudolphi, the celebrated Berlin helminthologist, the scientific names of Nematoda, Acanthocephala, Trematoda, Cestoda, and Cystica. The latter have since been shown to be immature stages of the Cestoda, and C. Vogt in 1851 demonstrated the unnatural character of the association Helminthes, making as a natural group the flatworms in which are now included the flukes, the tapeworms, and the free living flatworms, as three great classes of the phylum designated Plathelminthes.

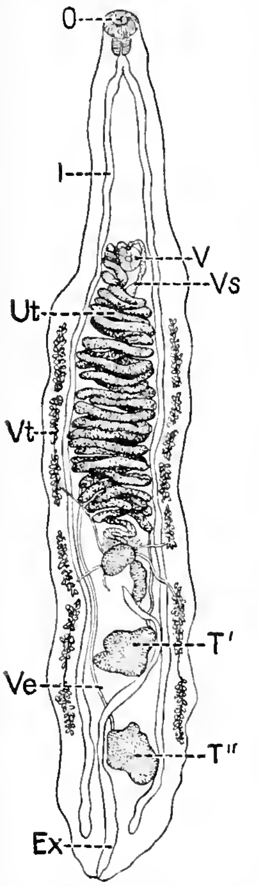


FIG. 4772.—*Opisthorchis pseudofelineus* Ward. From liver of cat. *Ex*, Excretory bladder; *I*, intestinal crura; *O*, oral sucker; *T'*,*T''*, testes; *Ut*, uterus; *V*, ventral sucker; *Vt*, vitellaria; *Ve*, vas efferens; *Vs*, vesicula seminalis. × 7. (Original.)

In certain features, such as the simple body, the presence of an alimentary canal, and in some cases even of special sense organs, the Trematoda stand much nearer the free living forms than do the Cestoda, although all of the species included in both classes are parasitic. The consistent parasitic habit, in which the flukes resemble the tapeworms, is varied by a modification in degree among the flukes which serves to show their relation also to free living species and contrasts strongly with the intensive endoparasitism of the Cestoda. Thus among the flukes there are not only the endoparasitic species, but also such as are ectoparasitic and preserve in some degree those features of free living forms that are lost with the assumption of endoparasitic existence. Withal the group is a well-defined one, and manifests greater uniformity in structure than the Cestoda, while it also embraces both fewer species and fewer human parasites than the latter class.

In form the Trematoda are generally flattened and elongate, more rarely cylindrical, conical or irregular, with plane ventral surface on which are located the sexual pores and arched dorsum. The mouth is at or near the anterior tip of the body and the excretory pore is similarly related to the posterior end. The mouth is nearly always surrounded by an oral sucker, and other suckers may occur on the ventral surface, at the posterior end, or more rarely on the margin or dorsal surface. In connection with the suckers chitinous hooks or anchors are found as additional organs of attachment, and the exterior of the body is often covered more or less completely by scales or spines of varying form and size. Most flukes are comparatively insignificant in size, measuring only a few (1 to 15) millimetres in length, though rare species largely exceed both limits.

A cross section shows that a body cavity is wanting. The trematodes belong to the group of forms in which the space between all organs is filled up by parenchymatous tissue, giving a firm consistence to the mass. The exterior is bounded by a homogeneous membrane of varying thickness known as the cuticula, which actually is formed by the fused bases of cells lying deeper in the tissue, but which presents the appearance of a basement membrane. It was formerly construed as such, and the trematodes were believed to be without an epithelial covering in the adult condition. As a matter of fact the pyriform epithelial cells lie in bunches between or within the diagonal muscles, and are connected by numerous fine processes with the basal surface of the so called cuticula. Some of these cells are especially developed as unicellular glands.

The dermomuscular sac lies just within the cuticula and consists of layers of circular, longitudinal, and diagonal fibres which surround the body, though of varying thickness in different regions. Running obliquely from one surface to the other occur also dorsoventral or parenchymatous muscles which are inserted on the cuticula. Especial development of the muscular layers is found in the suckers, which consist of muscle fibres extending in three directions and designated as equatorial, meridional, and radial; these correspond to the circular, longitudinal, and dorsoventral muscles respectively. In addition one finds a special set of muscles radiating from the sucker through the tissue. In certain cases at least special mus 'es are developed in connection with the reproductive organs, with the hooks, and even with the surface spines, as in the common liver fluke. The high development of the muscular system, associated with the absence of special skeletal structures, combine to make the form of the flukes extremely mobile and variable. Locomotion is achieved by means of the body musculature and the suckers, aided in rare cases by the cuticular spines already mentioned.

An alimentary canal is always present and forms the ultimate distinctive feature between Trematoda and Cestoda. In all cases it has but a single opening, the mouth, which lies at the anterior tip of the body, or more rarely on the ventral surface and in all higher forms is surrounded by the oral sucker (*O*, Fig. 4772). In lower members of the group, two or more suckers may lie near the oral opening or the latter may be entirely unarmed. In form the alimentary canal may be rhabdocœl, though much more frequently it is of the triclad type. In the latter case one can distinguish an initial unpaired region variable in length, which extends posteriad from the oral opening and is called the œsophagus. It is thin-walled and not digestive in function, though frequently numbers of unicellular salivary glands are connected with it. Near its oral end a prominent sphincter muscle forms a bulbous mass known as the pharynx. By its action the oral sucker is closed posteriorly to act as a simple organ of prehension, or stands in open communication with the canal, for which it serves as an aid in the ingestion of food.

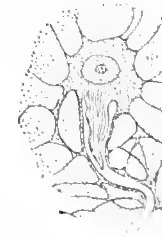


FIG. 4773. Flame Cell and Excretory Tubule of *Azygia tereticollis* (R.) × 700. (After Looss.)

The simple œsophagus divides into two intestinal crura (*I*, Fig. 4772), which form the digestive and absorptive region of the canal. They are blind sacs, usually symmetrically placed right and left, but of variable length and character. In some genera they are so short as not to reach the sides of the body; in other cases they extend to the posterior end, and may even be connected by several commissures or anastomoses. Usually the crura are of uniform calibre throughout, and yet in some genera they manifest an irregular wavy outline, or even possess numerous lateral diverticula which may branch again and give the system a dendritic aspect. The endoparasitic forms subsist on the intestinal contents and secretions of the host, but also ingest epithelial cells and blood, thus giving rise in some cases to severe hepatic or intestinal disturbances, the gravity of which is proportionate to the extent of the invasion.

The excretory system agrees in general with that of the Cestoda. One finds a variable number of primitive nephridia or "flame cells" (Fig. 4773), scattered throughout the tissue. These cells are stellate in form, with a huge bunch of cilia which lie on one side in a narrow canal. The constant motion of the group of cilia simulates the flickering of a candle flame, whence the name. The tubules from these flame cells unite into larger ducts, and ultimately combine in a single vessel, which opens at the posterior end of the body by a simple excretory pore (*p*, Fig. 4774). The final vessel may be short and expanded or a longer median canal. In both cases it apparently functions as an excretory reservoir or bladder (*ves*, Fig. 4774). The system, which was formerly called a water vascular system, contains a clear fluid, sometimes slightly tinted, with occasional granules or concretions. It is produced by the activity probably of the terminal cells, the cilia of which serve to maintain movement. The presence of uric acid in the fluid is sufficient evidence of its excretory nature.

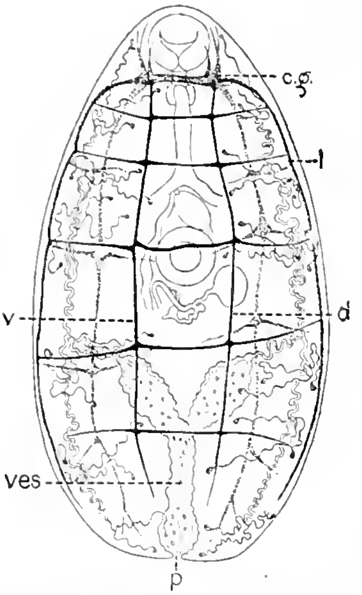


FIG. 4774.—Nervous and Excretory Systems in *Opisthioglyphe endoloba* (Duj.). *c.g.*, Cerebral ganglion; *d*, dorsal, *l*, lateral, *v*, ventral nerve trunks; *p*, excretory pore; *ves*, excretory bladder. × 30. (After Looss.)

The nervous system is poorly developed in accord with the parasitic habit of the group. It consists of two small lateral aggregations of ganglion cells (*c.g.*, Fig. 4774) near the pharynx which are joined by a ring of fibres that encircles the œsophagus, and of nerves extending anteriad and posteriad from these ganglia. The three pairs passing anteriad are short and innervate the oral sucker with adjacent dermal areas, muscles, and primitive sense organs. The posterior nerves form dorsal, (*d*), lateral (*l*), and ventral (*v*) paired cords. The ventral nerve cords are much the most prominently developed; they join each other near the posterior end as do also the dorsal cords. Circular commissures at somewhat regular intervals unite all three pairs of nerves, and ganglion cells occur most frequently at the points of union, though also rarely elsewhere in the course of the nerves. A dermal nerve plexus is at least often present, and stands in immediate connection with the main nerve trunks. Sense organs, of the most primitive sort, occur in the skin, while in the free swimming larvæ as well as in ectoparasitic forms simple eye spots are found. Other sense organs are not known.

Reproductive System.—The Trematoda are all but universally hermaphroditic, and possess highly complicated organs of reproduction. One of the human parasites illustrates the rare secondary condition of separate sexes, and will be considered under the appropriate heading; here it is sufficient to outline the general conditions.

The testes (*T*, *T*, Fig. 4772) are usually two in number, symmetrical in size and location, although there may be but a single one, or on the other hand a series of several. These organs are commonly round or oval in outline, with frequent variations toward a lobed condition, or even to a dendritic form. The two vasa efferentia unite sooner or later into a single vas deferens, which may or may not possess an enlarged region used as a seminal vesicle. The duct opens on the surface of the body, or into a genital cloaca at the common genital pore, and the terminal portion of the canal may form by eversion a protrusible copulatory organ. More frequently this region possesses a highly developed muscular organ known as the cirrus, and this with or without the seminal vesicle may be enclosed in a sac denominated the cirrus pouch, and provided with unicellular glands (prostata). When highly developed this copulatory apparatus forms a conspicuous organ, and, as has recently been elucidated by Looss, constitutes a valuable taxonomic character.

The female reproductive organs show an unusual specialization in the separation of the germarium, often incorrectly denominated the ovarium, from the vitellaria or yolk glands. The germarium (*G*, Fig. 4775) is small, located ordinarily in front of the testes, and usually round or oval in outline, although it may also be dendritic in form. The vitellaria are paired, highly lobed or dendritic in form, and extended usually along the sides of the body lateral to the intestinal crura. Their extent is of importance in specific determinations. The duct from each vitelline gland tends toward the germarium, and near this organ unites with that from the opposite side in a common yolk or vitelline duct, on which at the junction there is at times an enlargement known as the vitelline reservoir. The short germ duct, coming from the germarium, and the common yolk duct, unite to form a short, slightly expanded tube known as the ootype on the sides of which are found unicellular glands, often crowded together into a mass and collectively denominated the shell gland (*Sg*, Fig. 4775). From the ootype a short inconspicuous canal rises to the dorsal surface; this organ, called Laurer's canal (*L.C.*), is clearly rudimentary, and its significance is not beyond dispute, although it is usually homologized with the vagina of ectoparasitic forms; and, according to recent observations, still functions as such in rare cases. It may bear near the proximal end a bulbous lateral expansion, the seminal receptacle (*R*).

The ootype expands immediately beyond the shell gland to form the uterus (*Ut*), which as a long convoluted tube fills the major portion of the body with its coils crowded with opaque brown-shelled eggs. In the portion of the uterus which lies near the ootype there is usually a mass of sperm, so that the region has been called the uterine seminal receptacle. The uterus terminates in short heavy-walled region devoid of eggs, known as the metraterm. This lies alongside of the cirrus pouch, and opens at the female genital pore on the surface of the body, or into the genital cloaca and serves to receive the cirrus in coition. In these forms cross fertilization is the rule, and cases have been observed in which one individual only functioned as the male as well as such in which both were thus functional. In a few instances self-impregnation has been found. The genital pore lies ordinarily in the median line near the ventral sucker, or between it and the fork of the alimentary canal; but a marginal position, or one near the oral sucker, or even at the posterior end of the body, is also to be found.

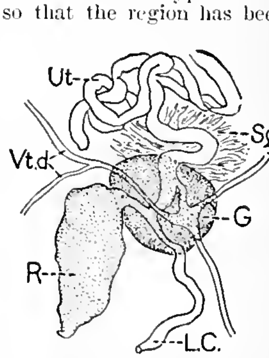


FIG. 4775.—Female Sexual Organs of *Opisthorchis pseudofelineus* Ward. Highly magnified to show relation of ducts. *G*, Germarium; *L.C.*, Laurer's canal; *R*, seminal receptacle; *Sg*, shell gland; *Ut*, beginning of uterus; *Vt.d*, vitelline ducts. (Original.)

In the arrangement of the reproductive organs one finds the double condition designated sexual amphitypy, in which one individual is, as it were, the mirror image of the other. Usually one can be designated as having the normal arrangement, but the relative frequency may be such that neither can be said to be more typical than the other. Such a reversed arrangement was first observed among the Opisthorchiinæ, where it seems to be very common; it has also been shown to exist among the Dicrocœliinæ, and the difference in Paragonimus Westermanii referred to later (Figs. 4782, 4784) may be explained in the same way.

This description obtains for the endoparasitic forms, particularly for the Fasciolidæ, which are of especial importance here. In other families, especially among the ectoparasites, somewhat radical differences from the plan outlined may be observed.

The egg of the Trematoda is more or less oval or ellipsoidal, rarely flattened asymmetrically. It is provided with a heavy chitinous shell which is transparent when first formed, but darkens soon in the first coils of the uterus to a deep yellowish-brown, which is almost entirely opaque. In ectoparasitic forms the egg shell possesses a polar filament by which it is attached when deposited; but this is not present in endoparasitic forms. At most one finds an irregular, insignificant protuberance at one pole, such as is present in *Schistosoma hæmatobium.* The shell regularly possesses a cap or lid which is sprung at the appropriate time to allow of the escape of the enclosed embryo. Such eggs may be found in the waste of the body, excreta, or sputa, or may occur adventitiously in various tissues. Under such circumstances they have in the past been diagnosed as coccidia.

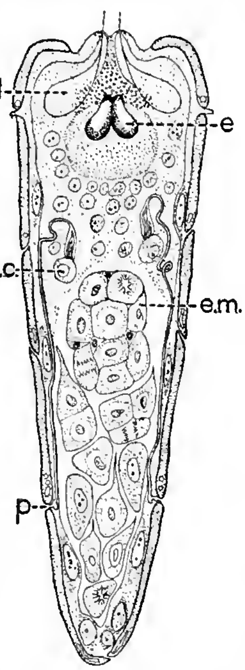


FIG. 4776.—Miracidium of *Fasciola hepatica* (L.); in cross section, showing eye spot (*e*), embryonic cell masses (*e.m.*), flame cells (*fl.c.*), cephalic glands (*gl.*), and excretory pore (*p*). Much magnified. (After Coe.)

Development.—When first formed the shell contains the single fertilized egg cell surrounded by a mass of highly granular yolk cells. The latter may be distinct or may be already broken down into an indistinct granular mass. This serves for the nutrition of the embryo during early development. The cleavage of the fertilized ovum begins at once, and ordinarily proceeds so as to bring the embryo to development at the time when the egg, extruded from the uterus of the parent worm, is carried into the external world with the waste products of the host. This is simple since the normal seat of the parasite is the alimentary canal, or some of its outgrowths, liver, lungs, etc., and the eggs are distributed with sputa, fæces, or rarely urine.

The modified environment brings about the opening of the egg shell and the escape of the embryo, which follow experimentally when the ripe eggs are brought into water at suitable temperature. The embryo (Fig. 4776), which is designated a miracidium, is somewhat elongated in form, with a conical tip, and sometimes also a sharp boring spine at the anterior end. The ectoderm is composed of large cells and is ciliated. One may distinguish also a pair of flame cells (*fl.c*, Fig. 4776), or primitive excretory organs, and a rudimentary **X**-shaped eye spot (*e*). In the interior the cells are smaller and are arranged irregularly about a cavity into which they are set free singly or in groups. These do not become prominent until the miracidium has attained its location in a new host, and this, which it seeks at once on emergence from the egg shell, is almost universally a mollusk. Embedded in the tissue of the mollusk, which is known as the secondary or larval host, the miracidium loses its coating of cilia, its eye

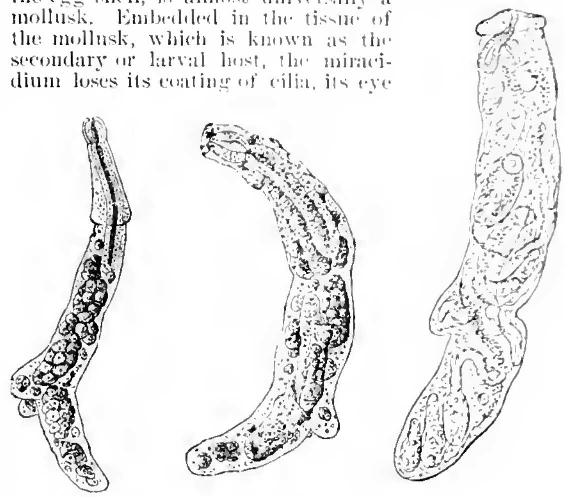


FIG. 4777.—Rediæ of *Fasciola hepatica* (L.). × 120. *A*, Young specimen with cell masses just forming; *B*, older individual with young rediæ developing; *C*, form with developing cercariæ. (After Leuckart.)

spot and its special form becoming a mere irregular sac, now designated as the sporocyst, in which one finds cell masses crowding the cavity and developing into a new generation. In the ordinary case their form is that known as the redia, and when developed they escape from the sporocyst only to enter upon a similar method of reproduction, which gives rise to another new generation. In structure the redia (Fig. 4777) is characterized by an elongate form, a mouth with single oral sucker, a rhabdocœl alimentary canal, two short locomotor protuberances, and an orifice known as the birth opening through which the new brood escapes.

This new generation originates as did that in the sporocyst from cells or cell masses set free from the wall of the cavity. The form developing therefrom may be a redia like that which produced it; more often it is still another new form, known as a cercaria, and in some cases the cercaria may even be produced directly from the first generation, the miracidium metamorphosed into a sporocyst or a redia. The form of the full-grown cercaria (Fig. 4778) is sufficiently characteristic to allow of its easy recognition. It is somewhat broader than the redia, possesses a ventral sucker as well as an oral, a triclad alimentary canal, and an active caudal appendage for swimming, though in some forms designated as varieties of this stage this tail may be wanting or modified. The cercaria is in fact the young distome, supplied with an organ of locomotion when some part of the life cycle is to be spent in the open. Now, if not before, the young fluke is ready for the change of hosts which accompanies its attainment of the adult condition. The transfer may be passive or it may be associated with an active migration from the secondary host and a period of existence in the open water before the primary host is reached. Once that the latter is attained,

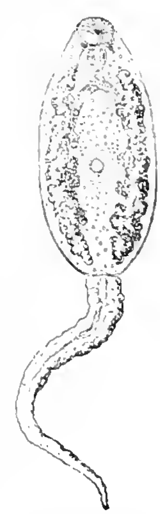


FIG. 4778.—Free Cercaria of *Fasciola hepatica* (L.). Magnified. (After Leuckart.)

the tail of the cercaria is thrown off and the further development to the adult form is growth, chiefly of the reproductive organs which were present before only in rudimentary form. An encysted stage frequently intervenes. This the cercaria attains by burrowing into the tissue of some animal, or by settling upon the surface of some plant or other object. In the latter case the cyst is formed of the expressed secretion of dermal glands which hardens about the cercaria, which now has cast off its tail. In either event the digestive fluids of the final host are the means of liberating the worm from its cyst to enter upon the final stage of its career.

Great differences in detail are found in different species. The following table, taken from Hertwig, exhibits in synoptic form the principal lines of development. Individual features connected with the species which occur as human parasites may be found under the appropriate headings. The entire process was formerly regarded as the true alternation of a sexual generation, the adult worm, with one or more asexual generations, sporocyst, and redia; but at present the reproduction of the latter is regarded rather as premature parthenogenesis or pædogenesis, and the alternation is called alloiogenesis. Some authors regard it, however, as merely a complicated metamorphosis, which is distributed over several generations. The transportation of the parasite from one host to another may be passive, as when the encysted form is eaten and set free in the alimentary canal of the new host by digestion, or it may be active in that the free swimming larva is engulfed with drinking-water by chance, or bores its way into the body of the water-inhabiting mollusk which it seeks out.

secondary host is somewhat narrow, so that not only is a direct infection from the adult fluke contrary to all experience, but also the introduction of the adult and the dissemination of the ova in a new region can be followed by the permanent establishment of the parasite only when a suitable larval or secondary host is available. The sheep liver fluke, *Fasciola hepatica*, has thus secured a footing in certain regions of the United States, and has become an important factor in the handling of domestic animals. It remains to be seen whether the human blood fluke, *Schistosoma hæmatobium*, probably introduced from Africa to the southeastern States, and the Asiatic fluke, *Opisthorchis sinensis*, undoubtedly brought to the Pacific coast from the East, will establish themselves similarly to the detriment of the human species.

The encysted cercaria or immature distome occurs rarely in mammals, *e.g.*, the pig, more frequently in amphibians and fishes and generally among invertebrates. The mature trematodes are parasitic only among vertebrates; the ectoparasitic forms inhabiting chiefly the skin or gills of aquatic species, and the endoparasitic forms occurring largely in the alimentary canal, though almost all organs may harbor them at times. Next to the canal, its adnexa, the lungs and liver, are favorite seats of these parasites, but the latter are not wanting in the genito-urinary ducts, where for instance in birds they occur so frequently as to be occasionally enclosed within the egg shell during its formation and are subsequently discovered there. While the flukes usually move freely about in the cavity of the affected organ, they are in some cases more or less completely encysted in its substance. Thus the Asiatic lung fluke, *Paragonimus Westermanii*, is found in pairs in pulmonary cysts, and in rare instances such an association in pairs is connected with the secondarily acquired diœcious condition of the individual species.

Development of the Distomes.

	Simple.		Ordinary.		Complicated.	
First generation....	Miracidium........ Sporocystis.........	Water.............. Host I. (Mollusk)..	Miracidium........ Sporocystis (possibly also redia).	Water.............. Host I. (Mollusk)..	Miracidium........ Sporocystis........	Water. Host I. (Mollusk).
Second generation .	Encysted distome.. Sexually mature distome.	Host I.............. Host II............	Cercaria........... Encysted distome.. Sexually mature distome.	Water.............. Host II............ Host III...........	Redia..............	Host I. (Mollusk).
Third generation...	....	....	....	....	Cercaria........... Encysted distome.. Sexually mature distome.	Water. Host II. Host III.

Thus far only thirteen species of fluke have been listed as human parasites; they are as follows:

Family: Paramphistomidæ.
  Gastrodiscus hominis.
Family: Fasciolidæ.
  Fasciola hepatica. Species recorded in United States of America.
  Fasciola angusta.
  Fasciolopsis Buski.
  Fasciolopsis Rathouisi.
  Paragonimus Westermanii.—Species recorded in United States of America.
  Opisthorchis felineus.
  Opisthorchis sinensis.—Recorded from man in United States of America.
  Opisthorchis noverca.
  Metorchis truncatus.
  Heterophyes heterophyes.
  Dicrocœlium lanceatum.—Species recorded in United States of America.
Family: Schistosomidæ.
  Schistosoma hæmatobium.—Recorded from man in United States of America.

It thus appears that only five species have ever been found in the United States, and that but two of these have been recorded from the human host. It may be further noted that of these two, one (*Schistosoma hæmatobium*) was certainly acquired in other lands and apparently has not gained a footing in our own, while the same is probably true of the other, leaving for the human host not a single record of trematode infection originating within the limits of the United States.

The earlier stages in the life history, sporocyst and redia, occur only in mollusks, and the selection of the

The effects of parasitism have already been discussed (see *Parasites*); special features as well as means of treatment are treated under individual forms. The human parasites belonging to this group, as already recorded, are too few in number of species to call for a special key as an aid to identification.

Taxonomy.—Valuable recent work by Braun and Looss on the taxonomy of the group makes it possible to give a reasonable system. Only the parts dealing with human parasites will be particularly considered.

Order Heterocotylea.—Ectoparasitic forms with powerfully developed organs of attachment; excretory organs open separately on the dorsum; development direct. Parasitic on body and gills of fishes chiefly. No human parasites.

Order Aspidocotylea.—Endoparasitic Trematoda of simple organization with large ventral organ of attachment; excretory organs open by a single posterior pore; development direct. No human parasites.

Order Malacocotylea.—Trematoda with one or two suckers, or rarely accessory lateral suckers also, for attachment; no chitinous organs of attachment. Intestine usually forked and mouth anterior; mostly hermaphroditic with sexual pore ventral; excretory pore posterior. Always endoparasitic in vertebrata. According to mode of development divisible into two groups:

(*a*) *Metastatica*. Development without alternation of generations, but with two larval forms and change of hosts. No human parasites.

(*b*) *Digenea*. Development complicated by alternation of asexual generations (sporocyst, redia) with sexual generation. One or more changes of host. All human trematode parasites fall in a few families of this very large and varied group, viz.: Paramphistomidæ, Fasciolidæ, Schisto somidæ.

The family of the Paramphistomidæ is characterized by a terminal sucker, dorsal to which the excretory pore is located. The genital pore lies in the midventral line in the anterior third of the body; the pharynx is far forward and ordinarily designated the oral sucker; the intestinal branches are always simple, hermaphroditic. Only one genus is of interest here:

Gastrodiscus Leuckart.—Paramphistomidæ with slender anterior region and large discoidal posterior region, which is concave ventrally. The small terminal sucker lies on the posterior ventral margin of this concavity. Pharynx with two outpocketings.

Various species occur in the alimentary canal of the horse and cattle in Egypt and India; one has been found parasitic in man.

Gastrodiscus hominis (Lewis and McConnell 1876.)—(Syn.: *Amphistomum hominis* Lewis and McConnell 1876.) Body 5–8 mm. long, 3–4 mm. broad, reddish when living. Genital pore at bifurcation of intestinal crura. Eggs oval, 0.150 mm. long, 0.072 mm. broad.

The structure of this species is only imperfectly known. It has been found twice in Assam and India in the cæcum and colon of natives who had died from cholera. Although present in large numbers in these cases Braun regards it as undoubtedly an occasional parasite, the normal host of which is as yet unknown. Giles, however, found it frequently in Assam, and according to Leuckart never more than twelve individuals in a single host, which militates against the idea that it was only an occasional parasite.

The family of the Fasciolidæ is characterized by the presence of oral and ventral suckers, by the genital pore ventral, rarely lateral or terminal; always hermaphroditic, two testes, one germarium, with receptaculum seminis or Laurer's canal, or both, and with paired lateral often highly branched vitellaria.

The majority of human trematode parasites fall within the limits of this very large and highly differentiated family.

Fasciola Linnæus 1758.—Large Fasciolidæ with leaf-shaped body, the anterior end of which has the form of a conical cap or tip, distinctly set off from the posterior region; acetabulum on the boundary of the two regions, large and powerful. Œsophagus short, with pharynx; intestinal crura reaching almost to posterior end near the median line of the body, with short branches on median side and with long, highly dendritic branches on lateral side. Excretory system much branched, reservoir a long median sac. Genital pore in midventral line in front of acetabulum; germarium in front of testes and transverse yolk duct, highly dendritic, as also the testes which are located obliquely behind one another and posterior to transverse yolk duct; uterus in form of a rosette in front of germ glands; vitellaria on sides even to posterior end, well developed. Laurer's canal present, receptaculum seminis wanting. Eggs large, not numerous, developing after deposition. Parasitic in gall ducts of herbivora, more rarely omnivora.

Fasciola hepatica L. 1758.—(Syn.: *Distoma hepaticum* Retzius 1786; *Fasciola humana* Gmelin 1790. *Distomum cariæ* Sonsino 1890; *Cladocœlium hepaticum* Stossich 1892). Body flattened like a leaf (Fig. 4779), reddish-brown in color, 20–30, rarely 35–50 mm. long, 5 or 8–13 mm. broad, with anterior region 4–5 mm. long, and distinctly set off from the posterior; posterior extremity bluntly pointed. Dermal spines over entire body except a small area near the posterior end. Oral sucker terminal, nearly spherical, about 1 mm. in diameter, acetabulum at junction of two regions about 1.6 mm. in diameter, spherical with triangular aperture. Pharyngeal bulb covering nearly entire œsophagus, intestinal crura, with numerous dendritic branches directed laterad; vitellaria, lateral, dendritic, both dorsal and ventral of intestine. Germarium and testes both dendritic, former anterior, latter posterior to transverse yolk duct and side by side. Eggs oval, 0.130–0.145 mm. long by 0.07–0.09 mm. broad, deposited before commencement of cleavage.

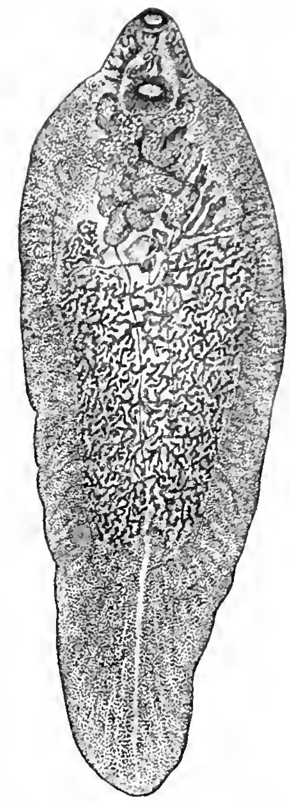


Fig. 4779.—*Fasciola hepatica* (L.). American Specimen from Cattle. Magnified. (After Stiles.)

This species is parasitic in the biliary ducts of sheep especially, but it also occurs in many other ruminants, cattle, goat, horse, ass, deer, antelope, camel, as well as in the kangaroo, squirrel, beaver, rabbit, guinea-pig, and man.

Life History.—The complicated development of this form has been elucidated chiefly by the researches of Leuckart and Thomas. The eggs must remain some weeks in water at the ordinary temperature to complete the development of the miracidium, which on being set free seeks out a small snail (*Limnæa truncatula* Müll. = *L. minuta* Drap.) that is commonly found in small pools or on partially flooded meadows.

The miracidium (Fig. 4776) attaches itself to some fleshy region of the snail, throws off its ciliary coating and then penetrates to the snail's liver, where it becomes a mere sac filled with masses of developing germ cells. This sac, known as the sporocyst, produces rediæ, which remain in the same host, and sometimes give rise to a second generation of rediæ (Fig. 4777, *A*, *B*). The cercariæ (Fig. 4777, *C*, and Fig. 4778), which are produced by rediæ sooner or later, make their way out of the snail and encyst on blades of grass, with which they attain the final host in its food. The young distome set free in the stomach is small, transparent, without separate regions of the body, and with only rudiments of the reproductive organs. It makes its way far up into the gall ducts of the liver and there attains its maximum size. The life of the adult lasts probably not more than a year, but infection of the final host takes place most commonly in the early fall or late summer. In the spring the eggs are most abundantly distributed over the meadows, with the excrement of the sheep. Lutz found that in the Hawaiian Islands *Limnæa oahuensis* and *L. rubella* served as intermediate hosts. None of these species occur in the United States, and the species which actually serves as larval host is as yet unknown.

The common liver fluke is distributed over nearly the whole of Europe; it also occurs in North and South America and Australia, where it has been introduced in domestic animals. Records of its occurrence in Africa and Asia are undoubtedly due, in part at least, to confusion with closely related species, and must be verified before they can be accepted as final.

Pathology.—Known since the middle of the sixteenth century, the common liver fluke was first positively identified as a human parasite by Pallas in 1760, although earlier reports of Malphighi and others probably concern this species. Between twenty and thirty well-established cases are on record; they have been compiled and discussed by Leuckart, Blanchard, and Moniez. All degrees of infection are represented, from such as were so slight as to have been discovered by accident to such as were the direct cause of death. In the bile ducts the flukes have only rarely evoked serious symptoms, though in two or three cases fatal termination was due to obduction of the ductus hepaticus s. choledochus by one of these flukes. In the majority of cases the parasite produced no noticeable symptoms, evidently due to the presence of only a small number of individuals, and it is possible that infection is more general than heretofore believed. At any rate Kratter proclaims it to be frequent in Dalmatia, and Perroncito found distome eggs frequently in fæcal examinations among laborers at the St. Gothard tunnel. Even in severer cases the symptoms are general, indicating only some affection of the liver. Thus pain in that organ, swelling and icterus have been mentioned by different observers. In the majority of cases, also, the parasite has not been found in its normal seat, the liver, but as an erratic in the lungs, in blood-vessels, in subcutaneous tumors, and elsewhere. This is not strange in the light of Railliet's demonstration that the liver fluke subsists on blood; thus young flukes especially may make their way into the circulatory system and be carried by the blood current into any part of the body.

Such occurrences of erratic individuals give some basis for the interpretation of other doubtful organisms as also belonging to this species, and many authors regard the *Hexathyridium venarum*, reported by Treutler in 1793, from the tibial vein of a young man which ruptured while the patient was bathing, as an erratic specimen of *Fasciola hepatica*. Leuckart, however, says there is more reason to regard it as a free living planarian, which did not actually come from the vein, but was obtained accidentally from the water.

These cases of parasitism of *Fasciola hepatica* in man have been reported largely in European countries, the only one outside being from Australia. The record of Chabert in 1852, that this species occurred in Boston in company with *Tænia*, rests upon an erroneous view regarding the isolated segments of the tapeworm, as Leuckart and Cobbold have clearly shown. Nevertheless in those parts of this country where *Fasciola hepatica* is common, cases of human infection are likely to occur. This takes place supposedly through the consumption of cress, lettuce, and other uncooked plants which have been grown in low, damp regions where infected snails were present, and where consequently the liberated cercariæ had opportunity to encyst upon the leaves. The evident infrequency of such an occurrence coincides with the usually mild infection in man as compared with the domesticated animals.

Associated with the light infection and also with its infrequency is the absence of any definite symptoms in the human host which denote the presence of the parasite. As already explained, the infection usually becomes known only by chance; but even were it determined by accidental discovery of the eggs in fæcal examinations, no special means could be suggested to bring about the evacuation of the parasite, which lies deep in the ducts of the liver, and is held against retrograde movements by the thick-set, retrorse spines that cover nearly the entire body. So far as can be determined the life of the adult lasts not more than about a year. Care in the use of uncooked plants should be exercised in all regions where these flukes are abundant.

Agamodistomum ophthalmobium (Diesing 1850).—(Syn., *D. oculi humani* Gescheidt 1833; [?] *Monostomum lentis* Gescheidt 1833; *Distomum ophthalmobium* Diesing 1850.) Two cases of some interest may be noted here in which the parasites are too poorly known to allow of exact identification. In one case four immature distomes were removed from the eye of a five months' child with lenticular cataract with partial opacity of the capsule. The other case was that of an elderly woman from whose eye eight so-called monostomes were removed from the lens substance. The descriptions do not enable one to determine the species or to assert the identity of the forms. They were undoubtedly erratic parasites, and it seems highly probable that in the former case at least the parasite was the young form of one of the liver flukes of man. Several authors regard them as very young lancet flukes (*Dicrocœlium lanceatum*) which had strayed into this unusual location. There is every ground for believing them to be pathogenic, as are other species in the eyes of other vertebrates (*e.g.*, fish), and a repetition of the occurrence on the part of the erratic young of the same or other species may be confidently predicted. (For full data on these cases compare Stiles 1902.)

Fasciola angusta (Railliet 1895).—(Syn: *F. hepatica* var. *angusta* Railliet 1895). Body flat, linguiform, with sides nearly parallel and slenderer than *F. hepatica*. Length, 26–38 mm.; breadth, 6–8 mm. Anterior region short. Posterior end broadly rounded. Acetabulum large, prominent, only 2 mm. from anterior tip of body. Eggs oval, 0.143 to 0.151 mm. by 0.082 to 0.088 mm.

Railliet described this form from the liver of cattle slaughtered in Senegal, and at the same time called attention to a case recorded by Gouvea, a physician in Rio Janeiro. The patient, a French marine officer, suffered from fever, cough, and blood spitting. The only pulmonary defect demonstrable was a sharply defined spot at the base of the left lung. Some twenty days later he coughed up a fluke, which probably belonged to this species, and was acquired during a residence in Senegambia. Blanchard regards it, however, as *F. gigantica* Cobb, mentioned below.

The case demonstrates also the susceptibility of man to other species of the genus Fasciola as well as to that ordinarily known, and renders it advisable to make brief mention here of the other species of this genus which are likely to be encountered in various regions.

Very closely related to the last species are *Fasciola ægyptiaca* Looss, which occurs in the domesticated herbivora of Egypt, and *F. gigantica* Cobbold, which was originally described from the liver of the giraffe, but which, according to Blanchard, occurs in the cattle of Senegambia and other regions in Africa. Probably these species may be introduced under favorable chances into the human host as well as the related species already described.

More important for American physicians is the allied native species which is so widely distributed on this continent. Although it has not yet been reported as a human parasite, the probability of its occurrence as such is sufficiently immediate to call for its description here.

Fasciola magna (Bassi 1875) Stiles 1894.—(Syn.: *Distomum magnum* Bassi 1875; *F. carnosa* Hassall 1891; *F. americana* Hassall 1891; *D. texanicum* Francis 1891; *D. crassum* [in part] Leidy 1891; *Cladocœlium giganteum* [in part] Stossich 1892.) Body flesh-colored when alive, broad, thick; much larger and thicker than *F. hepatica*; length, 23–100 mm.; breadth, 11–26 mm.; thickness, 2–4.5 mm. The conical anterior part is not distinctly set off from the posterior. The posterior end is bluntly rounded, and margin more convex. In general the structure is very similar to *F. hepatica*, except that the œsophagus is longer, one-and-a-half to three times as long as the pharynx, the intestines more branched, and the yolk glands confined to the ventral side of the intestine; eggs oval, 0.109–0.168 mm. long by 0.075–0.096 mm. wide.

This fluke is found in cysts in the liver and lungs of cattle and of several species of deer, and is very widely distributed, occurring on the authority of various persons in Texas, Arkansas, California, Iowa, Illinois, New York (Adirondacks), and Italy. It is probably present in most parts of this country. In importance it stands hardly second to *F. hepatica*, but of its life history nothing is definitely known. Its close relationship to other species which have been reported occasionally from the human host in Europe indicates that this species also may adopt the same rôle here when circumstances favor.

Fasciolopsis Looss.—Fasciolinæ without distinct anterior and posterior regions. Cuticula smooth. Acetabulum powerfully developed with cavity extended posteriad as sacculate invagination and much larger than oral sucker. Intestinal crura simple, slender, wavy but without evaginations. Testes dendritic, with branches growing smaller toward distal ends. Cirrus pouch very long, cylindrical, containing spiral tubular seminal vesicle with peculiar cæcal appendage. Cirrus closely covered with fine spines. In alimentary canal of mammals.

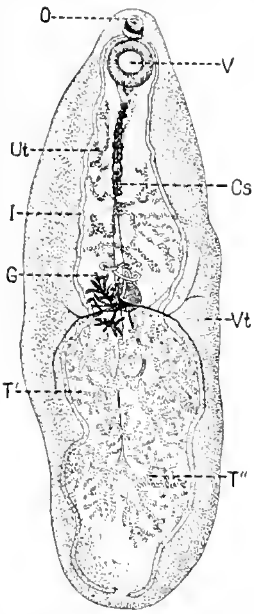


FIG. 4780.—*Fasciolopsis Buski* (Lank.). *Cs*, Cirrus sac; other abbreviations as before. × 3. (After Odhner.)

Fasciolopsis Buski (Lankester 1857).—(Syn.: *Distomum Buski* Lank. 1857; *Distoma crassum* Busk 1859, nec v. Sieb. 1836). Length, 24–37 mm., average about 30; breadth, 5.5–12 mm., average, 9 mm.; greatest thickness, 1.5 mm.; body (Fig. 4780) flattened, linguiform, anterior region tapering, but not sharply marked off from posterior body. Anterior sucker 0.5 mm. in diameter, acetabulum separated by not more than its diameter (1.6–2 mm.) from anterior end, with deep triangular lumen. Pharynx large, powerful; prepharynx present; œsophagus very short; intestinal crura slender, extending to extreme posterior end in three shallow curves. Testes dendritic one behind the other in median field, and both posterior to transverse yolk duct; cirrus sac median, cylindrical, much elongated, enclosing long spiral seminal vesicle with lateral elongate cæcal appendage. Germarium small, dendritic, anterior to testes, and to transverse yolk duct; Laurer's canal present, receptaculum seminis wanting; uterus in scanty irregular open coils, anterior to ovary; yolk glands lateral with numerous very small acini extending length of body; genital pore immediately at anterior margin of acetabulum, cirrus covered with many fine spines; eggs numerous, 0.12–0.126 mm. in length, 0.077 mm. in breadth; similar to those of *Fasciola hepatica*.

Eight positive and several uncertain cases of the occurrence of this species are on record. They are all from southern or eastern Asia and all concern the human host. The parasite occurs in the duodenum according to Busk, and the symptoms of Cobbold's and Olhner's cases pointed unmistakably to this as an intestinal parasite. No facts on the life history are recorded as yet. In 1891 Leidy reported as belonging to this species specimens received from New York, Arkansas, and Texas, where they were collected from the liver of a doe in the first case and from cattle in the other two instances. The species he had under observation, however, was actually *Fasciola magna*, and there is no evidence that *Fasciolopsis Buski* has been found on this continent, although its occasional introduction by the Chinese is not a remote contingency in view of the known facts regarding other species (*cf. Paragonimus Westermanii* and *Opisthorchis sinensis*).

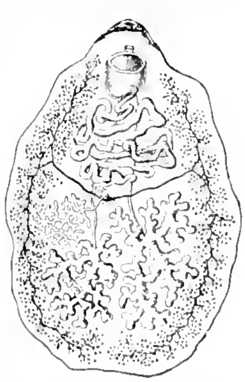


FIG. 4781.—*Fasciolopsis Rathouisi* (Poirier). × 2. (From Leuckart, after Poirier.)

Fasciolopsis Rathouisi (Poirier 1887).—(Syn.: *Distomum Rathouisi* Poirier 1887.) Length 25 mm., breadth 16 mm., oval, with indistinctly marked anterior region (Fig. 7481). Cuticula smooth. Oral sucker 1.5 mm., ventral 2 mm. in diameter. Intestinal crura unbranched; germ gland dendritic, posterior to transverse yolk duct; vitellaria lateral, not joined posteriad; uterus in centre of anterior half of body; genital pore just in front of acetabulum. Eggs 0.150 by 0.08 mm.

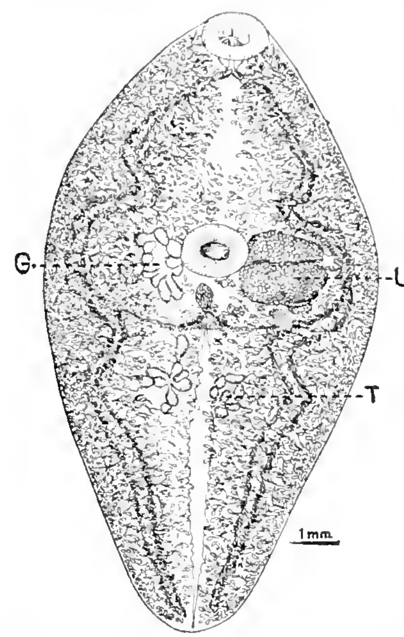


FIG. 4782.—*Paragonimus Westermanii* (Kerb.) in Ventral Aspect. American specimen from dog. Note reverse position of reproductive organs as compared with Fig. 4784. × 5. (Original.)

Nothing is known of the development of this species. It has been observed only once in a Chinese woman, who vomited the specimens after violent pain in the region of the liver. Possibly the cases reported by Blanchard from correspondence with P. Manson belong to this species.

Paragonimus Braun 1899.—Body thick, oval, or spindle-shaped, and nearly circular in transsection. Cuticula spinous. Acetabulum near centre of body. Alimentary canal with prominent pharynx, very short œsophagus, and intestinal crura extending in irregular zigzag to posterior end. Excretory bladder large, extending nearly to pharynx. Genital pore lateral near acetabulum. Special copulatory organs wanting. Testes dendritic, right and left in posterior region. Germarium also dendritic, anterior to left testis. Receptaculum seminis lacking. Laurer's canal present. Vitellaria extensive, on side of body almost the entire length and dorsal also almost to median line. Uterus scantily developed as coil lateral to and near acetabulum. Eggs large. Usually by pairs in cysts in lungs of mammals.

Paragonimus Westermanii (Kerbert 1878).—(Syn.: *Distoma Westermanii* Kerbert 1878; *D. Ringeri* Cobbold 1880; *D. pulmonale* Baelz 1883, *D. pulmonis* K. S. and Y. 1881; *Mesogonimus Westermanni* Railliet 1890.) Length 8–16 or even 20 mm., breadth 4–8 mm., body thick and plump, posterior end more pointed, ventral surface more flattened (Fig. 7482); color, deep red or reddish brown when alive, or dark gray in alcoholic material, with conspicuous black dendritic acini of the yolk gland along the side. Cuticula spinous; oral sucker 0.53–0.75 mm. (Leuckart), or 0.86–1.2, or even 1.4 mm. (Ward). Acetabulum 0.6–0.75 mm. (Leuckart), 0.75–1.02 mm. (Ward); slightly larger than oral sucker, situated anterior to middle of body; œsophagus short, intestinal cæca wavy, with irregular outline, extending to posterior end of body. Germarium branched, posterior to acetabulum, lateral, opposite the lobate shell gland, which lies directly in front of the condensed uterus. Yolk glands highly developed, extending from anterior to posterior end, absent only over narrow median field. Testes branched, lateral, in posterior portion of body; cirrus and cirrus pouch wanting genital pore, near posterior margin of acetabulum, either median, right, or left; eggs oval, 0.08–0.1 by 0.05 mm. (Leuckart) or 0.096–0.118 by 0.048–0.055 mm. (Ward) (Fig. 4783).

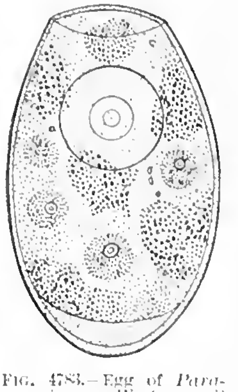


FIG. 4783.—Egg of *Paragonimus Westermanii* (Kerb.). Magnified 500. (After Katsurada.)

The oval ciliated embryo develops within the egg some time after the latter has been discharged with sputum from the host. Further life history unknown.

This parasite has been found in the tiger, cat, dog, and hog as well as in man. It appears from the studies of Ward and Stiles that differences in size are noticeable between the Asiatic (Fig. 4784) and American (Fig. 4782) forms. These differences are noted in the specific description given above. Further study may show them to be distinct species. The different arrangement of the sexual organs may represent the condition of sexual amphitypy noted above.

Distribution.—The parasite is known from Japan, China, Corea, and Formosa, where according to good authorities fifteen per cent. of the entire population is infected. In this country it has been reported from Michigan and Ohio by Ward, and from Kentucky and West Virginia by Stiles, according to whose accounts it seems to be common in hogs of the infested district. Thus far it has not been reported from a human host in the United States. Stiles has made an exhaustive study of the species, but is unable in spite of the recorded differences in size to differentiate specifically the American and Asiatic forms. Even should they prove to be distinct, however, possible danger to man would not be eliminated since the Asiatic form has been found in cat, dog, and hog as well as man, and the American form, which has thus far been reported only from the cat, dog, and hog, may confidently be expected to recur in man in the infected district. Until the announcement by Stiles of the existence of an extensive infection among hogs, it was not clear that the species had actually established itself in the United States, as the two cases in cat and dog which Ward reported might have been introduced from Asia after infection. Now that a large number of cases is known from this country, the endemic character of the species cannot be doubted. It is of the greatest importance that the distribution be more precisely established, and the life history worked out to show the points of danger for the infection of man and the precautions which must be taken to guard against it.

Pathology.—The disease was first reported from man in 1880 by Manson, who called it parasitical hæmoptysis and later endemic hæmoptysis. The term pulmonary distomatosis has also been used. From the cases thus far on record in detail, it is apparently much more prevalent in males than in females, and seventy-five per cent. of these cases occurred among farmers. Both of these facts undoubtedly point to factors in the life history which make infection of such persons easier rather than to any inherent susceptibility; in fact Yamagiwa states that strong persons are more susceptible than weak, but this is evidently because they are more given to outdoor occupations, and hence more open to infection.

Ordinarily the worms are found in the lungs, where they lie in tumors about the roots and along the dorsal border directly under the pleura, sometimes surrounded by a capsule or again burrowing into the lung tissue. The worms occur in man usually one, but in other hosts two, in each cyst, although instances are not rare where one or several have been taken from a cyst, and some cysts contain eggs but no adult worm. The cysts contain not only the worms, but also masses of eggs, and Charcot's crystals, while cholesterin crystals are also occasionally present. The eggs and crystals reach the exterior in masses of mucus and blood through fine openings which communicate with the bronchi. The number of eggs discharged in the course of a single twenty-four hours may be enormous, and was estimated in case of one patient who had suffered thirteen years from the disease as not less than twelve thousand daily.

Yamagiwa has also found in the brain cysts containing the parasites and eggs or simply the eggs. Foci of these eggs and small blood-vessels filled with them occurred in the cortical substance of occipital and parietal lobes; these were associated with giant cells and surrounded by proliferating connective-tissue and round-cell infiltration. The lungs of the same host showed characteristic lesions due to these flukes, so that Yamagiwa concluded that this was the source of the egg emboli found in the brain. These cases, of which several are already on record, are characterized by epileptic attacks (Jacksonian or cortical epilepsy).

Yamagiwa has also found cysts containing the eggs of this species in the liver, causing or associated with cirrhosis of that organ, as well as in the diaphragm, peritoneum, mesentery, and walls of the intestine.

Symptomatology.—When in the lungs, its common abiding place, the distome gives rise to periodic hæmoptysis and chronic cough, with rusty, mucoid expectoration; spitting of blood is common but not constant. The condition of the patient remains good, and almost no abnormal sounds can be detected by percussion of the chest. Yamagiwa says that the general appearance of the expectoration is identical with tuberculosis, and that the disease was formerly diagnosed as such in Japan. The presence in the sputa of the eggs already described makes a positive diagnosis by microscopic examination easy. Accidental rupture of a large blood-vessel by the destruction of lung tissue, and in severe cases general anæmia, are the dangers to be feared.

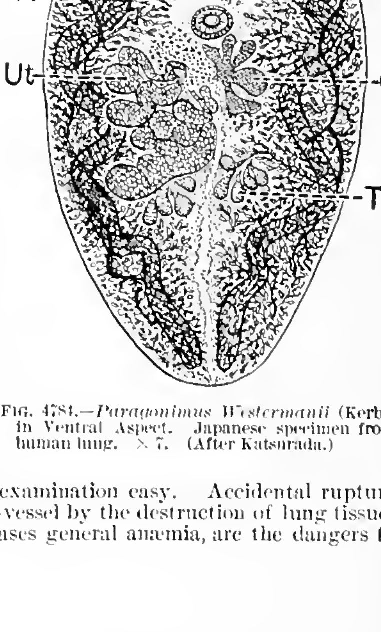
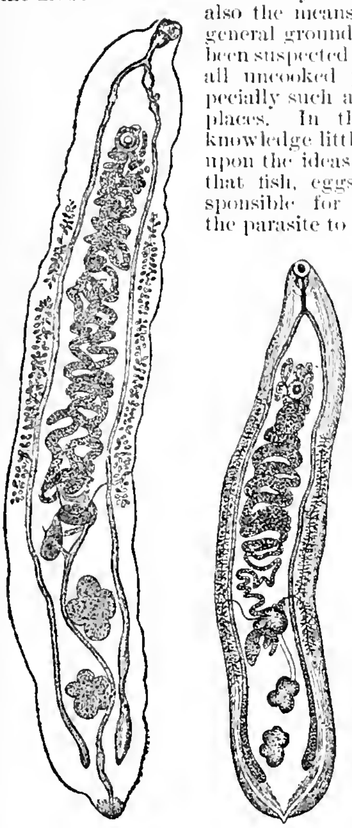


FIG. 4784.—*Paragonimus Westermanii* (Kerb.) in Ventral Aspect. Japanese specimen from human lung. × 7. (After Katsurada.)

Removal from an infected district is followed usually by complete recovery.

In absence of any knowledge regarding the life history the mode of infection is entirely in the dark, and equally also the means of prevention. On general grounds drinking-water has been suspected; more suspicious are all uncooked plant foods, and especially such as are grown in moist places. In the light of present knowledge little weight can be laid upon the ideas of certain Japanese that fish, eggs, and meat are responsible for the transference of the parasite to the human host.



A. B.

FIG. 4785.—*Opisthorchis felineus* (Riv.). *A*, Elongated Specimen from Liver of Cat. (After Braun.) *B*, "Distomum sibiricum" from liver of man. (From Braun, after Winogradoff.) Magnified.

Opisthorchis R. Blanchard 1895.—Body flat, elongated, broad posteriorly, but tapering toward the anterior end. Cuticula without spines. Testes, lobed or even branching, located one obliquely behind the other in posterior region. Genital pore just in front of acetabulum; no special copulatory organs. Receptaculum seminis large, Laurer's canal present, germarium anterior to testes. Uterine coils anterior to germarium and within intestinal crura. Vitellaria lateral, never anterior to acetabulum. Excretory bladder **Y**-shaped, the long unpaired stem curved like an **S** between the testes.

Opisthorchis felineus (Rivolta 1885.)—(Syn.: *Distoma conus* Gurlt 1831, nec Creplin 1825; *D. lanceolatum* v. Siebold 1836, v. Tright 1889, nec Mehlis 1825; *D. sibiricum* Winogradoff 1892; *D. tenuicolle* Mühling 1896.)

Body much flattened, with sides parallel save that the region anterior to the acetabulum is conical and very changeable in form when alive. Posterior end often slightly pointed. Color faint reddish-brown or yellow; when alive, transparent. Length 8–11 mm., breadth 1.5–2 mm. Suckers separated by only one-fifth to one-sixth of the length, nearly equal in size (0.23–0.25 mm.). Œsophagus very short, intestinal crura reaching nearly to posterior end. Excretory bladder forking anterior to testes. Anterior testis four-lobed, posterior five-lobed. Germarium median, transverse, smaller than the pyriform seminal receptacle just behind it. Uterus entirely within intestinal crura. Vitellaria, in the broad lateral fields, composed of seven to eight distinctly separated groups of follicles, all anterior to ovary. Genital pore immediately preacetabular. Eggs oval with distinct lid at pointed pole, 0.030 by 0.011 mm.

This much confused species has been carefully studied by Braun. It inhabits the gall ducts and gall bladder of the cat, dog, fox, glutton, and man. Of the life history little is known. The eggs when laid contain a ciliated miracidium which, according to Braun, will not hatch out in water, although in Winogradoff's experiments they are said to have done so. Further knowledge on the development is lacking.

Distribution.—Germany, France, Italy, Holland, Scandinavia, Hungary, Russia, Siberia, and if correctly reported Japan also, are the countries in which the species has been found. It is apparently most abundant on the shores of the Baltic, and the general correspondence of its distribution with that of the human tapeworm, *Dibothriocephalus latus*, is worthy of note.

Pathology.—In 1892 Winogradoff found in post-mortems at Tomsk (Siberia) cases of what he thought to be a new human parasite. This he described as *Distoma sibiricum* (Fig. 4785, *B*), but it is probably identical with the species from the cat studied by Braun (Fig. 4785, *A*). Fifteen cases have been reported from Siberia, Russia, and East Prussia. In Tomsk it is the most common human parasite and in East Prussia is also common. Although in no case was a fatal termination attributable to this parasite, yet pathological changes in the liver were noted, such as dilatation of the gall ducts with inflammation and thickening of the walls, and atrophy of hepatic tissue. In recently infected cases the liver was enlarged; in older ones, on the contrary, smaller than normal. Ascites was noted in three cases, icterus in five. Askanazy found hepatic carcinoma in both of the cases he studied closely, and noted that it occurred in the region most visited by the parasites. He was accordingly inclined to place these facts in causal relation since the changes incited by the flukes consisted in manifold, even dendritic, proliferation of the mucosa into the like ise proliferating connective tissue. In both these cases there were over a hundred parasites found in the infected organ, and they were met with also in the pancreatic duct and in the intestine. In other cases on record the number of parasites found varied from a few to several hundred.

In view of the frequent confusion of this species with *Dicrocœlium lanceatum* it is possible that some records included under the latter actually concern the former species. It has been conjectured with good reason that man acquires this species, like *Dibothriocephalus latus*, through the consumption of uncooked fish in which the young distome is encysted, and it is striking that in all of Askanazy's cases in East Prussia both these parasites occurred together. That author, however, was unsuccessful in the effort to infect experimentally with this parasite, or to discover its immature stage.

A closely related American species is one which I originally described as a variety of *O. felineus*, but now believe to be entirely distinct. This is *O. pseudofelineus* Ward 1900 (Fig. 4772), which is a frequent parasite of the cat in some parts of the country, and has been found in the dog and coyote also. The intermediate host is unknown, but many facts point to some fish. Its transfer to the human host might be brought about by chance, or as in the case of the closely related species of the Old World. It occurs here in much the same hosts save man, and consequently would probably be able to maintain itself in the latter host also.

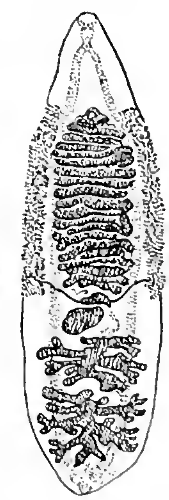


FIG. 4786.—*Opisthorchis sinensis* (Cobb.). Contracted specimen from man in Japan. × 6. (After Katsurada.)

A small spiny distome which Winogradoff found in man in one instance, and which he regarded as the immature form of *O. felineus*, has been tentatively identified by Braun as *Metorchis truncatus* (Rudolphi 1819). This species is a normal parasite of the cat and had probably reached the human host in the same manner as *Opisthorchis felineus*, with which it is moreover often associated in the cat. As this form is parasitic not only in the cat, dog, fox, and glutton, but also in two species of seal, still further evidence is furnished of the transmission of this and the preceding species through fish food.

Opisthorchis sinensis (Cobbold 1875).—(Syn.: *Distoma* *sinense* Cobbold 1875; *D. spathulatum* Leuckhart 1876, nec Rudolphi 1819; *D. hepatis endemicum* s. *perniciosum* Baelz 1883; *D. hepatis innocuum* Baelz 1883; *D. japonicum* R. Blanchard 1886; *D. endemicum* Ijima 1886.) Length 9-15 or even 18 mm.; breadth 2.4-4 mm.*

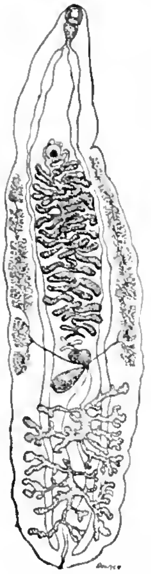


FIG. 4787. *Opisthorchis sinensis* (Cobb.). Moderately extended specimen from man in California. Case of White. Magnified. (Original.)

Body translucent, slightly tinted with yellow or red; form elongate, attenuated toward anterior end, bluntly pointed at posterior (Fig. 4786). Oral sucker larger than ventral and separated from it by one-fourth the entire length. Testes deeply lobed or dendritic, one behind the other in posterior end and overlapping the intestinal crura; anterior to them the prominent receptaculum seminis and then the germarium, faintly lobed, in the median line. Vitellaria lateral, extending from the acetabulum to germarium or slightly further posteriad. Uterus in transverse coils between acetabulum and germarium, but within intestinal crura. Genital pore at anterior margin of acetabulum. Eggs, from fæces 0.027–0.030 mm. long, and 0.015–0.0175 mm. broad; exceptionally 0.035 by 0.019 mm., or at the other extreme 0.02 by 0.0157 mm.; miracidium developed before extrusion from uterus. Parasitic in the cat, dog, and man.

It has been found abundantly in Japan, but occurs also in Corea, Formosa, Tonquin, China, India, and Mauritius. A single case has been reported from New York City by Biggs; the host was a Chinaman. Recently White has found eighteen cases of infection with this parasite (Fig. 4787) in San Francisco. All were detected at necropsies, and of the cases sixteen were pest infected, one had beriberi, and one valvular heart disease. White was inclined to believe that some of the cases were infected in California, though no evidence has yet been published to show that the species has actually established itself on this continent.

In Japan the population is widely infected; the parasite is sporadic in some regions, but in other localities in several provinces it is endemic; in some districts of the province Okayama, according to Katsurada, from fifty-six to sixty-seven per cent. of those subjected to fæcal examination were infected. Of the development the ciliated embryo alone is known. This is formed when the eggs (Fig. 4788) are passed in the fæces of the host; but, according to Ijima, it does not desert the shell spontaneously, even after five months. The intermediate host is probably a mollusk, and the rice fields, which are often fertilized by human excrement, are centres of infection. The mode of transmission can only be conjectured.

The parasite occurs either in the gall ducts and gall bladder or in the pancreatic ducts. It is present also in the duodenum and rarely in the stomach and spleen. The pathological changes are of a mechanical type, and apparently generally proportionate to the duration of the disease and to the number of worms present, which may reach ten thousand or more in a single host. In cases of severe infection the death of the patient follows; this occurs in about fourteen per cent. of the sick. Two hundred and twenty fatal cases were recorded in twelve years in the province of Okayama. Like other species, this parasite has been found outside the liver in pus of a phlegmon on the right side of the abdomen, and in a second case on the diaphragm.

Pathology.—The hepatic lesions produced by flukes were first accurately determined by Schaper for *Fasciola hepatica* in cattle and sheep, and subsequently confirmed by Katsurada and Blanchard, both of whom studied the changes in the human liver produced by *Opisthorchis sinensis*. The results show essential similarity in all cases studied. The lesions are of two sorts; the first, due to the occlusion of the biliary ducts by the parasites, is largely mechanical, and consists in stasis of the bile and dilatation of the ducts with resulting effects on general nutrition. At the same time the resulting inflammation leads to desquamative catarrh accompanied by thickening of the mucosa and glandular hyperplasia. There is also a proliferation of the connective tissue together with increase in blood capillaries and cellular infiltration, which aids in the reduction of liver tissue and in the obliteration of bile ducts. Atrophy of the parenchyma and granular degeneration bring about the destruction of the capillaries, and ultimately the transformation of a larger or smaller portion of the liver into a mass of cicatricial tissue containing only metamorphosed gall ducts.

The effects upon the circulatory system are primarily mechanical in the injuries to capillaries producing multiple hemorrhages, and where these discharge through gall ducts resulting in anæmia. The inflammation produced by the movements of the flukes affects the walls of the blood-vessels and renders it possible for the flukes to gain entrance to the system, and thus be carried to various parts of the body. The growth of connective tissue serves ultimately to compress branches of the portal system, or even partially to obliterate them, and the circulatory stasis is followed by ascites or œdema. Enlargement of the spleen, pathological changes in the pancreas, when that organ also becomes infected, and chronic gastro-intestinal catarrh have been recorded. In fluke disease among animals it has also been noted that the blood is poor in hæmoglobin and subnormal in number of corpuscles.

Opisthorchis noverca Braun 1902.—(Syn.: *Distoma conjunctum* Lewis and Cunningham 1872, McConnell 1876, nec Cobbold 1859.) Body lancet-shaped, spinous, 9.5–12.7 mm. long by 2.5 mm. broad. Suckers close together, the oral being larger than the ventral. Pharynx spherical, intestinal crura extending far posteriad. Genital pore immediately in front of acetabulum; testes round or only slightly lobed, at limit of posterior third of body and nearly opposite. Germarium slightly lobed, in front of bifurcation of the **Y**-shaped excretory reservoir. Uterus in loops through central area from germarium to genital pore. Vitellaria lateral, from testes anteriad nearly to acetabulum. No cirrus sac. Eggs oval, 0.034 by 0.021 mm.

Found in a necropsy in Calcutta in large numbers in the gall ducts of two Mohammedans by McConnell. Similar parasites were discovered a few years earlier by Lewis and Cunningham in the liver of street dogs in the same city. No doubt these forms were both the same species, but Braun has shown clearly that they cannot be the species which Cobbold had found earlier in the liver of an American fox that died in London, and to which the discoverers had assigned them.

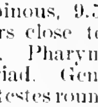


FIG. 4788.—Egg of *Opisthorchis sinensis* (Cobb.) ×500. (After Katsurada.)

Heterophyes Cobbold 1866.—Body without distinct separation into anterior and posterior region. Oral sucker without crown of spines. Pharynx close to oral sucker, intestinal crura extend to posterior end of body. Genital orifice lateral, near acetabulum, surrounded by prominent muscular genital sucker with circle of branched chitinous spines. Vitellaria near posterior margin, scantily developed.

Heterophyes heterophyes (v. Siebold 1852).—(Syn.: *Distomum heterophyes* v. Siebold 1852; *Mesogonimus heterophyes* Railliet 1890; *Cœnogonimus heterophyes* Looss 1900; *Cotylogonimus heterophyes* Lühe 1900.) Length 1–1.7 mm., breadth 0.3–0.6 mm. Limit between anterior mobile and posterior regions often indistinct in alcoholic material (Fig. 4789). Acetabulum very powerful, thick-walled, about

* According to previous reports the worm varies widely in size with hosts and number of individuals present. Even yet it may be questioned whether two or more species are not confused under this name by different observers.

two and one-half times and genital sucker about one and one-half times as large as oral sucker; average diameter of oral sucker 0.09 mm., of ventral sucker 0.23 mm., of genital sucker 0.15 mm. Intestinal crura thin, terminating posteriorly at excretory bladder. Lateral acini of vitellaria outside intestinal crura, sometimes even extending on to ventral surface. Testes near posterior end, just anterior to tips of intestinal crura. Germarium median in posterior region, uterus covering nearly entire posterior end. Eggs light brown, thick-shelled, 0.03 by 0.017 mm.; ciliated miracidium fully developed when egg is deposited (Fig. 4790).

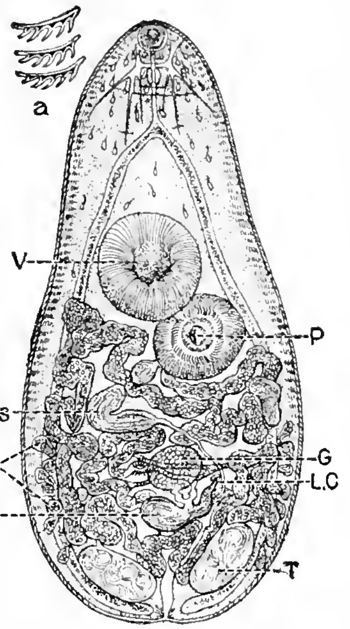


FIG. 4789. — *Heterophyes heterophyes* (v. Sieb.) in Ventral Aspect. *a*, Cuticular spines from margin of genital sucker, *P*. Other letters as before. × 42. (After Looss.)

Parasitic in dog, cat, fox (?), and man in Egypt. A single record of its presence in dogs in Japan needs confirmation. The species was discovered in 1851 by Bilharz in the intestine at the necropsy of a boy in Cairo. The belief that the species was rare in man has been dispelled by the studies of Looss, who finds it rather common; on account of its diminutive size, however, it is easily overlooked. This author has also recently differentiated some closely related species which have been found in other hosts and listed heretofore under the same name. Its seat is the middle third of the duodenum, and it is often found by the hundreds. It usually moves about freely in the chyle, but may remain attached to the wall or concealed in the folds of the mucosa. The parasite feeds on the contents of the intestine, and neither blood corpuscles nor epithelial cells could be found in its alimentary canal. This accounts for its apparently harmless character even when present in large numbers. In spite of the prominent spines on the skin Looss was unable to recognize in any case alterations in the mucosa of the host, which could be attributed to the work or presence of the parasite. According to Looss also the parasite affects particularly the country population and is wanting in those who live in the cities as well as in Europeans.


FIG. 4790.—Egg of *Heterophyes heterophyes*. × 500. (After Looss.)

Dicrocœlium Dujardin.—Body delicate, semitranslucent; form elongate, foliate, tapering toward both ends, with smooth cuticula; oral and ventral suckers separated by less than one-fourth total length. Pharynx small; œsophagus short; intestinal crura long but not extending to posterior end. Cirrus sac anterior to acetabulum, enclosing coiled seminal vesicle and long slender cirrus. Genital pore between pharynx and fork of intestine. Testes compact, forming with the smaller compact germarium a median series directly posterior to acetabulum. Laurer's canal and receptaculum seminis present. Uterus in transverse coils, filling region posterior to germarium. Vitellaria lateral to intestinal crura, only moderately developed. Eggs dark brown, numerous.

Dicrocœlium lanceatum Stiles and Hassall 1896.—(Syn.: *Fasciola lanceolata* Rudolphi 1803, nec Schrank 1790; *Distomum lanceolatum* Mehlis 1825; *Dicrocœlium lanceolatum* Dujardin 1845.) Length 4, usually 8–10 mm., breadth 1.5–2.5 mm. Body flattened, lanceolate, attenuated toward both extremities, especially the anterior (Fig. 4791). Suckers separated by about one-fifth total length; diameter of oral sucker about 0.5 mm., of ventral about 0.6 mm. Intestinal crura terminate one fifth of total length from posterior end. Genital pore at intestinal fork. Testes slightly right and left of median line. Vitellaria from posterior testis through about the middle fifth or fourth of body. Loops of uterus extending laterally beyond intestinal crura. Eggs 0.038–0.045 by 0.022–0.030 mm., thick-shelled, dark brown when deposited, and containing a spherical or oval miracidium ciliated only at anterior end and supplied with rudimentary intestine and boring spine.

Parasitic in gall ducts of herbivorous and omnivorous mammals very generally, often in common with *Fasciola hepatica*. Among the hosts given are sheep, cattle, horse, ass, deer, goat, hare, rabbit, pig, and man. The records in accordance with which this species occurs in dog and cat rest on confusion with *Opisthorchis felineus*.

The development of the species is unknown. Leuckart found that the miracidia spontaneously desert their shells in the intestine of certain slugs (*Arion*, *Limax*), but that no further development could be induced here or in other snails. On the basis of a single feeding experiment, however, he considered small species of *Planorbis* from fresh water to be the larval host. Piana conjectured that land snails were more probably responsible. No further evidence has been obtained.

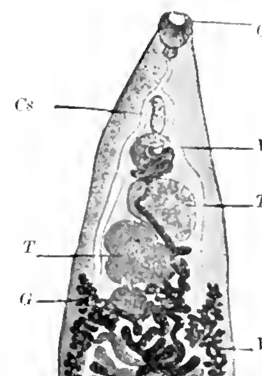


FIG. 4791. — *Dicrocœlium lanceatum* Stiles and Hassall. × 12. (After Braun.)

The distribution of this species is less extended than that of *Fasciola hepatica*, though in general much the same. Leuckart believed it more abundant in southern Europe than in the north. It is wanting in England, but has been recorded among extra-European countries in northern Africa, Siberia, Turkestan, North and South America.

Seven cases of human infection are on record. They come from Germany, Bohemia, Italy, France, and Egypt. With possibly a single exception the parasite was not the cause of any apparent trouble. In view of this absence of dangerous symptoms Braun conjectures that mild infections may be much more frequent than is known.

The family of the Schistosomidæ Looss contains flukes of separate sexes with the male shorter and thicker than the slender female, and having a canal formed by the ventrally turned margins of the body. The acetabulum is stalked and the intestinal crura unite posterior to it. Only one genus is important here.

Schistosoma Weinland 1858.—Female filiform; male very broad with body rolled together ventrad to form completely closed *canalis gynæcophorus*. Suckers near together. No pharynx. Intestinal crura in male join often far back. Genital pore in both sexes median, postacetabular, no copulatory organs. Testes of five to six vesicles. Seminal vesicle small. Uterus of female very long, at times with large numbers of eggs. Eggs tapering equally to both ends with small terminal spine at posterior end, without lid. In venous system of mammals.

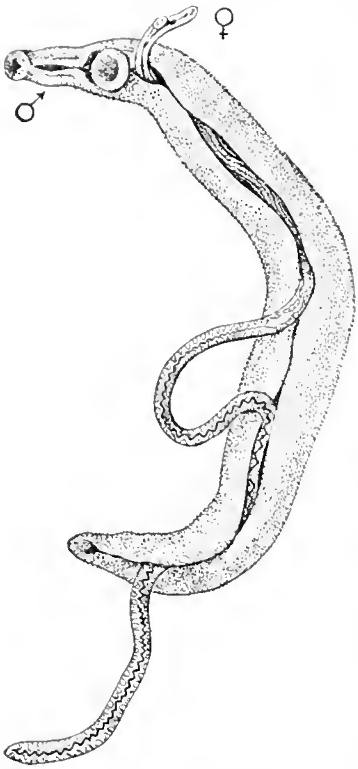


FIG. 4792.—*Schistosoma hæmatobium* (Bilharz). Male and female *in copula* and before the beginning of the production of eggs. × 12. (After Looss.)

Schistosoma hæmatobium (Bilharz 1852).—(Syn.: *Distoma hæmatobium* Bilharz 1852; *Gynæcophorus hæmatobius* Diesing 1858; *Bilharzia hæmatobia* Cobbold 1859; *Thecosoma hæmatobium* Moq.-Tand. 1860; *Bilharzia capensis* Harley 1864.) Male 4, or usually 10–14 mm. long, 1 mm. broad, 0.14–0.17 mm. thick; female 8, or usually 13–20 mm. long, 0.28 mm. broad, 0.21–0.25 mm. thick, oral sucker 0.2 mm. in male, 0.07 mm. in female. Acetabulum pedunculate; diameter 0.28 mm. in male, 0.059 mm. in female. Eggs 0.12–0.19 mm. long, 0.05–0.073 mm. broad, spindle-shaped with median enlargement and with rudimentary filament at posterior end.

Structure.—Through the admirable recent studies of Looss the earlier work of Leuckart and others has been confirmed and extended so that a precise account can now be given of this unique form. The two sexes must be considered separately save that both agree in the delicacy of structure consonant with their existence in the blood current. The male (Fig. 4792) shows papillæ or warts over the entire dorsal surface, except near both ends of the body. Fine dermal spines cover the suckers both within and without. Slightly larger spines cover ventral surface of the body from the genital pore to the posterior tip, *i.e.*, the so-called *canalis gynæcophorus*, as well as form a zone on the dorsal margin of that side which lies within in the formation of the canal. A pharynx is wanting and the œsophagus with two expansions (*A*, *B*, Fig. 4794) covered with a layer of salivary cells terminates at or near the acetabulum, branching to form the intestinal crura. These may join soon to form the unpaired cæcum, which extends in the median line nearly to the posterior end, or their junction may not occur until the posterior fifth of the body is reached; one also finds the crura separating for short intervals in the course of the unpaired cæcum. The food mass in the alimentary canal of the parasite consists chiefly of leucocytes with pigment from the liver and a few erythrocytes.

The reproductive system departs widely from that of other Trematoda described in general above, first in that the sexes are separate, but secondly and equally strikingly in its structure. In the male (Fig. 4794) the testes, four or five in number, lie alternately right and left of the median line not far behind the acetabulum. As the apparent common duct is in reality a part of the organ, the group represents rather a very deeply lobed single testis. The short duct joins this to the sausage-shaped seminal vesicle, from which a short simple canal extends to the sexual pore. This pore is always located exactly at the entrance to the canalis gynæcophorus. Special copulatory organs and glandular adnexa are entirely wanting.

The body of the female is smooth except on the inner surface of the suckers, where extremely fine spines are numerous and the posterior tip of the body, which carries much stronger spines, pointed in various directions. A pharynx is wanting; the œsophagus with dilatations and gland cells, as in the male, divides anterior to the middle of the acetabulum, to form the intestinal crura, which unite behind the germarium to proceed as an unpaired cæcum in a zigzag line, with regularly alternating lateral diverticula to the posterior end.

The female reproductive system (Fig. 4793) lies largely between the acetabulum and the posterior junction of the intestinal crura. Just anterior to this junction one finds the median, elongated oval germarium. The single vitellarium with symmetrical follicles right and left of the intestinal cæcum, occupies the posterior end of the body. Its duct lies parallel to the germ duct coming from the posterior end of the germarium, and joins it at the shell gland, which is located a short distance anterior to the germ gland. After a short ootype the uterus extends nearly directly as a tube of uniform calibre in the median line to the genital pore which lies immediately behind the acetabulum.

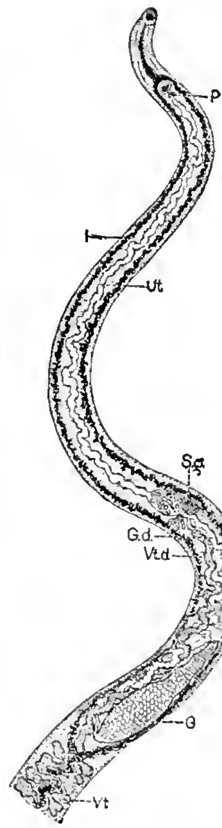


FIG. 4796. *Schistosoma hæmatobium* (Bilharz). Anterior region of female in ventral aspect. The uterus does not contain as yet any developing ova. Letters as before. × 19. (After Looss.)

The egg (Fig. 4795) has the form of a compressed spindle somewhat inflated at the middle. At the posterior pole one finds a short irregular tip, homologous to the filament on the eggs of ectoparasitic trematodes. In those eggs which are discharged in urine this process is terminal, in such as remain in the body of the host it is slightly lateral. The egg shell contains a mature embryo, cylindrical in form with conical anterior tip, or papilla, and covered by a coating of fine cilia. A rudimentary alimenatry canal, cephalic gland, and the usual masses of germ cells in the posterior end are easily distinguishable.

All authorities, save one, agree that the embryos do not hatch out if the eggs are left in unaltered urine, but that the addition of fresh water, especially if warm, brings about at once the opening of the shell and escape of the embryos. If left in urine the embryos die in the shell in from six to twenty-four hours. The further fate of these embryos is entirely unknown, as also the manner of infection. It has been conjectured that the sporocyst stage also occurred in the human host, but the experiments of Looss on apes were without result.

This species occurs as a parasite in the portal system of man, perhaps also in the Sooty monkey and in cattle.

It is widely distributed in Africa, records being at hand of its occurrence in Egypt, along the eastern coast, at Cape of Good Hope, and at points on the western and northern shore as well as in the interior. It is very common among the Egyptian laborers, and boys and youths seem to be particularly susceptible to its attacks. One-third or more of those examined by different observers were found to harbor the parasite. The centre of infection at Mecca (Arabia) is regarded as introduced, and that recently discovered on the island of Cyprus is probably similar.

A case has just been reported by Manson in which the eggs were found in the fæces but not in the urine of an Englishman in the West Indies, who had never been in any country where the parasite is known to exist. On account of its peculiar features the case needs confirmation, but if correct demonstrates the existence of a new centre of infection near our shores.

Stiles says that the human blood fluke has been found twice in this country; once in a foreigner on the "Midway" during the Columbian Exposition and once in New York City. I have found another case recorded from Georgia. All these cases were certainly infected elsewhere, and there is no evidence to show that the parasite has been able to gain a footing as yet in this country.

Pathology.—The females apparently go into the venous plexus of the pelvis to oviposit, and the eggs are carried thence by the blood current into various organs. Here they accumulate, occluding the vessels and causing various symptoms according to the organ affected. Such accumulations have not been found as yet in spleen, stomach, or pancreas. In the lungs they determine lesions which simulate those in miliary tuberculosis, and though rarely recorded as yet are believed to be common. Tumors of similar origin have been rarely met with in mesenteric ganglia, on the peritoneum and in the skin.

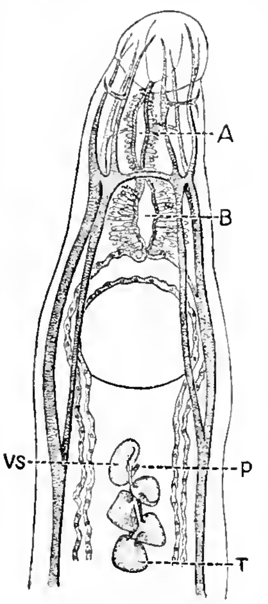


FIG. 4794.—*Schistosoma hæmatobium* (Bilharz). Anterior end of male showing male genital organs and also in part nervous and alimentary systems; *A*, *B*, enlargements of œsophagus with glands; *P*, sexual pore; *T*, testis; *VS*, seminal vesicle. × 48. (After Looss.)

In the liver cirrhosis and biliary calculi are produced by their presence. More frequently one can trace them to the walls of the urinary passages or of the large intestine, and here more serious difficulties arise. Catarrh of the bladder and pain in the lumbar region ensue and are accompanied by the appearance of blood or bits of blood and pus at the close of micturition, which at first occur only occasionally but later regularly. This so-called Egyptian hæmaturia, or bilharziosis as it is called after Bilharz, the discoverer of the parasite, can be definitely diagnosed by the microscopical demonstration of the eggs in the urine. It should be noted, however, that these may be present in the urine without the least trace of blood. The disease may continue for some time, even six to eight years, and eventually terminate without more extended symptoms.

Renewed or reinforced infection, however, intensifies the cystitis and often brings about urethritis as well. Frequently one finds urinary calculi, in many of which the nucleus of the calculus can be shown to consist of one or more fluke eggs. In Egypt one series of observations showed the coincidence of bilharziosis with lithiasis in eighty per cent. of observed cases. In more severe cases the changes may extend to the ureters, kidneys, and colon. The urine contains larger amounts of blood and eggs, and the fæces present a similar appearance. The symptoms then resemble tropical dysentery, and Bilharz, the discoverer of this parasite, originally connected the two in a causal way. As a result of the changes outlined, nutrition suffers and finally death ensues from uræmia, pyæmia, pyelonephritis, or general marasmus. The wall of the bladder shows under these conditions excessive thickening, together with the formation of excrescences, 1–2 cm. in diameter, filled with the eggs of the parasite; the cavity of the organ is diminished materially, and also the elasticity of its wall. Extensive ulcerations are not uncommon, and in connection with the rupture of small vessels determine the characteristic hæmaturia.

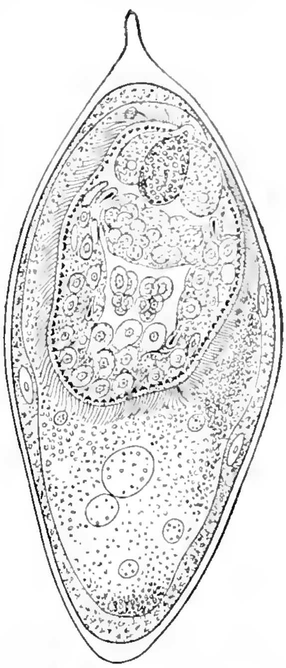


FIG. 4795. — Egg of *Schistosoma hæmatobium* (Bilharz). × 500. (After Looss.)

The disease cannot be regarded as necessarily fatal; its severity depends in general upon the degree of infection. In cases of moderate intensity appropriate treatment of a general character effects a noteworthy amelioration, and in many cases at least the disease is self-terminating. Anthelminthics and other medicaments have been employed with variable results.

Infection is generally attributed to the use of impure water from pools and canals. It has been observed that those villages supplied directly from the Nile are badly infected, while in those using filtered water the parasite is almost unknown. Looss has urged strong reasons in favor of the view that bathing affords the opportunity for the parasite to enter the body through the skin. Both the means of infection and the subsequent course of the parasite in reaching its location in the portal system are, however, entirely conjectural. *Henry B. Ward.*

PRINCIPAL ARTICLES CONSULTED.

Blanchard, R.: Lésions du foie determinées par la présence des douves. Archives Parasitol., iv., 581, 1901.
Braun, M.: Die thierischen Parasiten des Menschen. Würzburg, 1902.
Katsurada, F.: Beiträge zur Kenntniss des *Distomum spathulatum*. Beitr. z. path. Anat., Bd. xxviii., 479, 1900. Beiträge zur Kenntniss des *Distomum Westermanni*. *Ibid.*, p. 506.
Leuckart, R.: Die Parasiten des Menschen, 2d ed., vol. ii., Leipsic, 1894.
Looss, A.: Ueber den Bau von *Distomum heterophyes*, Kassel, 1894. Zur Anatomie und Histologie der *Bilharzia hæmatobia* (Cobbold), Arch. mikr. Anat., xlvi., 1895.—Recherches sur la faune parasitaire de l'Égypte. Mém. Inst. Égypt., iii., 1896.—Weitere Beiträge zur Kenntniss der Trematoden-Fauna Aegyptens.—Zool. Jahrb., Syst. xii., 1899.
Moniez, R.: Traité de Parasitologie, Paris, 1896.
Odhner, Th.: Fasciolopsis Buski. Centr. Bakt. u. Par., i., xxxi., Orig., p. 573, 1902.
Stiles, C. W.; Anatomy of the Large American Fluke. Journ. Comp. Med., 1894–95.
Stiles and Hassall: Notes, 51. The Lung Fluke in Swine and Its Relation to Parasitic Hæmoptysis in Man. Ann. Rept. Bureau An. Ind., 1889, p. 560.
Ward, Henry B.: On the Presence of *Distoma Westermanni* in the United States. Centr. Bakt. u. Par., xv., 362, 1894.—A Second Case of *Distoma Westermanni* in the U. S. Vetr. Mag., ii., 87, 1895.—On *Distoma felineum* in the United States. *Ibid.*, p. 152.—Parasitic Worms of Man and the Domestic Animals, 1895.
Also numerous shorter papers by the same authors, Askanazy, Cobbold, Ijima, Leidy, Lühe, Railliet, Yamagiwa, White, and others.

TRENTHAM SPRING.—Campbell County, Georgia.
POST-OFFICE.—Fairburn.

ACCESS.—Viâ Atlanta and West Point Railroad to Fairburn, thence by private conveyance three miles north to spring.

For a number of years this spring had considerable local reputation. The principal ingredients of the water are as follows: Calcium carbonate, magnesium carbonate, iron carbonate, potassium carbonate, magnesium sulphate, sodium chloride, alumina, organic matter. The waters of this spring are said to be highly efficacious in the treatment of syphilis and scrofula.

James K. Crook.

TREPANNING; TREPHINING.—By common consent these terms are applied, not merely to the application of that form of circular saw known as the *trepan* (or diminutive *trephine*), but to any procedure by which a piece of bone is elevated, or is removed, in order to permit the elevation of some adjoining portion, or the exposure of the membranes or brain beneath. The operation dates back to the remotest antiquity, and seems to have been practised at various times among various peoples as a rite or ceremony. Except when performed by surgeons, it seems to have been done usually with the rudest of implements, and even the instruments used by the previous generation of surgeons were in most respects clumsy and coarse.

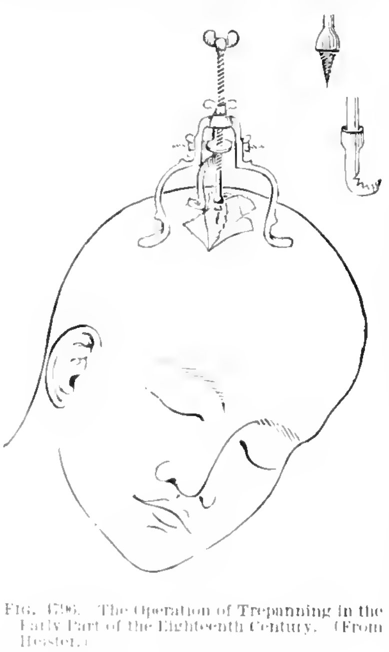


FIG. 4796.—The Operation of Trepanning in the Early Part of the Eighteenth Century. (From Heister.)

INDICATIONS.—1. Simple fractures of the skull, with signs of compression.

2. Compound fractures, with depression, even without signs of compression, except over the frontal sinus, in adults.

3. Punctured and gunshot fractures, even without symptoms. (The reader is referred to the article on *Head, Wounds of*, in Vol. IV. of this HANDBOOK, where I have considered these indications in greater detail.)

4. Coma, with signs of compression, contusion, or laceration of soft parts, without fracture of the external table.

5. Hemorrhage. The operation is done in this case either to tie a vessel or to remove a clot. This is partially included under heading 4.

6. Abscess of brain.

7. Tumor of the brain or meninges.

8. Bone abscess in the frontal sinus, mastoid process, etc.

9. Purulent meningitis, the object here being to wash out the suppurating cavity.

FIG. 4797.—1, A Fractured Skull after the Application of the Trephine and the Removal of the Fragments. (After Charles Bell.) *A*, *B*, The flaps of integument; *C*, the cranium; *D*, the dura mater exposed.

10. Acute infectious osteomyelitis of the diploë.

11. Epilepsy or insanity, when any lesion can be localized with sufficient definiteness.

12. To afford a so-called "relief opening," for relief of pain or cerebral irritability. (See also under *Brain, Surgery of*.)

Each one of the foregoing conditions is an indication for working through and underneath one or both tables of the skull, in order to effect whatever may be possible beneath the level of the bone removed. The various conditions are discussed in their appropriate places; we speak here only of that which pertains to the operation proper.

DANGERS.—The South Sea Islanders scrape through each other's skulls with pieces of glass, we are told, and with impunity. Among the Cornish miners the operation was, up to a comparatively recent date, according to Michel (*American Journal of the Medical Sciences*, October, 1879), one of daily occurrence. The Count of Nassau was trephined by Chadbourn some twenty-seven times. And all this at a time when, or among a people in whom, fear of sepsis has not prevailed. And yet, until very recently, there has been a recognized school of practising surgeons who have uttered solemn warnings against even a properly discriminating resort to the procedure, and fierce wordy battles have been waged concerning it. But the medical profession is now almost a unit in favor of a diagnostic use of the instrument, as it is in favor of an exploratory abdominal section. We are now in a position where one may boldly affirm, even in courts of law, that *trephining is not, by itself, a dangerous operation, when properly done*, but it must be insisted that the *proper* performance of the operation includes the most careful attention to antiseptic or aseptic measures. When these are rigorously carried out the *operation* is no more dangerous than the amputation of a finger with the same precautions. *The condition which*

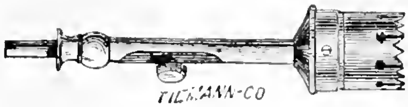


Fig. 4798.—Crown Trephine.

necessitates the operation constitutes the main element of danger. Patients frequently die after trephining, but very seldom because of it. This statement cannot be too strongly emphasized.

Moreover, the operation is frequently too long delayed. Michel's dictum, "The early trephine is gold, the late trephine is lead," should sink deeply into the mind of every one who may ever be compelled to use the instrument. This obtains especially with regard to fractures of the skull. Much better is it to make a puncture and then find it unnecessary to proceed further, than it is to have it appear later that early operation might have saved a life.

The Operation.—Even the instruments and methods of twenty years ago are almost abandoned in favor of those of recent introduction. The Hey's saw and the old bone-cutting forceps are now relegated to the past. The former is never used and the latter are superseded by so-called rongeur forceps, which not only divide the bone, but bite out a small section. They are of various patterns, and can be made extremely useful. Three different methods of operating are now in vogue:—

(*a*) The old-fashioned method, which called for the use of the trepan or trephine, such as is shown in Fig. 4798. When the surgeon's intent is merely to make an opening in the skull through which he may elevate depressed bone, or drain an abscess, this pattern of instrument will still be found useful. It is made in various sizes, but for ordinary work one about 2 cm. in diameter will be found the most serviceable. Small trephines will answer for the introduction and exit of small wire saws, such as those introduced by Gigli and known by his name. These had recently a short vogue, but have been found likely to injure the dura.

(*b*) The mallet and chisel have come into quite general use especially among the continental surgeons. Chisels of various sizes or gouges, variously patterned, will be found in many instances very serviceable, and with them openings of any desired shape and size can be made. The use of the chisel is, however, attended by the theoretical danger of injury from the repeated blows of the hammer, which it has been supposed might cause some molecular disturbance or concussion. Moreover, frequent blows of the hammer may under, certain circumstances, produce a noise which would be distasteful to those within hearing. Still it is not always possible to dispense with these instruments in this kind of work.

(*c*) The osteoplastic method of operating has come into general use since the previous edition of this work. It consists of raising trap door flaps of bone by circular or lateral cuts, which leave a base at that point where the largest vessels enter the scalp, and of springing back this bone flap by breaking it across the base without separating from it the overlying scalp and soft tissues, through which it may still be nourished after its replacement. This method has a very great advantage over any other in that it provides a perfectly adequate bony covering for the bone defect made by the operation, that this covering is of the patient's own tissues and not a foreign body, and that the area thereby exposed can be made of any desired extent in almost any desired location. Thus it has an advantage over all other methods in suitable cases.

This bone flap may be cut out with the chisel, which often takes a long time, by the electric saw or surgical engine, which is an elaborate, e pensive, and unreliable device, or, best of all, by the Stellwagon trephine as improved by Da Costa (Fig. 4802). This is a recent device corresponding very nearly to the carpenter's expansive bit. It contains an arm whose outer extremity carries a small saw, which can be fastened into the axis of the instrument so as to cut in a circle of any desired diameter. The centre pin may be fixed in a small metal plate with sharp point, which may be made to perforate the scalp and penetrate the bone deeply enough to serve as a centre for the rotation of the instrument. With it sections of a circle may be success-

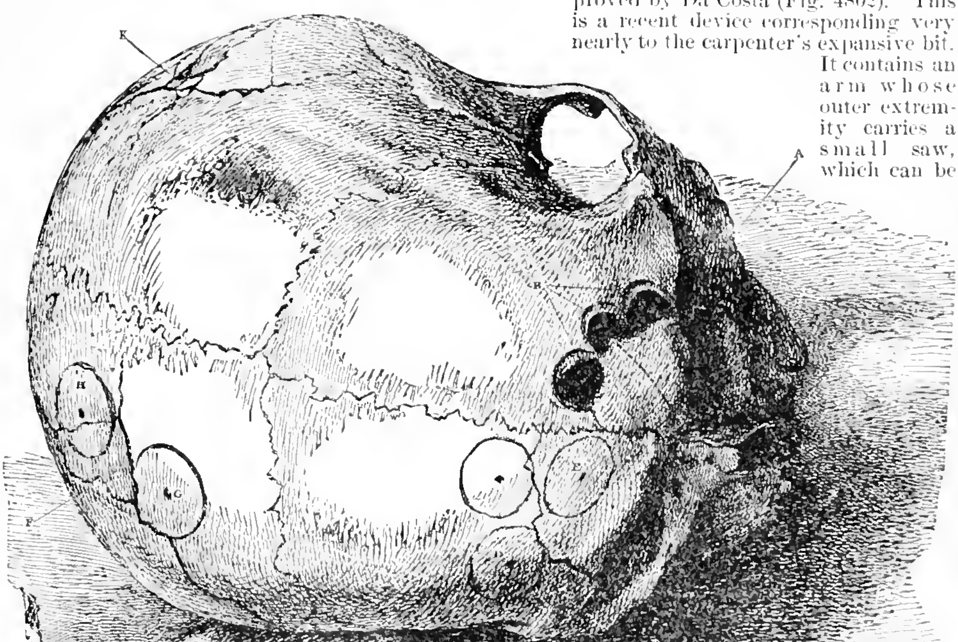


Fig. 4799.—1, A Skull showing Various Examples of Fracture. (After Charles Bell.) *A*, A triangular portion of the os frontis fractured and depressed. *B*, The three perforations found necessary for its elevation and extraction: the second and third were rendered necessary by the fact that the edge of the inner table lay under the sound bone. *D*, A point where the trephine was employed for a fissure of the os frontis represented on its right side; a second perforation was made in the sound bone a little higher up, still the bone could not be extracted; the trephine was then applied at *E* and the bone lifted up. It should have been applied at *E* in the first place. *F*, A fracture with depression at the lower angle; the trephine was placed at *G*; it ought to have been a large one, and placed at *H*, by which a portion of the bone would have been saved and a more favorable form of opening obtained; by perforating at *G* an acute angle of bone was left between *G* and *F*. *K*, A comminuted fracture.

ively cut out from the bone without having to make an opening for the centre pin, and, if it is desired, a small knife may be inserted in place of the saw and made to cut the first circular incision in the scalp. This should be made at a point outside the line where it is proposed to cut the bone, in order that the skin incision shall not exactly overlie that in the bone. If three hundred degrees of a circle be cut with this instrument, it will be easy to snap across the base of the circular bone flap thus made. In this way a veritable trap door may be made to open and afford easy access to the cranial contents beneath.

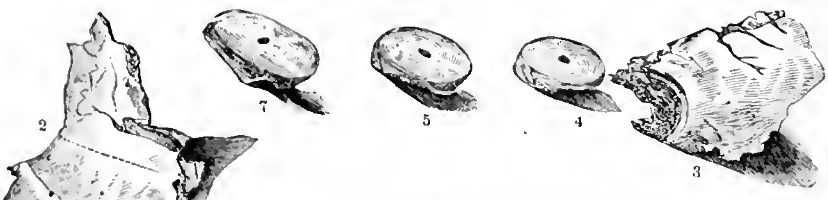


FIG. 4800.—2, The piece of bone removed from *A*, Fig. 4799, with its inner table projecting beyond the outer. 4, The button of bone removed in order to elevate the fragment represented in 3. Here by careless work the surgeon might have pressed on the depressed portion with the trephine, and thus have depressed and chafed the dura. 5 and 7, Buttons of bone having inequalities on their lower surfaces, showing the necessity for extreme caution during the operation. 6, Another button having considerable inner table attached to it, as occurs when the surgeon is obliged to break up the circular portion.

Everything being prepared as for every aseptic operation, the patient's scalp should be carefully shaved and cleansed. If he be in a condition of coma no anæsthetic will be required; if he be restless though unconscious, chloroform should be administered. An existing wound may be utilized, for purposes of exploration at least. If there be no external wound, an incision should be made; and this the writer prefers to make **U**-shaped, in such a way that, as the patient lies on his back, the wound may drain by virtue of gravity from the cut made in raising this **U**-shaped flap. A flap of scalp is thus made over an area as large as may seem indicated. Hemorrhage, which will usually be quite free, must be checked by means of the hæmostatic forceps. Or an Esmarch tourniquet or a thick rubber ring may be passed around or over the cranium. The pericranium is then raised, over a small area, if it be merely for the exploratory use of the trephine, or from the entire area of the depressed bone which is to be removed, if such a measure seem indicated.

If we are dealing with a compound fracture, in which the depressed bone is yet not easily removed, the sole object in trephining is to make an opening through which leverage can be exerted and instruments introduced. Here the ordinary trephine, like that shown in Fig. 4798, may be employed. In order to use it to advantage it must therefore be planted on a rigid and unyielding bony surface. The exigencies of the case can alone make it clear just where this spot may be. Unless it be unavoidable, the trephine should not be applied in the middle line (over the superior longitudinal sinus), nor over the course of any of the large sinuses or vessels, *e.g.*, the middle meningeal. The instrument is provided with a centre pin which is thrust forward a little beyond the level of the teeth so as to secure accurate implantation and prevent sliding. A good way of beginning is to make a little depression—by means of the point of a chisel and a few light blows with the hammer—at the point where one desires to place the centre pin of the trephine. The latter is then applied perpendicularly to the plane of the skull and worked by an alternating motion (pronation and supination of the operator's hand) till its teeth have cut a circular groove. The centre pin is then withdrawn, and the trephine is again applied with the same motion till it has cut through the outer table. Its entrance upon the diploë will be known by the free flow of venous blood. It should now be handled with extra precaution, and a probe or fine-pointed instrument should be frequently passed around the groove to ascertain if the inner table has yet been perforated at any point; if it has, the instrument must be made to bear upon the opposite side of the cut. At last, when a locking of the instrument, combined with a definite but indescribable sensation, makes the operator aware that he has nearly perforated the inner table all around the cut, the instrument may be gently rocked, and thus, by a little leverage, the button of bone is sprung loose and either comes out with the instrument or is left somewhat tilted in its place, attached perhaps by dural adhesions or undivided spicula of bone. A probe or the point of an elevator will now dislodge it.

We have spoken of the diploë; the reader must remember that children and the aged have no such tissue between the two compact outer and inner cranial surfaces; hence he must not look for the sign of its being perforated which has been mentioned above, *i.e.*, free venous oozing, nor for the diminished resistance to the hand, nor the altered character of the detritus thrown up by the saw. Moreover, skulls vary in thickness within wide limits. The skull of the colored race is proverbially thick, yet we find just as thick ones in individuals of the white races. The better rule, then, to follow is to act as if each skull were very thin. As every one should know also, its inner surface is liable to be very irregular; therefore to cut through *every* particle of bone would be to make a serious wound of the dura with the saw teeth.

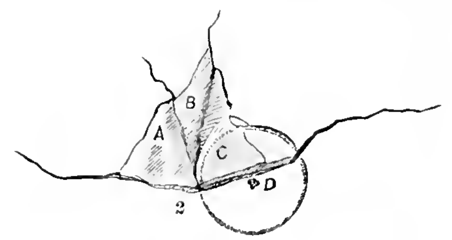


FIG. 4801.—2, Sketch of the Fractured Bone; *A*, *B*, *C*, the three portions of the fractured bone, with depressed edges, which, being sharp, are irritating the dura; they must therefore be removed. They are, moreover, so separated from their attachments as to have lost their vitality. There being no "purchase" for the elevator, the trephine is applied at *D*, and the broken pieces are elevated and picked away. 3, Two discs of bone cut by the trephine, showing the varying thickness of the skull. 4, Exfoliation of bone after use of the trephine. 5, Button removed by the trephine, showing the two tables of the skull with diploë between.

The accompanying illustrations (Figs. 4799, 4800 and

4801) from Charles Bell's "Illustrations of the Great Operations of Surgery" (London, 1821), with their commentary and explanation, will serve to illustrate, much better than can be done by a long description, some of the practical points in the operation. They are also of historical interest since they were drawn by himself.

This is the classical operation with the trephine. With the removal of the disc of bone the first part, at least, of the operation is ended; depressed bone may be elevated, pus or blood evacuated, etc. Still it may be found that *one* such opening is not enough. In this case another suitable position is selected and the manœuvre is repeated, once, twice, or thrice if need be. By means of openings thus made sufficient room may be secured for any further proceeding. Now the rongeur forceps, the Gigli saw, the chisel, or the surgical engine, as the fancy or the equipment of the operator may dictate, may be used to enlarge the openings in any desired direction.

When the opening through the skull has been made for exploratory purposes, or when the contour of the circular aperture has not been disturbed, the disc of bone which was removed, and which may have been kept in a clean, warm, and moist place, may be utilized for the closure of the defect; in other words, a species of osteoplasty may be practised. A little notch is cut, for drainage purposes, on the edge, at what will be its inferior margin when the patient is lying on his back; it is then carefully replaced, the periosteum sutured above it, and over this the scalp, as usual. If the operation has been, as it should be, *aseptic*, this portion of bone should be firmly united with its surroundings in a few days. But if there have been any failure in the precautions such union cannot occur. Those who are unskilled in such technique had better, perhaps, refrain until practice has made them sure.

When the dura mater bulges into the wound, or appears very much discolored, one reasonably infers that it does so because distended by blood or pus within its cavity. In this case it is not only proper but indicated to incise it and explore further. If there be fluid blood it should be allowed to escape, and its source should be looked for. If a clot is found, then it must be gently broken down or dislodged with the probe or irrigating stream and washed away. If pus is present, the dura should be freely incised and its cavity washed out as thoroughly as possible, while subsequent provision must then be made for drainage. We are discussing here the mechanical features of the operation rather than the theoretical and practical applications of the measure, else we should be tempted to enlarge upon the more widespread application of the same to purulent meningitis, whether traumatic or idiopathic.

Bleeding vessels in the dura may be caught with the hæmostatic forceps; if the bleeding be not checked by such forcipressure, a curved needle threaded with catgut may be carefully passed under the vessels and the ligature then tied. So also a wound of a sinus may be treated, only it might be better to use a very fine needle and fine braided silk. When, however, suture of a sinus wall is impracticable, antiseptic gauze may be packed in, or a piece of absolutely aseptic sponge may be used as a compress and allowed to remain without attempting its subsequent removal. Even should a single sinus become obliterated from such treatment, no apprehension need be felt, as Schellmann's researches have shown ("Ueber Verletzung der Hirnsinus"). Injuries to the middle meningeal artery and its large branches are by far the most common of vascular lesions, and when distinct hemiplegia and signs of compression, even without any external signs of fracture, make it probable that this vessel has been ruptured, it is a legitimate and well-recognized operation to trephine over its course, find, and tie it, and remove any clot that may have formed. Parker (*Med. Times*, 1877, i., 91) trephined a case on one side, there being no external lesion, though coma was profound, and found nothing; he then trephined over the artery on the other side, and found no coagulum outside the dura, but since the latter had a distended and bluish appearance, he incised it and removed a considerable amount of blood. In three days the patient became conscious, and then quickly recovered.

The middle meningeal is to be found about one and one-fourth to one and one-half inches back of the external

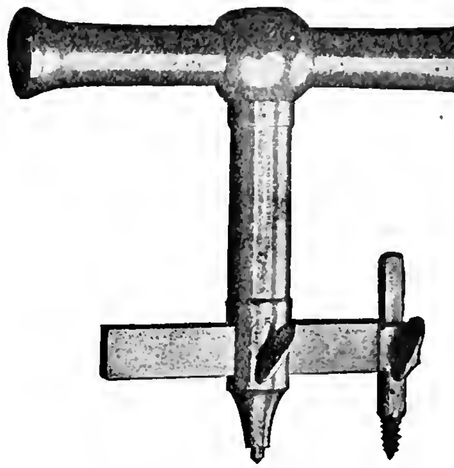


FIG. 4802.—The Stellwagon Trephine.

angle of the orbit. It runs sometimes quite within the bone, sometimes in a groove on its inferior surface, and sometimes quite within or upon the dura.

When one operates for compound fracture every loose piece should be removed. A considerable area of bone, especially in children, is sometimes depressed without being broken loose. In this case it must be raised to its proper level by a combination of dexterity and force properly applied. So much of the periosteum must be saved as is clean and viable. Any portion which has had dirt or foreign material ground into it must be cut away. The scalp will adhere nicely to bare bone, and the periosteum is not necessary, though of advantage, especially over a bony defect.

The medium-sized needle of a good aspirating syringe may be introduced, almost with impunity, to a reasonable depth, in the search for blood, pus, accumulations of fluid in the lateral ventricles, or in testing the density of the brain tissue when hunting for subcortical tumors. It may be used before or after opening the dura. In certain cases its use affords information of great value.

When the brain itself is injured, so that portions of its substance come through the wound, there is not very much to do save to wash away, with extreme care, with a gentle irrigating stream, so much as will easily come away, and then provide for drainage.

All indications having been met, all that remains is to properly close and dress the wound. In a serious compound fracture with deep laceration, the dura should be sutured over the wound in the brain, enough room being left at one point for the introduction of a tent of horsehair, or of catgut, or a decalcified bone or rubber drainage tube, according to the exigencies of the case or the preferences of the operator. If it be so decided, the piece of bone may be replaced and the pericranium united over it in such a way as to hold it in place, provision being made at the same time for a drainage outlet from the deeper parts. The periosteum is best sewed with catgut, and the union should be made as neat and complete as possible. Over this the scalp is united, preferably with catgut; silk or silkworm gut being used only when considerable tension is expected, and with such attention to drainage outlets as the condition beneath demands. A fresh opening or a counter-opening should be made if a more direct outflow may thereby be secured. In an absolutely aseptic exploratory operation there will scarcely arise any occasion for drainage, and it will be enough to omit a suture here and there.

When discharge of pus or any fluid is expected, it is well to provide for it in the dressing. In this case a piece of protective, perforated opposite the drain outlets, may be laid over the wound, and this may be covered with such absorbent material as the operator prefers. But when no discharge is expected and it is desired to leave the dressings undisturbed till healing has occurred, it will be well to cover the wound with one or more thicknesses of gauze, and over this to apply in layers a smooth, equably distributed dressing, with some impermeable stuff outside. At all events, the dressing must be used unsparingly, and it is better to fasten it on with a bandage of starched material. Outside of all a retentive towel, neatly pinned so as snugly to fit the head, will be found very serviceable. Sometimes an ice-bag applied to the head, or an ice-cap, will be found of advantage, especially if oozing be feared. Many surgeons are fond also of administering an active purgative, which certainly is not without value in some cases. *Roswell Park.*

TRI-BENZOYL-GALLIC ACID occurs in odorless and tasteless crystals which are insoluble in water and soluble in alcohol. It is said to set free gallic acid in the intestine, and is employed as an intestinal astringent. Dose 1 gm. (gr. xv.). *W. A. Bastedo.*

TRI-BROM-PHENOL. See *Bromol.*

TRIBROMPHENOL-BISMUTH, Xeroform, $C_6H_2Br_3.O.BiO$, is a fine yellow, almost tasteless powder of slight carbolic odor. It is insoluble in water, alcohol, chloroform, and the oils, but dissolves in two-per-cent. hydrochloric acid. It is unimpaired by heat below 120° C. (248° F.), and so may be sterilized.

Reynders states that in the gastric juice this substance splits into bismuth oxide and tribromphenol. It would seem, therefore, to be a serviceable gastric and intestinal sedative and antiseptic. R. W. Wilcox recommends it especially in the fermentative diarrhoeas, though Brochocki failed to obtain good results in twelve cases of tuberculous enteritis, four of acute gastro-enteritis, three of catarrhal dysentery, and three of typhoid fever. The dose is 1 gm. (gr. xv.) three times a day. It may be found in the urine for twenty-four hours after ingestion, and one of Reynders' patients showed the carbolic reaction with brown urine. In daily doses of 6–7 gm. (gr. xc.–cv.) Hueppe saw no untoward action, and 1 gm. (gr. xv.) administered to a frog, and 8 gm. (ʒ ij.) to a guinea-pig produced no undesirable effect.

The chief use of the remedy, however, is as an external application. There is much clinical evidence showing it to be an antiseptic, deodorizing dusting powder of great value, stimulant to granulation, analgesic, and preventing the formation of pus. It has also been much employed in the treatment of eczema, furuncles, tuberculous ulcerations, chancroids, etc. In ophthalmic work it has been applied as a five- or ten-per-cent. ointment in conjunctivitis, eczema of eyelids, and corneal ulcers; in nasal, pharyngeal, and laryngeal catarrh, and in suppurative otitis media as an insufflation; in gynecological and venereal disease as a local application. There is also on the market a ten-per-cent. xeroform gauze, which has the advantage of being sterilizable by heat. *W. A. Bastedo.*

TRI-BROM-SALOL, Cordol, $C_6H_4.OH.COO.C_6H_2Br_3$, is made by acting on salol with bromine in excess. It occurs in long white needles, which are insoluble in water and slightly soluble in chloroform or glacial acetic acid. It has been proposed as a gastric sedative and intestinal antiseptic in dose of 1–2 gm. (gr. xv.–xxx.), and is said to split in the intestine into salicylic acid and tribrom phenol. The methyl compound of tri-brom-salol, known as "cordeine," and the acetyl compound "cordyl" are also in use. *W. A. Bastedo.*

TRICHINOSIS; TRICHINIASIS. — Although previously observed after death in the muscular tissues of human beings by others, the trichina spiralis was first fully described by Owen in 1835. In 1847 it was discovered by Leidy in the flesh of swine, and in 1849 by Guret in the cat. In 1851–52 Herbst succeeded in developing trichinosis in the dog by feeding the flesh of a trichinous badger. It remained, however, for Zenker, in 1860, to make the first clinical record of a case of trichinosis in man. The disease simulated typhoid fever, but, death resulting, post-mortem examination disclosed the presence of sexually mature parasites in the intestine and of living unencapsulated parasites in the muscles. It was further discovered that others who had partaken of some pork in company with the patient had been made ill, and on investigation this meat was found to contain trichinæ. Subsequent inquiry showed the course of events to be as follows: Human beings become infected through the use of trichinous pork. The capsules of the ingested parasites are digested in the intestine, where sexually mature trichinæ then develop. These begin to give birth to young in the course of a week, and the embryos bore their way through the wall of the intestine into the abdominal cavity, and pass thence by way of the connective tissues to the muscles or to other serous cavities; or they make their way through the mucous and muscular coats of the intestine and between the layers of the mesentery to the vertebral column, whence they migrate to the muscular tissues. In the muscles they penetrate the primitive bundles and cause destruction of the contractile substance. Occasionally the parasites are distributed through the blood stream and the lymph channels. They continue to develop in the muscles for a short time —from two to three weeks—and as a result of their activity febrile symptoms arise, together with others referable to the invaded muscles. In the course of another week the worms curl upon themselves, and in the further progress of the case the irritation to which their presence gives rise causes the formation of a capsule of connective tissue, by which they become surrounded, and which eventually may undergo calcification. The calcified capsule appears as a small grayish nodule, just visible macroscopically. Sometimes the parasites themselves undergo calcification, and occasionally both parasite and capsule disappear entirely. On the other hand, the parasite may retain its vitality for many years and it may even survive the death of its host. It can be destroyed by a temperature of −11° or of 55° C., although greater extremes of temperature are required when the parasite is encapsulated within muscular tissue.

In addition to human beings, trichinæ have been found in rats, mice, cats, foxes, polecats, martens, and raccoons, and trichinosis has by feeding been induced in rabbits, hares, marmots, hedgehogs, moles, sheep, calves, horses, hens, pigeons, and ducks. Dogs are not readily infected. Trichinæ ingested with food remain at times alive for several days in the larvæ of flies. Swine are generally infected through eating the flesh of infected swine fed to them, and occasionally through the flesh of rats infected by eating the refuse from infected porcine cadavers. It is possible also for infection of swine to take place through the ingestion of intestinal discharges from infected human beings or other animals. In man the danger of infection is greatest from the use of raw or imperfectly cooked pork, and it is slightest when the pork is well cooked or roasted. The trichinæ can be destroyed by cooking, provided the temperature in the interior of the meat reaches 75° C. Well-pickled meat is less infective than fresh meat, the trichinæ being destroyed in part by the necessary withdrawal of water. The danger of infection from meat is lessened also by thorough smoking.

Morbid Anatomy.—When opportunity is afforded for post-mortem examination in cases of trichinosis, the mucous membrane of the small intestine is found swollen, in recent cases injected, at a later stage pale. At times there is capillary hyperaemia and there may even be ecchymoses. Swelling of the solitary follicles and of Peyer's patches has been observed, with enlargement of the mesenteric glands. The parasites may persist in the bowel for as long as seven or eight weeks. The spleen is little changed, if at all. The liver becomes pallid and anæmic and of doughy consistence, and its cells the seat of fatty infiltration. The kidney exhibits cloudy swelling or fatty degeneration. The myocardium also may undergo cloudy swelling. The lungs exhibit the signs of bronchitis, with hypostasis, and they may undergo splenization or lobular hepatization. Rarely they are the seat of metastatic abscesses or of hemorrhagic infarction. The muscles may in the first week be light grayish-yellow, dark-red or bluish-violet in color. At a later period the muscle fibres undergo longitudinal and transverse splitting, and degenerative changes take place in the contractile substance, together with hyperplasia of the interstitial connective tissue. Trichinæ may be present in large numbers, especially at the junction of the belly and the tendon of the muscle. They predominate in the diaphragm, the intercostal, the cervical, the laryngeal and the ocular muscles. In the extremities they occur especially in the biceps and the triceps. They have been found also in the heart muscle. Large numbers of polymorphonuclear leucocytes, more especially eosinophile cells, have been described in the affected muscles, particularly in the more degenerated areas.

Symptomatology.—The intensity of the symptoms of trichinosis varies in accordance with the number of parasites introduced into the digestive tract. Three phases of the disease may be considered, namely, that of the entrance of the parasites into the stomach and the small intestine, that of their migration to and through the muscles, and that of encapsulation, with subsidence of the myositis. These are, however, not distinguishable clinically. The ingestion of trichinous meat is followed shortly by symptoms of marked digestive derangement. Among the more common of these are malaise, nausea, eructation, vomiting, and cardialgia, and with them may be associated vertigo, a sense of fulness in the head, and of heaviness in the lower extremities. In some cases the symptoms of an acute gastro-enteritis develop, with diarrhœa, hypogastric pain, weakness, and fever. The diarrhœa may be succeeded by constipation. The appetite is lost, or there may even be repugnance for food. Thirst is increased and sweating may be free. On the other hand, this train of symptoms may be wanting, wholly or in part. The tongue may be dry; it is often swollen and painful, and it may be movable only with great difficulty.

Rheumatoid pains in the extremities develop gradually, with ill-defined feelings of illness. Fever appears, and some of the muscles begin to swell. The affected parts become œdematous and the seat of pain and tenderness. The muscles exhibit weakness and want of elasticity, and there is a sense of soreness such as is observed after unusual exercise. This is noticeable especially in flexion and in the muscles of the neck, and often also in the lumbar muscles. Patients complain further of a sense of heaviness and weight in the extremities.

Febrile symptoms appear, as a rule, on the third or fourth day of the disease, being ushered in by repeated chilliness, rarely by a severe chill. There is slight elevation of temperature in association with the gastro-intestinal symptoms, but the pyrexia becomes more marked with the onset of the symptoms referable to the muscles. The temperature may reach 40° or 41° C. in the afternoon, declining a little in the morning, and being of remittent or subcontinuous type. This higher degree of pyrexia persists for from nine to eleven days, and it is succeeded by a lower range of temperature for a further period of from three to five weeks. In mild cases the temperature may return to the normal level in the third week, or it may become intermittent in character. Defervescence is usually gradual and slow. The pulse frequency corresponds with the degree of pyrexia.

Œdema of the face, especially of the eyelids, appears in the second week of the disease, and is one of the most characteristic and most constant symptoms. There may be an associated chemosis of the conjunctiva. Œdema of the extremities is less common. This symptom, when present, disappears in from two to five days, but it may reappear later.

The trichinæ invade the muscles, and the symptoms referable to these appear at the end of about nine or ten days, though sometimes later, in accordance with the intensity of the infection. The affected muscles become swollen, hard, and sensitive to touch and pressure. Movement induces cutting or boring pain. Such pain as is present is naturally less when the parts are at rest. In mild cases there may be merely a sense of stiffness and of tension. Any muscle of the body may be invaded, but especially those of the extremities and of these particularly the flexors are affected. The patient assumes a characteristic attitude, in consequence of his efforts to relax the involved muscles. In the dorsal decubitus arm, forearm, and hand are flexed at an acute angle, and the lower extremities are partially flexed at the knee and the hip. Stiffness and rigidity are apparent especially in the masseters and the muscles of the neck and the upper extremities. Frequently there is difficulty in deglutition from invasion of the muscles of the tongue and the pharynx, and there may be trismus. Involvement of the muscles of the larynx gives rise to hoarseness and aphonia; of the respiratory muscles, to difficulty in breathing and dyspnœa. Deep inspiration induces dry cough. Œdema of the glottis may develop and give rise to alarming if not dangerous symptoms. In severe cases the ocular muscles may be the seat of pain. This often occurs only on movement, which in consequence is embarrassed. At times the eyes xhibit increased sensitiveness to light, and there may be conjunctivitis and ecchymoses in the scleral conjunctiva. Mydriasis has been observed in some cases.

Pruritus is a frequent symptom, while formication and cutaneous anæsthesia are less common. Eruptions on the skin, such as acne, furunculosis, herpes, petechiæ, prurigo, and urticaria, are not rare as late manifestations. Free desquamation occurs frequently during convalescence. Sweating may be a troublesome feature in both mild and severe cases, and not rarely it continues throughout the course of the disease. Bronchitis is often present early, while in some cases hypostatic and even fibrinous pneumonia develops, and occasionally pleurisy. At times cardiac irritability appears in the second week. Pericarditis also has been observed. In severe and protracted cases venous thrombosis may occur, particularly in the lower extremities, as a result of marantic enfeeblement of the circulation. Rarely epistaxis and intestinal hemorrhage occur, while oligæmia, oligocythæmia, and hydræmia develop early. In the acute stage of the disease the blood exhibits characteristic alterations. The number of leucocytes is increased, at times to a remarkable degree. As many as 35,700 in the cubic millimetre have been reported. This increase involves especially the eosinophile leucocytes, both absolutely and relatively, with coincident diminution in the proportion of polymorphonuclear neutrophile leucocytes. The percentage of eosinophiles has been reported as high as 68.2 per cent., as against the normal of two or three per cent., the percentage of neutrophiles at the same time being 6.6 per cent.

The urine is diminished in amount and is high-colored during the febrile stage, and when sweating is profuse. At a later stage the amount may be increased. Occasionally albuminuria is present, together with tube casts and renal epithelium. Disorders of menstruation are frequent in women, and abortion is not rare when pregnancy exists. Trichinæ have, however, not been found in the fœtus. Insomnia is a constant symptom at the height of the disease, and is invariably present in severe cases. Even in mild cases sleep is disturbed by restlessness. Children, however, may sleep well throughout the disease. The superficial and deep reflexes and the electric irritability to both faradic and galvanic currents are enfeebled. Consciousness is rarely deranged. In some cases impairment of hearing occurs.

The period of incubation of trichinosis—that is, the period of time that elapses between the ingestion of trichinous meat and the development of symptoms—is variable, and may be from a few hours to many days or even weeks. As a rule the first conspicuous symptoms appear during the second or the third week. In mild cases the attack lasts for from one to two weeks. Fever is then likely to be wanting. In severe cases the duration of the attack may be from five to seven weeks to months. The disease not rarely terminates in death. When this occurs it usually does not take place in the first two weeks, but principally between the fourth and the seventh weeks. It is most commonly preceded by symptoms of respiratory paralysis, at times by high fever and typhoid symptoms. Death may be due to complicating pneumonia. The mortality is variable, in different epidemics ranging from none to thirty per cent. In large numbers of cases it averages about five per cent. In children recovery is almost invariable.

Diagnosis.—The diagnosis of trichinosis is based upon the presence of the gastro-intestinal symptoms of the onset of the disease, followed after a varying interval by the development of the symptoms referable to the muscles, with fever, transitory œdema of the face, hoarseness, difficulty in swallowing, profuse sweating, dyspnœa, sleeplessness, and the characteristic changes in the blood, taken in conjunction with the knowledge of a source of infection. In doubtful cases microscopic examination of the stools may disclose the presence of ova or of mature parasites in the stools, or of parasites in a bit of excised muscle, preferably the biceps or the deltoid. Similar examination of any remaining suspected food may yield conclusive evidence of the infection.

If the early gastro-intestinal symptoms of trichinosis are violent they may suggest the existence of cholera; but the characteristic muscular symptoms, the weakness, the sweats, the neuralgic abdominal pains, the changes in the blood, the protracted course, and the absence of the characteristic intestinal discharges, will remove doubt in this connection.

In cases of botulism—poisoning with sausage or meat—the symptoms appear earlier than in cases of trichinosis, and the disease pursues a more rapid course. There is profound depression of the nervous system, with an absence of the peculiar muscular phenomena and of œdema, and the presence of visual derangement, dryness of the throat, slowing of the pulse, icteric discoloration, and dryness of the skin.

The febrile symptoms of trichinosis may suggest typhoid fever, but the presence of the pain and stiffness in the muscles and of œdema of the face, the leucocytosis and the eosinophilia, the results of histologic examination of a bit of muscle, the failure of the blood to cause agglutination and sedimentation of typhoid bacilli in culture, the absence of the diazo-reaction, of rose spots and of enlargement of the spleen will aid in the differentiation.

Mild cases of trichinosis may simulate so-called muscular rheumatism or myalgia from various causes, but the early gastro-intestinal derangement, the puffiness of the face, the respiratory difficulty, and the blood state should be sufficient to prevent error here.

Acute progressive polymyositis is to be differentiated from trichinosis by the absence of gastro-intestinal symptoms and also of the specific etiologic factors, while examination of a bit of muscle will disclose the presence of signs of inflammation, but not of trichinæ.

Prognosis.—The course and termination of an attack of trichinosis depend upon the severity of the infection. When the trichinæ are present in large numbers in the ingested meat, and the method of preparation is inadequate for their destruction, the resulting disease is likely to be severe; while under the reverse conditions the disease is likely to be mild. In general, further, the earlier the appearance of the symptoms the more intense is the infection and the more severe the course of the disease. Persistent and profuse diarrhœa is of evil prognostic omen, as is also initial constipation. The presence of persistent high fever, with slight remissions, of severe and widely distributed muscular pains, of extensive involvement of the respiratory muscles, of intense dyspnœa, of profuse sweats and diarrhœa, of cardiac weakness, of tremor, of delirium and of coma are indicative of an unfavorable prognosis. Want of completeness in the development of the characteristic symptoms, undisturbed sleep, integrity of the respiratory functions and of the circulation after the second week are of favorable prognostic significance. In general the prognosis grows progressively more favorable with the duration of the disease. In mild cases and in children the prognosis is absolutely good.

Prophylaxis.—Human beings can be protected against trichinosis by preventing the spread of the disease in swine. This end can be attained by forbidding the feeding of offal to animals, by systematic and thorough inspection of meat proffered for sale, by prohibition of the sale of trichinous meat, by thorough pickling or smoking, but above all by thorough and prolonged cooking of all meat, and especially of pork, used as food.

Treatment.—Should the patient come under observation soon after the ingestion of the infected meat, emetics or purgatives may be administered, in order so far as possible to expel ova set free in the gastro-intestinal tract. An ounce of castor oil may be employed for this purpose. Anthelmintics have not been found useful, nor have digestive agents proved efficient. Glycerin has been administered in drachm doses every hour for ten or twelve hours consecutively, with the object of abstracting water from the ova, and thus rendering them inert. Benzin has been employed as an anthelmintic, and has been administered internally and also by enema. It may be given by the mouth for several days consecutively in doses of from forty-five to ninety minims in combination with laxatives, and be introduced into the bowel as an addition to an enema through the long rectal tube in doses of from forty-five minims to two drachms. Santonin may be administered in doses of from one-fourth to one grain twice daily, alone or in conjunction with laxatives.

Severe individual symptoms may require special treatment. The initial gastro-intestinal symptoms generally subside spontaneously. In any event remedies that predispose to constipation are strictly to be avoided. To insure thorough evacuation of the bowels laxatives, such as calomel, castor oil, salines, and the like may be administered. For the relief of the muscular pains and stiffness prolonged warm baths may be employed, but they cannot be used if the pain is severe. Inunctions with tepid oil or friction with chloroform or turpentine may afford temporary amelioration. Sleeplessness may be overcome by the use of morphine, but this should be avoided if paralysis of the respiratory muscles is threatened. Hot affusions may aid in inducing sleep. The sleeping-room should, of course, be well ventilated and be kept cool. Sponging with cool water, to which aromatic spirit of ammonia or alcohol is added, also large doses of quinine and the administration of atropine, will prove serviceable in the relief of sleeplessness due to profuse sweating. The application of wet cups to the back will temporarily mitigate the severity of the dyspnœa. Emetics sometimes bring about the same result. In the presence of bronchitis expectorants may be indicated. The diet should be bland, simple, easily digestible, and nutritious.

Augustus A. Eshner.

TRICHLORACETIC ACID.—$C_2HCl_3O_2$. This is one of three chloracetic acids produced by the substitution of chlorine for hydrogen atoms. It is a colorless crystalline salt, deliquescent and freely soluble in water, alcohol, and ether; it has a faint odor and a sharp caustic taste.

This acid is used as a very convenient and delicate test for albumin in the urine. A crystal is to be dropped into the urine, where it rapidly dissolves and produces a cloudiness if albumin is present. A saturated solution may also be used, a few drops being allowed to fall upon the surface of the urine; at the point of contact a cloudiness is at once observed.

This test was proposed by Boymond (*Répert. de Pharm.*, October, 1889), and has been indorsed by numerous observers. The reaction is very prompt and does not require to be confirmed by heat, as peptones are not acted upon. The only danger to be guarded against is the presence of an excessive amount of urates, which will cause a similar cloudiness. This, however, is very slow in appearing and may be overcome by diluting the urine with water.

The chloracetic acid has also been recommended as an escharotic to replace chromic acid. The advantage of this cauterization is that the effects are very localized and do not extend into the surrounding soft tissue. It has been used with success in the treatment of venereal warts, papillomata, and other cutaneous growths. It is used pure, a crystal being placed upon the part, which produces its effect at once. A dry, white, adherent scab forms, which detaches itself after a few days without causing any reaction whatever, and leaving a raw surface which rapidly cicatrizes. A single application may be sufficient for small growths, while for larger ones it may be necessary to repeat the application several times.

These are not very painful, and may be rendered painless by the use of cocaine. Nævi are also reported to have been cured by three or four applications, the cicatrix remaining being very superficial and hardly noticeable. It has also been used successfully in the treatment of chronic inflammations and hypertrophied conditions of the mucous membrane of the nose and throat. In chronic gonorrhœa it has been used by applying it directly to the source of the trouble by the aid of an endoscope.

Beaumont Small.

TRICHOCEPHALUS DISPAR. See *Nematoda.*

TRICHOPHYTOSIS. See *Tineas, The.*

TRICRESOL is a clear, colorless (reddish when older) watery liquid claimed to consist of 35 parts of orthocresol, 40 parts of metacresol, and 25 parts of paracresol. It is soluble in 50 parts of water, and readily in alcohol, ether, and the fatty oils. Major Reed, in a bacteriological investigation, obtained prompt destruction of many pathogenic bacteria by a one-per-cent. solution.

Tricresol was designed as a purified substitute for creolin or lysol, a liquid similar to the latter being prepared by adding 50 parts of tricresol to 35 of soft soap and 15 of water. For use, 4–30 c.c. (ʒ i.–℥ i.) of this mixture is added to one or two litres (quarts) of water. Tricresol has been used for sterilizing instruments, and as a preservative of diphtheria antitoxin. Some of the untoward effects of antitoxin have been attributed to tricresol. De Schweinitz and subsequently Jackson found one part in a thousand an excellent non-irritating preservative of eye washes. McGowan cites a number of cases indicating its efficiency in alopecia areata; other observers have used it much as a vaginal douche; and Vopelius has given it internally in dose of ten to fifteen drops as a substitute for creosote in respiratory troubles. (See also article on *Ethylene-diamine.*)

W. A. Bastedo

TRICRESOLAMINE. See *Ethylene-diamine.*

TRIFACIAL NERVE. See *Cranial Nerves.*

TRIFORMOL. See *Paraform.*

TRI-IODO-META-CRESOL. See *Losophan.*

TRIMETHYLAMINE.—$N(CH_3)_3$. Trimethylamine is a tertiary monamine, found native in various plants and also in various animal fluids, notably in *herring-brine*, whose strong, rank odor is due to this ingredient. Prior to the researches on the amines by Hofmann, native trimethylamine was thought to be the isomeric body, *propylamine*, $NH_2(C_3H_7)$, and considerable confusion still exists in medical understanding on the subject, through the misapplication of the term *propylamine* to what is, in truth, *trimethylamine*. As a matter of fact, *propylamine*, properly so called, is not, and never has been, used as a medicine, and all medical preparations passing under that name are preparations of trimethylamine. Trimethylamine is a mobile, colorless liquid of the specific gravity 0.673 at 0° C. (32° F.), and boiling point between 9° and 10° C. (48.2° and 50° F.). It is very soluble in water, which fluid also eagerly absorbs and dissolves the vapor of trimethylamine. It is combustible, and so, too, is its concentrated aqueous solution. Trimethylamine has a powerful and very searching ammoniacal and fishy odor.

For medical purposes an impure solution in water, prepared from herring pickle, was first employed. This solution contained also ammonia and various undetermined ammoniacal compounds, and probably other organic matters. Its proportion of trimethylamine was variable, in accordance with the varying constitution of the samples of herring-pickle of different years' make. Hence, of later years, the definite salt *trimethylamine hydrochloride*, $N(CH_3)_3HCl$, was proposed. This salt occurs in white, very deliquescent crystals, freely soluble in water, and is the best form of trimethylamine for medical administration.

Trimethylamine is a powerful irritant, its concentrated solution being even mildly caustic. Taken internally, large doses—such as in excess of 2.00 gm. (about thirty grains)—produce decided symptoms of gastro intestinal irritation with burning in the throat and stomach. After absorption the medicine evinces a tendency to depress the force and frequency of the pulse, the body temperature, and the excretion of urea.

Trimethylamine was at one time used for the treatment of rheumatism and gout, but of late years has been so completely superseded by the salicylates as to have become obsolete as a medicine. If used at all, the drug is best administered in the form of an aqueous solution of the hydrochloride, aromatized to cover the rank, fishy taste. The dose of hydrochloride will range between 0.25 and 0.50 gm. (between four and eight grains, about), several times a day.

Edward Curtis.

TRIONAL and **TETRONAL.**—These two hypnotics are closely allied to sulphonal, being formed by substituting ethyl groups for those of methyl. In sulphonal there are two ethyl and two methyl groups; in trional an additional ethyl group replaces a methyl group; and in tetronal the two methyl groups are replaced by two of ethyl. The following formulæ explain the differences in their construction:

Sulphonal, $(CH_3)_2C(SO_2C_2H_5)_2$; trional, $C_2H_5CH_3C(SO_2C_2H_5)_2$; tetronal, $(C_2H_5)_2C(SO_2C_2H_5)_2$.

They are the result of a series of experiments for the purpose of determining upon which of the radicals the therapeutic action of the several sulphones depended (*British Medical Journal*, January 11th, 1890). The sulphur-containing radicals were generally supposed to be the active element, but it was found that these had little influence, while the various compounds were more or less active, according as they contained a greater or smaller number of the ethyl groups. Sulphonal with two ethyl groups possessed a certain hypnotic action; when the number was increased its therapeutic power became greater, and when fewer groups were introduced it became correspondingly less. To the compounds containing three and four groups, respectively, the names trional and tetronal were given, the title indicating the number of groups present. They both form in lustrous, tabular crystals; soluble in alcohol, but only slightly so in water—trional to the extent of one part in three hundred and twenty; tetronal, one in four hundred and fifty. The taste of both is bitter, somewhat resembling camphor.

Trional has proved to be an excellent hypnotic, and it is now employed almost to as great an extent as sulphonal. Tetronal, on the other hand, has fallen into disuse. It has proved less manageable and ill effects after its employment are very frequent.

The action of trional is the same as that of sulphonal but more rapid and certain. It acts in from fifteen minutes to half an hour. There is not the delayed action, nor the prolonged sleep that frequently accompanies the effect of sulphonal. It, however, more frequently gives rise to toxic symptoms. These are the same as are caused by sulphonal: lassitude, giddiness, ataxic symptoms, nausea, irritation of the kidneys, diminished secretion of urine, with discoloration due to *hæmatoporphyrinuria*. Cases of prolonged peripheral neuritis have also been reported to have followed its administration. No deaths have been reported from single doses, but many fatalities have followed its prolonged use. A cumulative effect has been noted, which is observed when chronic constipation is marked. A peculiar camphoraceous odor of the urine is an early sign of its toxic action.

The dose is from ten to twenty grains, in hot milk, at bedtime. It has recently been shown that when given in water charged with carbonic acid gas, its action is much more marked, and that ten grains will produce its full effect. Seltzer water is selected for that purpose.

Beaumont Small.

TRIONAL, POISONING BY. See *Synthetic Products, Toxicology of.*

TRIOXYBENZOPHENONE. See *Salicyl-resorcin-ketone.*

TRIOXYMETHYLENE. See *Paraform.*

TRIPHENETOL GUANIDINE HYDROCHLORIDE is a local anæsthetic used in eye treatment in 0.1-per-cent. solution. Anæsthesia is prompt and the pupil is not dilated.

W. A. Bastedo.

TRIPHENIN, $C_6H_4.C_2H_5O.NH.CH_3CH_2CO$, obtained by heating paraphenetidin with propionic acid, differs from phenacetin only in the substitution of the propionyl radical for the acetic. It occurs as an odorless, white, crystalline powder of feebly bitter taste, and is soluble in two thousand parts of water. It is antipyretic and analgesic, its action being practically that of phenacetin. Dose 0.3–0.7 gm. (gr. v.–x.).

W. A. Bastedo.

TRITICUM. See *Dog-grass.*

TROPACOCAINE HYDROCHLORIDE, $C_8H_{14}.NO.C_7H_5O.HCl$, is benzoyl-pseudotropeine, a principle at first isolated from a Java coca leaf, but now prepared synthetically from atropine or hyoscyamine. It forms colorless crystals which are readily soluble in water and have strongly alkaloidal properties. Resembling cocaine in its physiological effects, tropacocaine is said by Vamossy to be much less toxic and more rapid in its local action, and to cause none of the ischaemia, hyperæmia, and irritation of cocaine. It is employed in solution of one half to ten per cent. in the same manner as cocaine, but its use is confined to that of an anæsthetic.

In spinal anæsthesia, K. Schwarz, who employed it in one hundred cases, reports better results than with cocaine; but two of the cases had vomiting and eleven headache, and there was more or less pallor, cyanosis, slow pulse or fever. Neugebauer, McLean of Detroit, Willy Meyer, and Fowler prefer it in spinal analgesia, while Bier thinks cocaine superior. For use in the eye Vamossy recommends ℞ Tropacocaine 0.3 gm. (gr. v.), sodium chloride 0.06 gm. (gr. i.), and distilled water 10 c.c. (ʒ iiss.), a solution which is non-irritating and strongly anæsthetic, and has little, if any, mydriatic action. Veasey considers the drug especially valuable in keratitis, as it does not deplete the corneal blood-vessels. Its action seems to be very rapid; Silex was able to perform a painless tenotomy one minute after the application of a three-per-cent. solution. Hugenschmidt injected 0.04 gm. (gr. ⅗) in his own lower jaw region, and in three minutes he became dizzy, felt precordial anxiety, and exhibited a marked lowering of blood pressure. Ten minutes after the injection the effect had passed away. In dental surgery Pinet and others recommend it highly, either as a hypodermic injection or in ten-per-cent. solution locally applied.

W. A. Bastedo.

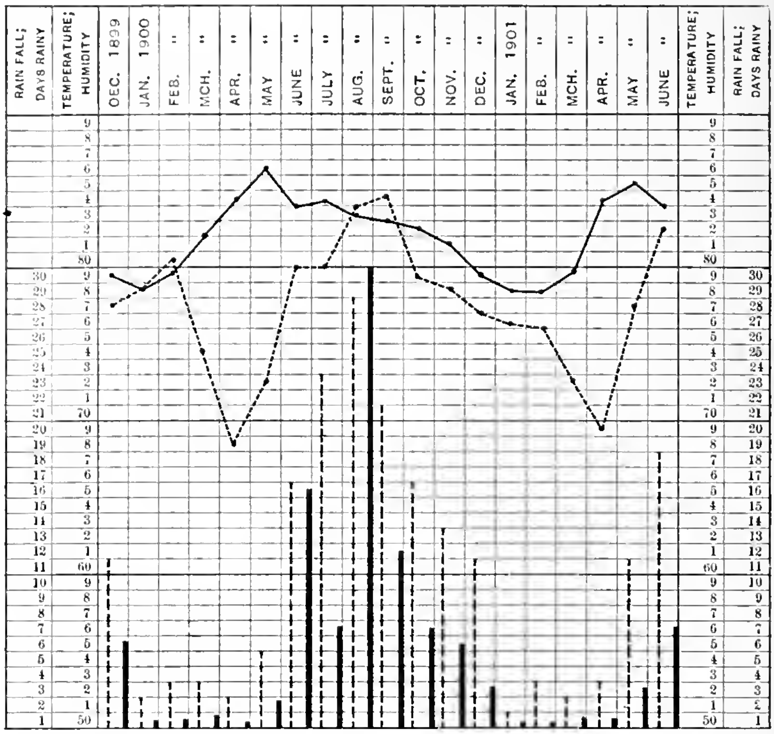


FIG. 4803.—Description of Chart. Each horizontal line represents one degree of temperature and humidity; one rainy day and one inch of rainfall; each perpendicular line, one month; continuous heavy curve, average mean monthly temperature; light broken curve, average mean monthly humidity; heavy black lines in right side of monthly columns, rainfall in inches per month; heavy broken lines near centre of monthly columns, number of rainy days per month; inside column of figures marks degrees of temperature and humidity; and outside figures, number of inches of rainfall and rainy days per month.

TROPICAL DISEASES: GENERAL INTRODUCTION. —Those who desire to acquire a satisfactory knowledge of "tropical diseases," as they are encountered in some special part of the world, must first acquaint themselves to some extent with the surface configuration of the country which is under consideration, with its climatic characteristics, its fauna and flora, and with its people, and then they must study the pathologic aspects of the diseases themselves.

Climate.—To present more clearly the essential features of climate, chart Fig. 4803 has been constructed from data collected in Manila, P. I. Although it is based upon the climatic phenomena observed at only one place in the Philippines, it will serve for most tropical localities, except those situated far inland, where the rainfall may be greatly diminished and where intense hot winds prevail instead of the more pleasant sea breezes.

An analysis of the curves for temperature and humidity shows that these curves cross the 80° (and 80 per cent.) line in February, June, October, and December, thus permitting a more or less arbitrary division of the tropical year into seasons. It will be observed that during December, January, and February, the temperature and humidity are below 80° and 80 per cent.; that during December and a part of January there are a relatively large number of rainy days, but relatively little rainfall; that, as the season progresses, the number of rainy days and the number of inches of rainfall gradually diminish until February, when almost no rain falls. These months are the coldest of the year, and constitute what may be termed the winter season. During the winter the early morning, the late afternoon, and the nights are cool, often cold, on account of the cool monsoons from the north. On the other hand, the middle portion of the day is warm, with blue skies dotted with numerous white clouds. In other words, the days at this season, which is by far the most pleasant of the year, resemble those of our early autumns.

About the first of March the temperature gradually rises above 80° F., each day being just a little hotter than the preceding. In April and May the highest temperature is noted. As the temperature rises humidity sinks to its lowest point in April and May, when the increased rainfall produces a gradual rise to 80 per cent., about the first of June. This is the hot, dry season which continues from the rise of temperature above 80° in March to the rise of humidity above 80 per cent. in June. During this season the temperature is regularly high; humidity low; monsoons frequently absent and often hot, and the skies more or less dotted with white clouds. This is the most unpleasant season of the year. To recapitulate, the hot, dry season continues from early March to June; the temperature is regular and high; humidity low; rainfall almost nil; monsoons often absent and often hot.

In June the number of rainy days and the number of inches of rainfall show a decided increase; in some regions the rainy season may be ushered in by a typhoon. This season continues from the rise of humidity above 80 per cent. in June, to the fall of temperature below 80° F. in November. During the early months, the temperature is a few degrees lower and more irregular than in the hot, dry season. Often during a typhoon relatively low temperatures (62° to 70° F.) are noted. In the last months of the rainy season the temperature gradually sinks below 80° F., when the season merges into winter. The humidity is high; during a typhoon the atmosphere is saturated. These typhoons occur from June to October. They are circular wind and rain storms, the centre of which slowly moves along a fairly well-defined path from southwest to northeast. The nearer the centre is approached, the severer the storm becomes. Destructive winds are frequent during these storms, and the rainfall is often extraordinary; as much as sixteen inches of water having fallen in one day. In the absence of typhoons light showers occur daily. Often every day is rainy. To recapitulate, the rainy season continues from June to November; the temperature is high and irregular; the humidity is high and the rainfall is great; typhoons may occur during this period. The change from one season to another is very gradual.

Throughout the year, monsoons materially diminish the discomforts of a tropical climate. They are winds, the direction of which depends on the location of the centres of high and low pressures. During the summer months the prevailing direction of the wind is toward the north —*i.e.*, toward the northern low-pressure centres. Coming from the equator, these monsoons are warm, often hot. On account of the northern high-pressure centres, winter monsoons have a southerly direction (*i.e.*, they blow from the north) and are cool. Monsoons naturally influence the climate.

In addition to the regular monsoons there are, along the coast, local land and sea breezes which serve to moderate a tropical temperature. These breezes are produced by the difference between the land and the waters as regards the radiation of heat. As heat radiates more rapidly from land, there are, in the late afternoon and during the evening, light winds from the water, whereas in the early morning light breezes blow from inland. These breezes may slightly change the direction of monsoons.

The range in temperature between the hottest and coldest seasons is only eight or nine degrees. This change, with that in humidity and in the monsoons, produces an effect which is felt by the individual in a more decided manner than is shown by the thermometer. The chief features, then, of a tropical climate are a hot, dry season, a rainy season, and a winter season, with a constantly high temperature in each. The latter is the most important feature and more accurately defines the word "tropical" in the expression "tropical diseases" than does the mere geographical signification of the term. In this sense a portion of the year in temperate climates is tropical, and the duration of this tropical period gradually increases as the distance from the equator diminishes, until the Tropic of Cancer and Tropic of Capricorn are reached. Within these parallels the entire year is tropical.

The term "tropical diseases," if used in its strictly geographical sense, includes only a few unimportant diseases; while in the broader sense (which has been given to it in the preceding paragraph) it may properly be said to include the following classes of diseases: First, a small group of unimportant diseases occurring only in the tropics. (Type: yaws.) Secc d, a larger group of diseases which occur in the tropics and subtropics, and occasionally during the hot months in temperate climates. (Type: yellow fever; dengue.) Third, a group of diseases which occur in all climates, but more persistently in the tropics and subtropics. (Type: malaria.) Fourth, a group of diseases which arise in tropical and subtropical regions—in which they are endemic—and at varying intervals of time spread to different parts of the world. (Type: bubonic plague and cholera.)

In addition to the above-mentioned classes, many diseases common to temperate climates are present in the tropics, but to include them in "tropical diseases" would necessitate a discussion of the entire realm of medicine. Diseases which are produced by factors that constitute an integral part of certain meteorological conditions are very few and, as a rule, unimportant. Except in rare instances, they may be prevented. Here may be mentioned frost-bite, sun-stroke, heat-exhaustion, etc.

Indirectly, climate plays an important rôle in all the diseases that are caused by specific agents, the viability, reproduction, pathogenicity and dissemination of which may be greatly influenced by cold, heat, drought, rain, etc.

The Surface Features of the Country.—The topography of tropical countries is essentially the same as that of countries belonging to higher latitudes. In some districts, by reason of their high elevation, several distinct climates may occur within a remarkably limited area. Woodland, often with heavy undergrowth, is abundant. This feature materially aids the long and severe rainy season to supply numerous small streams which often overflow the lowlands. The soil, which in general is very fertile, plays little or no part in the problem of tropical diseases.

The Character and Condition of the People.—Ignorance and poverty are the prevailing conditions in most of the tropical races. At the same time they are, as a rule, very prolific.

History gives us very little information in regard to the rise and progress of these nations. Most of them were found in a barbarous or semibarbarous state; consequently they fell an easy prey to any or all who had time or inclination to mix in their affairs. Generally speaking, their education has been little advanced. In many of the larger cities schools, colleges, etc., and in some country districts a few schools may be seen, but the type of these seats of learning has not been all that might be desired, and at best only a limited number could be benefited. Religions of various kinds have, too often, gained dangerous power; have handicapped their schools and virtually blocked their education and advancement. Their reading has been limited, travelling has been confined to local districts, and most new-comers have adopted local customs. For these reasons their customs, ideas, etc., have remained unchanged from one generation to another. Of modern ideas, they have no knowledge, especially regarding medical matters; their dogmatic religious beliefs are opposed to advancement, and the disregard shown toward their religions, traditions, etc., by civilized man foster, too often, a spirit antagonistic to modern learning.

Poverty and multitudes go hand-in-hand with ignorance to produce the most horrible conditions. The houses of the ordinary natives are poorly planned and constructed; light and sewerage are bad, and their streets are faulty and filthy. These defects become the more manifest in the presence of multitudes, when there is a rapid accumulation of filth, the decomposition of which is most repulsive and to foreigners often sickening. Their houses are crowded, often two hundred and fifty human beings finding lodgment in a single house not larger than an eight or ten-room residence. Their food is poor in quality and insufficient in quantity. Their water supply is usually obtained from small streams, surface wells, and pools. Their sewerage is deposited on the surface of the ground about their houses and yards. In habits they are lazy and little influenced by civil law save when coerced. Thus they fall an easy prey to all contagious, infectious, and parasitic diseases, unprepared as they are to combat infection, to seek the world's knowledge or to profit by the experience of other nations. Naturally, under these conditions epidemic diseases are always present, and it is often difficult to determine the extent of these epidemics.

In the tropics, the physical condition of the people is fairly good. In spite of the fevers, anæmias, etc., many aged people are present to demonstrate the facts that the tropics, *per se*, are not inconsistent with long life, and that the normal conditions of man in a warm climate are almost the same as they are in a cold one. The normal temperature, pulse and respiratory rates, digestion and other functions are about the same as in the higher latitudes. Again, the death rate in the larger cities is not materially larger than it is in other climates, except during an extensive epidemic.

Natives in all climates adopt those customs which are best suited to the local conditions. In the tropics, the houses consist mainly of a roof, floor and walls of such a character as will best keep out the intense light, the severe winds, and the copious rains, and will admit, during ordinary weather, as much air as possible. Their clothing is light. They work during early morning and late afternoon, leaving the middle of the day for lounging and napping. Their lack of mental activity is due more to their origin and ignorance than to a direct influence of climate.

In the tropics the heat-regulating apparatus is not so severely tried as in a temperate or cold climate. But when individuals from other climates enter the tropics the activity of their regulating apparatus must be of another kind. In place of the rapidly changing temperatures, the apparatus must adapt itself to a constantly high temperature. This change in activity is not a serious one, but when associated with changes in food, drink, exercise, etc., it may cause more or less disturbance in the general physiological activity, which may last a longer or shorter time, and may to a greater or less degree reduce the natural resistance of individuals to infection. But when this period is passed, no marked inconvenience from the heat should be felt, as the heat-regulating apparatus is sufficient to compensate the external temperature. When the meteorological observations are considered, it is found that only on rare occasions is the weather as hot in the tropics as it is during the summer months in a temperate climate. If harm does follow it is due more to the constancy than to the degree of heat.

Those who go to the tropics must be exposed to the same infections as are the natives—no more, possibly less, on account of their better hygienic surroundings. Consequently a certain percentage of new-comers will be ill for a certain length of time during their stay in a tropical climate; but if the opportunities for infection are the same as they are in other climates, there is no reason why new-comers should be ill oftener in the tropics than in their former homes. In support of this statement we may be permitted to cite the large number of old natives and foreigners who maintain good health in the tropics, the recent extensive movements of troops in the tropics without injurious consequences, and the specific causes of diseases. Usually, if an individual, shortly after entering the tropics, succumbs, some well-known cause for his death may be looked for.

Statistics of military operations possess practically no value in an inquiry of this nature, for troops campaigning in any country are most liable to diseases.

Fauna.—The fauna of the tropics, on account of an abundance of food, shelter and continuous warm weather, is more diversified than in other climates. The importance of this kingdom in medicine has only recently become prominent by the discovery of the rôle acted by mosquitoes in filariasis, malaria, and yellow fever; by flies, ants, etc., in some of the infectious diseases; and by rats, hogs, etc., in certain infectious and parasitic diseases. These discoveries have demonstrated our limited knowledge of the life-history, customs, anatomy, pathology, and ultimate fate of the several members of this kingdom; and they suggest the necessity for a more systematic study than has heretofore been made. The present importance of this subject, in anticipation of future discoveries relating to the propagation and transmission of disease, should give a new impetus to zoology and entomology. As a matter of course, scientific work along this line is important, but when we add to this the practical knowledge which is to be gained in regard to the dissemination and prophylaxis of diseases affecting man, the importance of this whole subject is greatly enhanced. To medical men, especially those working in pathology, the importance of a thorough training in zoology and entomology is manifest; in fact, there has been opened a new field which in time must yield the solution of many of our perplexing problems.

Recent work on yellow fever demonstrates how this disease depends on the life-history of the Stegomyia fasciata. This species of mosquito is tropical, but can thrive in temperate climates during warm months, to be killed by the first frosts. Yellow fever, therefore, is a tropical disease which often prevails in temperate climates during summer months, to disappear after the first few frosts. Dengue fever probably depends on similar modes of transmission. Future developments in this field cannot now be prophesied.

Flora.—In a general way, what has been said of the fauna applies also to the flora. Besides poisons of plants affecting our races, enzymes may play an important and at present an almost unknown rôle in medicine. Recent work demonstrates the importance of enzymes in plant pathology. May not some of these produce disease in the human being? Some have believed that beri-beri is caused by an enzyme. Whether this be a fact or not, it is plain that there is still abundant room for speculation in regard to numerous diseases of which, as yet, we do not know the causes.

Pathological Considerations.—As pathology and bacteriology have in recent years greatly extended the realm of medicine and have explained many of the formerly obscure points in the etiology, course, treatment, and prophylaxis of diseases, one must turn to these branches for more complete information in regard to "tropical diseases." As our knowledge advances, the rôle of specific organisms as etiological factors becomes greater and greater. The number of diseases now believed to be entirely due to the presence of a specific organism is large and increasing. In this way the group of infectious and contagious diseases has become the most important in medicine.

After the discovery of specific pathogenic organisms, it was found that these organisms usually exist as saprophytes outside of the body, or pass a portion of their life-cycle in some lower animal. These facts expose pathogenic organisms to the struggle for existence and make them, to a great extent, dependent on conditions existing in the several localities or climates.

For saprophytes, a certain amount of warmth, light, moisture, food, and transportation is necessary for their preservation, propagation, and dissemination. Experimentation has shown that many conditions influence the life, reproductive powers, preservation of virulence, etc., of micro-organisms. Consequently conditions present in the tropics may prove unfavorable to organisms which are able to weather temperate or cold climates, and vice versa; it is also possible for an organism to thrive in any climate; and, finally an organism may be so slightly influenced by climatic conditions that for a time it may thrive in almost any locality, only to die out after a longer or shorter period.

Pathogenic organisms, which pass a portion of their life-cycle as parasites in some host of a lower order than man, must depend on the presence of the host, the natural habitat and migrations of which must determine the geographical distribution of the disease produced by the respective parasite. Consequently if the host is tropical or subtropical, or if it has the power to migrate during warm months into temperate climates, the distribution of the disease is in the one case tropical and subtropical, or, in the other, may be present in temperate climates during the summer time. In all cases the fate of the host determines in great measure the fate of the parasite. Pathogenic organisms, which pass a portion of their life-cycle as saprophytes and a portion as parasites, are naturally subjected to all the injurious conditions and fate of the host above noted. On these conditions depend the differences which are observed in certain diseases according as they are encountered in the tropics or in other climates.

Diseases common to temperate and tropical climates may differ in severity, course, etc., even as they do in any given locality; but, as a rule, the clinical course and termination are essentially the same in the two climates. The field of medicine in the tropics has not been so thoroughly worked as it has been in many places; hence there are doubtless many unrecognized diseases which serve to complicate the picture of some common affections. This possible and unavoidable error in diagnosis should encourage the medical man, in the presence of a disease which simulates malaria or typhoid fever, etc., but in which the clinical diagnosis is not confirmed by laboratory methods, boldly to announce the diagnosis as undetermined. In this way the attention of pathologists could more easily be directed to undetermined diseases.

Certain organisms thrive luxuriantly outside of the body and produce toxins, which may, independently of the presence of these organisms, cause disease. This condition is called intoxication. Ergotism and pellagra belong to this class. Owing to the favorable conditions in the tropics for the growth of these parasites, their toxins may play a more important rôle than is at present recognized.

In no climate are the conditions so favorable to parasitic diseases as in the tropics. The dress of the natives and their peculiar customs favor parasitic skin diseases, and, as a matter of fact, these are very common. Intestinal parasites are rife and filariasis is quite a common disease.

Of the diseases which affect both man and animals, cysticercus, glanders, and anthrax, etc., are most important. They naturally vary in frequency in the several districts. In Manila about four per cent. of the hogs killed are infected with cysticercus; only a few with trichinæ. Yet the cases of these diseases in man are comparatively rare. In about two hundred autopsies only one instance of tænia was found; clinically, only a few cases were noted. Glanders is prevalent in some districts, but the disease in man is rarely noted. Anthrax is also rare.

Diseases among animals are rife; epidemics of cattle plague, etc., are frequent.

General Remarks.—While ordinarily the climate is equable, during the rainy and cold seasons sudden changes often occur which have a more pronounced effect on natives than on foreigners. During these times the natives wear their heaviest clothes, yet seem to be cold and uncomfortable. This condition is often intensified by the severe rainfall and high winds accompanying typhoons, at which times all note the marked increase in the amount of urine secreted, this increase being caused by the inactivity of the skin. The fact that an increase in the number of small cells has been observed in sections of kidneys removed at autopsy from cadavers of various ages has furnished ground for the belief that these organs were in a more or less irritated state, and that this irritation was probably due to a diminution in the excretion of urine, dependent upon the general increase in activity of the skin.

During ordinary weather the natives wear very few clothes, are barefooted, and thus are exposed to infection of various kinds. Living, as they do, crowded together in small rooms, usually on the floor, infection rapidly spreads. It is astonishing to see a native well dressed and apparently clean living in the filthiest surroundings. These people seem to like it. Often their food is kept, cooked, and eaten amidst filth. Their domestic animals, cows, hogs, goats, chickens, etc., have free access to the house, and often convert the premises about the home into a pen. In larger residences, in many places, the stable occupies a portion of the house. Night-soil is usually kept in pails in the house, to be carried off by tenders to garden patches. The water supply of the natives is often derived from pools and small streams which are unprotected and which flow through fields on which night-soil has been used, and into which all the filth about the houses drains. Their small streams serve as washtubs for clothing, etc., as bathtubs for the entire town, as wallowing holes for domestic animals, and finally as a source of drinking and cooking water.

When these conditions are realized, and especially when we reflect that cholera, plague, typhoid, etc., are always present in many countries, the wonder is that any of these unfortunate beings survive. Fortunately, Providence has mercifully arranged, through the agency of severe rain storms, for the washing out of many of these filthy places, and through that of a hot sun for the roasting of a goodly portion of the organisms which survive the floods. Notwithstanding these natural prophylactic measures, a variety of circumstances—as, for example, the protection offered by the flora and fauna of the region, and the ignorance and poverty of the people—preserve all the conditions required for the propagation and dissemination of diseases. To this normal condition of disease-promoting factors there must occasionally be added the occurrence of a famine, due to a general failure in crops or to an epidemic among domestic animals, etc. Consequently, preventive medicine must battle, not only with these natural difficulties, but also with unlimited poverty, with ignorance, and with multitudes influenced by dogmatic religious beliefs.

Owing to their origin, education, etc., the nations occupying tropical countries have, with rare exceptions, been incapable of self-government. This fact, coupled with the possible gain of riches, has attracted the attention of civilized nations to the tropics and has led, in many instances, to the active commercial exploitation of these countries. Naturally, the resulting increased intercourse between tropical and temperate climates has awakened a new interest in all conditions prevailing in the tropics, has furnished a means for the introduction of tropical diseases into temperate climates, especially during the summer months, and has given to "tropical diseases" a new interest and a practical bearing. This impetus has, within the past few years, resulted in a rapid development of our knowledge regarding the etiology, course, and prophylaxis of "tropical diseases." Each advance indicates more clearly that the greater number of these diseases are infectious and consequently may be prevented, and that each step in preventive medicine renders the tropics more habitable for races accustomed to temperate climates. Our increased knowledge of tropical diseases enables us to identify, in temperate climates, diseases—such as ankylostomiasis, filariasis, etc.—which, without the knowledge so acquired, would escape recognition. Thus at home, in a temperate climate, we are exposed to many so called "tropical diseases."

As a result of modern interest in the tropics, of modern research in regard to the dissemination and prophylaxis of "tropical diseases," the monumental work of the late Major Walter Reed, United States Army, must be cited.

Lastly, as our knowledge of "tropical diseases" increases, the importance of their geographical and meteorological relations diminishes, and the conclusion is reached that they are equally as important to the medical men of temperate climates as to those of the tropics.

W. J. Calvert.

TRYPSIN. See *Pancreas*.

TRYPTOPHAN (PROTEINOCHROMOGEN).—In their classic work on "Die Verdauung nach Versuchen" (1831) Tiedemann and Gmelin noted the peculiar red coloration which pancreatic juice and the intestinal contents of animals gave with chlorine water. Claude Bernard failed to observe the reaction with *fresh* pancreatic juice. The researches of Kühne and his followers have indicated that the color reaction is due to a product of the cleavage of proteids, especially through the agency of pancreatic digestion. Kühne found that the characteristic reaction could be obtained equally well with bromine water, which is now more generally used in testing for the substance. If a mixture containing the rose-colored product of the reaction be shaken with amyl alcohol the colored product is taken up by the latter solvent and shows in this a characteristic spectroscopic absorption near the D line. The name *tryptophan* (from *θρύπτομαι* and *φαίνω*) was introduced by Neumeister as indicating the origin of the body in the decomposition of proteids. Stadelmann applied the less familiar term *proteinochromogen*, reserving the word *proteinochrome* for the colored compound of which the halogen (Br) forms a part. Trytophan is now known as a typical and constant product of the tryptic digestion of proteids. It may also arise when the albuminous substances are split up by baryta water, dilute acids, or the action of bacteria. When proteids are digested with purified pepsin or papain (?) it is not obtained. Glaessner has shown, however, that it is formed by the enzyme pseudopepsin, which is associated with true pepsin in the gastric membrane. Tryptophan may arise in the autolysis (self-digestion) of tissues, even in the absence of bacteria. The vegetable enzymes bromelin (from the pineapple) and nepenthin (from Nepenthes), as well as those from many other plants, also form products which are said to give the violet color with chlorine or bromine water.

In the earlier attempts to isolate and identify tryptophan, the chromogen was precipitated from its solutions in the form of the halogen compounds which are obtained with bromine or chlorine. The results were not constant, and the products of different investigators varied in their composition, owing to the difficulty of separating them completely from other decomposition products of the proteids, such as peptones. Accordingly various analyses have been reported which showed the compound to contain carbon, hydrogen, nitrogen, and bromine (or chlorine). Pyrrol and indol derivatives were obtained as decomposition products. Nencki regarded tryptophan as the mother substance of some of the pigments (melanins, etc.) which have their origin in the animal body. The latter yield similar products of cleavage.

Tryptophan was first isolated as such by Hopkins and Cole. In composition it corresponds with the formula $C_{11}H_{12}N_2O_2$; and it has been identified as skatol amido-acetic acid, which Nencki believed would be found as the precursor of those indol derivatives that arise during the putrefaction of proteids. The pure, colorless crystals show great proneness to undergo brown pigmentation on heating with acids, or even with water alone. Tryptophan thus isolated gives the well-known Adamkiewicz proteid reaction (with glacial acetic acid and concentrated sulphuric acid), which has been shown to depend upon the presence of glyoxylic acid in the acetic acid used. Solutions of the isolated tryptophan also give the "pine-slip" reaction direct, offering strong evidence of the presence of the pyrrol ring (or the indol nucleus). The investigations of Ellinger have made it probable that tryptophan is a precursor of indol in the putrefaction of proteids, and that it thus bears a direct relation to the indican of the urine.

For the methods of isolating tryptophan, the reader is referred to the papers of Hopkins and Cole. To test for tryptophan in solutions containing products of proteid decomposition, the following method is usually employed: The solution is acidified with acetic acid, and gradually treated with two or three volumes of saturated bromine water until a reddish-violet precipitate is formed. Large amounts of proteid may first be separated by precipitation with alcohol. The tryptophan is then searched for among the alcohol-soluble products, after removal of the alcohol by evaporation.

Lafayette B. Mendel.

LITERATURE.

Tiedemann und Gmelin: Die Verdauung nach Versuchen. Heidelberg, 1831, i., pp. 31, 32, 358; ii., pp. 149, 248, 272.
Claude Bernard: Comptes rendus, 1856, supplement i., 403.
Kühne: Verh. des naturh. med. Vereins, Heidelberg, 1886, N. F., i., 236; ii., 467.
Krukenberg: Verh. der phys. medicin. Ges. zu Würzburg, 1884, 179.
Neumeister: Zeitschrift für Biologie, 1890, xxvi., 329.
Stadelmann: *Ibid.*, 1890, xxvi., 491.
Winternitz: Zeitschrift für physiologische Chemie, 1892, xvi., 462.
Nencki: Berichte der deutschen chemischen Gesellschaft, 1895, xxviii., i., 560.
Beitler: *Ibid.*, 1898, xxxi., ii., 1604.
Kurajeff: Zeitschrift für physiologische Chemie, 1899, xxvi., 501.
Malfatti: *Ibid.*, 1900, xxxi., 43.
Glaessner: Hofmeister's Beiträge zur chemischen Physiologie, 1901, i., 26.
Hopkins and Cole: Journal of Physiology, 1901-02, xxvii., 418; xxix., 451.
Vines: Annals of Botany, 1902, xvi., 1; 1903, xvii., 237.
Mendel: American Journal of the Medical Sciences, 1902, cxxiv., 310.
Ellinger and Gentzen: Hofmeister's Beiträge zur chemischen Physiologie, 1903, iv., 171.

TUBERCULIN. See *Tuberculosis*.

TUBERCULOSIS.—An infectious disease caused by the bacillus tuberculosis.

HISTORICAL.—It is possible to divide the literature of tuberculosis into six periods. 1st. The description of the tubercle as a specific structure. 2d. The early clinical and anatomical study of phthisis and other lesions of the disease. 3d. The discovery of the infectiousness of the disease and the proof by this of the etiological unity of the lesions. 4th. The discovery of the bacillus and the proof that it was the cause of the disease. 5th. The discovery of tuberculin. 6th. The study of modes of infection and the part played by animals in the extension of infection.

1st. Although the word tubercle had long been used to designate a small nodule, it was not until 1793 that it was described by Bailey as a specific structure. He described under this name a special formation which he found in the lungs in cases of phthisis. The tubercles are small round bodies, never exceeding the head of a pin in size, and which are formed in the cellular tissue of the lung. Large tubercles can be formed by the union of small. The centres of the large tubercles are converted into pus, and this transformation of tubercles into abscesses is the cause of phthisis.

2d. Bayle in 1811 made an anatomical study of phthisis based on one hundred and nine autopsies. He defines as phthisis all lesions of the lungs which produce disorganization and destruction of the lung tissue. He characterizes phthisis clinically as an *ensemble* of symptoms consisting in cough, dyspnœa, marasmus, hectic fever, and sometimes purulent expectoration. Anatomically he distinguishes six varieties of phthisis, but gives special importance to the first two, tuberculous phthisis and granular phthisis.

In tuberculous phthisis the lung contains tubercles formed of an opaque homogeneous substance having a whitish-yellow or grayish color. These tubercles are at first firm, but they afterward soften in their centre, and are finally destroyed by suppuration. The tuberculous affection is a chronic disease of a special character, but probably of a scrofulous nature, and should not be regarded as the result of inflammation. The second variety, granular phthisis, often accompanies the first. In this the lungs are filled with miliary transparent granules of cartilaginous hardness, from the size of a millet seed up to that of a grain of wheat. These granules are not exclusively localized in the lung, but may be met with in the peritoneum, intestine, and heart. This is the first description of miliary tuberculosis.

In 1826 Laënnec proclaimed from his study of pathological anatomy the unity of the different forms of phthisis, and he found the characteristics of the disease in the evolution of the tubercle. "The progress of pathological anatomy has demonstrated that pulmonary phthisis is due to the development in the lungs of a peculiar formation which has received the name of tubercle. The tuberculous material develops in the lungs and in other organs in two principal forms, as isolated bodies and as infiltrations. Each of these forms presents a number of varieties due chiefly to their different degrees of development. The isolated tubercles present four varieties which may be distinguished as miliary tubercles, crude tubercles, granulations, and encysted tubercles. The tuberculous infiltration presents three varieties which can be designated as crude tuberculous infiltration, gray tuberculous infiltration, and yellow tuberculous infiltration. Whatever may be the form into which the tuberculous material finally develops, it presents in its origin the appearance of a gray or semitranslucent mass which gradually becomes yellow, opaque, and very dense. It finally softens, becomes almost as fluid as pus, and is expelled by the bronchi, leaving in its place cavities commonly known as ulcers of the lung, and which we designate as tuberculous excavations." Laënnec also recognized the specific character of these lesions. "One cannot regard the tubercles as the result of inflammation of some one of the constituents of the lung without destroying the results of observation and making a strange abuse of reasoning. If inflammation has any influence on the appearance or the development of the tubercles, it is only to prepare the soil and make it favorable to their growth; in the same way as the soil when cultivated after a long repose will germinate a multitude of seeds which have lain in it for a number of years."

The views of Laënnec prevailed generally until the more careful anatomical investigations of Virchow. In his work on the lymph glands Virchow says: "More careful observation shows that the scrofulous affections of the lymph glands are secondary, and not due to any preceding blood crasis or any general change in the character of the blood, but secondary in relation to the local changes of those parts from which the glands obtain their lymph. The gland swelling is due to certain substances produced in consequence of pathological processes, which are carried over in the lymph to the next lymph nodes and produce in them similar irritation. This can take an inflammatory character or a progressive development without evidences of inflammation. The condition is called scrofula when slight irritation produces extensive glandular swellings. In certain individuals the swelling continues, and this is the reason why it appeals to some as an independent process. The condition is connected with a weakness of the individual or of certain parts of the body. This constitution can be acquired, as is shown by the frequency of such conditions in prisons, where the nutrition of the inmates is not sufficient. The signs of this weakness are a diminished capacity of resistance of the tissue toward disturbances and slighter powers of recuperation." After describing the caseation of the products of inflammation in the lymph glands he says: "A similar condition can take place in the inflammatory products of a mucous membrane when these remain for a considerable time at the place of their formation. They also become thickened and caseous. This takes place in no other part so often as in the lung, where the alveoli and small bronchi become filled with such caseous masses, and that condition arises which, since Laënnec, has been given the name of tuberculous infiltration, and which I consider as caseous infiltration or caseous hepatization. This may involve entire lobes of the lung, or it may be limited to single sections of the lung and then corresponds to what is ordinarily described as crude tubercle. Sometimes it is limited to small groups of lung alveoli; then it is miliary caseous hepatization. There is nothing that justifies us in considering these masses as tubercles. Along with this, tuberculosis can take place, but the tubercles are seated in the walls and not in the lumen of the air passages."

Virchow described the tubercle on the other hand as an organized structure, a neoplasm. It has a cellular structure, but is not vascular. It arises from the proliferation of pre-existing structures and is never an exudation. The larger tubercles are formed from the union of a number of small tubercles. These sharp, precise views of Virchow represent a great advance.

They were purely anatomical, and based on his studies of the histogenesis of pathological processes. His knowledge of microscopic structures enabled him to separate a new formation of tissue from an exudation. It was perfectly logical from such a study to make the distinctions which Virchow made. Laënnec's idea of the unity of the process was based on similarity of the gross appearances, and he was probably also influenced by his clinical knowledge of the disease, finding the same general clinical course in the various types of the lesions. There is no histogenetic unity of the tuberculous lesions, the only unity is the etiological one which was given by the work of Villemin and Koch.

3d. The infectiousness of the disease. Koch in his work on tuberculosis gives Klencke (1843) the credit for the discovery of its experimental transmission, but says he did not continue his experiments, and they were forgotten. Klencke's experiments on tuberculosis were undertaken in accordance with his idea that contagion was carried by pathological cells which have the power of generalizing an affection. He says he has been able to transmit cancer and melanosis, by intravenous injection of the cells, from man to the dog and cat. The tuberculous cells are capable of being transplanted in the same way. Tuberculous cells prepared by one of his assistants were introduced into the jugular vein of a rabbit, which when killed six weeks afterward showed extensive tuberculosis of the liver and of the lungs. The rabbit served to inoculate a crow, but without result. Although there is no doubt that Klencke did succeed in transmitting the disease, it in no way detracts from the credit of Villemin. Villemin (1865) showed that rabbits inoculated subcutaneously with tuberculous material from a man, from a cow, and from a rabbit became tuberculous. At the end of twenty to thirty days the animals began to emaciate and finally died in a state of extreme cachexia. The autopsies showed tuberculosis of the lymphatic ganglia and a formation of tubercles in the viscera and on the serous membranes. Cohnheim, in his celebrated address on tuberculosis, gives Villemin the credit of the discovery. He says: "At this time a discovery was made in France which not only marks an incomparable advance in the history of tuberculosis, but from which must date a complete change in the general conception of the process. There have been few discoveries which have so influenced medical thought as Villemin's proof of the transmission of tuberculosis. Wherever scientific work was carried on, head and hand were set in motion to repeat Villemin's experiments and to prove his views."

In 1868 Chaveaux produced tuberculosis in three heifers by giving them, by the alimentary canal, tuberculous material from a cow. He confirmed the work of Villemin and concluded that the alimentary canal constituted in cattle as in man an important channel of infection, and one more common than the air passages.

4th. The first publication of Koch in which he described the tubercle bacillus, its mode of culture and relation to the lesions of the disease was made in 1882, and was followed by a further paper in 1884. This is the most important contribution to our knowledge of the disease, and ranks among the most important contributions to medical knowledge. It marks the beginning of an enormous increase in the literature of tuberculosis, and did more than any other publication to stimulate research in infectious diseases. The structure and the histogenesis of the tubercle were studied by animal experimentation. The presence of the bacillus and the capacity of producing the disease experimentally were shown to be the criterion of what was tuberculosis. Every doubt as to the unity of all processes in which the bacillus was found, however varying their anatomical characteristics might be, was removed. The term scrofula disappeared from medical nomenclature.

5th. No less stimulating was Koch's discovery of tuberculin in 1890. He considered this the active chemical substance which was produced by the bacilli, to which important symptoms and lesions were due. The high hopes which he had of tuberculin in the therapy of the disease have not been entirely realized, but, from the work which the discovery of tuberculin stimulated, our knowledge of the disease has been greatly increased. More attention was directed to the study of the bacillus and its varieties.

6th. In the last period of the literature, which is not marked by any special publication and may be said to begin about 1898, attention has chiefly been directed to the study of the comparative pathology of the disease, modes of infection, and immunity. Methods of diagnosis have been made more accurate, the importance of early diagnosis has become more appreciated, and rational systems of prevention and treatment have been inaugurated.

The Bacillus.—The bacillus tuberculosis is a small, non-refractive, rod-shaped organism, generally from 2 to 2.5 μ in length, or from one-quarter to one-third the diameter of a red blood corpuscle. It is not motile, is usually slightly curved, and both in the lesions and in sputum is more often found in small groups than singly, the small groups of two or three bacilli representing those which were contained in a single cell. There is considerable variation in the morphology. Organisms are found which are much longer or shorter than the ordinary forms, and in recent years a number of observers have described, both in sputum and in old cultures, long, branched, and club shaped forms similar to the branched forms of the diphtheria bacilli. In many cases the bacilli do not stain homogeneously, but represent a striking alternation of unstained and brightly stained points, resembling a short chain of streptococci. Such forms are frequently found in the sputum, and the unstained points have been considered to be spores, but there is nothing in the life history of the organism to justify us in the belief that spores are produced, nor do the unstained areas have the refraction so characteristic of spores. This irregular staining is best shown by staining the bacilli intensely with fuchsin and decolorizing with sulphide of soda. The bacilli stain with difficulty. Staining reagents seem to penetrate with difficulty, but when stained they retain their color under conditions in which other bacteria are decolorized. It is this property which enables their detection and differentiation from other organisms. The best method for their detection in fluids is staining with carbol fuchsin with following decolorization in Gabbet's stain (two-per-cent. alcoholic solution of methylene blue in twenty-five-per cent. sulphuric acid). In tissues they are best stained by the method of Kühne, which consists of staining in warm carbol fuchsin, using hæmatoxylin as a counter stain and decolorizing in Orth's discharging fluid.

Their detection in sputum is a matter of great practical importance, for it is on this that the diagnosis of lung tuberculosis is principally based. The morning sputum coughed up by the patient should be examined. This should be spread out on a dark plate and the more opaque consistent particles picked out and spread on a cover slip in a thin layer. The cover slip is then dried and heated over a flame to render the albumen insoluble. Several drops of carbol fuchsin are placed on the dried surface, the cover slip is then boiled over the flame and placed in Gabbet's fluid for one to two minutes for decolorization and counter stain. The bacilli are usually fairly abundant in the sputum of cases of lung tuberculosis, and there is no difficulty in their detection. Occasionally small, hard masses may be found in the sputum, especially in cases of advanced tuberculosis with cavity formation, which are entirely composed of tubercle bacilli, and which represent pure cultures of the bacilli growing on the walls of the cavities. I have several times seen such masses in the sputum after the use of tuberculin. The positive diagnosis of the absence of bacilli can be made only after repeated examination of carefully selected portions of sputum, or by boiling the sputum in two-per-cent. caustic potash and examining the sediment. The sputum may also be digested in pancreatin and the sediment examined. In the lesions in the tissues the bacilli occur in extremely variable numbers, and the examination of numbers of sections may be necessary to detect them.

There are few bacilli with which they may be confounded. They closely resemble the leprosy bacilli, but it can rarely happen that the question of differential diagnosis from these can come up. The leprosy bacilli stain with carbol fuchsin in the same way, but they also stain with the ordinary bacterial stains. There is much more danger in confounding them with other bacteria of the acid-resisting group, such as the smegma bacilli and a bacillus frequently found in hay and in dairy products. There can be little doubt that these bacilli have been frequently confounded with the tubercle bacillus, the former in the examination of urine, and the latter in the examination of dairy products. The tubercle bacilli can be distinguished from these by the fact that they retain their color in alcohol after they have been differentiated, while the smegma and the hay bacilli are decolorized. There may even be difficulties in the inoculation test, for the hay and butter bacilli produce in rabbits and guinea-pigs nodules which closely resemble tubercles, though they lack the characteristic caseation.

The tubercle bacillus was first grown in pure culture by Koch on solidified blood serum. But little can be added to his description of the growth. In from ten to fifteen days the first sign of growth appears as dull white points or specks on the surface. These cling lightly to the surface and appear as dry scales. According to the amount of material used for inoculating the surface, the abundance of bacilli contained in it, and their distribution on the surface, there is a greater or less extent of surface covered by the scales. At first the single scales are separate, but finally they become joined and form a thin grayish-white coating over the surface. On transplanting to fresh tubes more bacilli are carried over, they are more homogeneously distributed, and the growth forms a connected membrane. The extension over the surface is not caused by the wandering of the bacilli, nor by the bacilli piling over the edge, but by the membrane being shoved over the surface by the continual growth. The bacilli never liquefy the serum, nor do they grow into it, but always remain on the surface. At the edge of the growth the small masses of bacilli have peculiar forms when examined under the low power. They grow in fine, bent, or curved lines, often having the shape of the letter **S**. The ends of the masses are pointed and the middle is swollen, giving them a spindle shape. When the bacilli are very numerous in the tissues they may appear in masses having this form. Such masses may be seen in the walls of tuberculous cavities of the lungs and in the tubules of the kidneys. (Plate LVI.)

EXPLANATION OF
PLATE LVI.

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Fig. 1.—Section from the Lung in a Case of Miliary Tuberculosis. *a*, Tubercle containing numerous bacilli; *b*, tubercle with fewer bacilli; *c* and *d*, tubercles with cheesy centre and containing no nuclei; *e*, cross section of a blood-vessel surrounded by a deposit of pigment. Magnified 50 diameters.

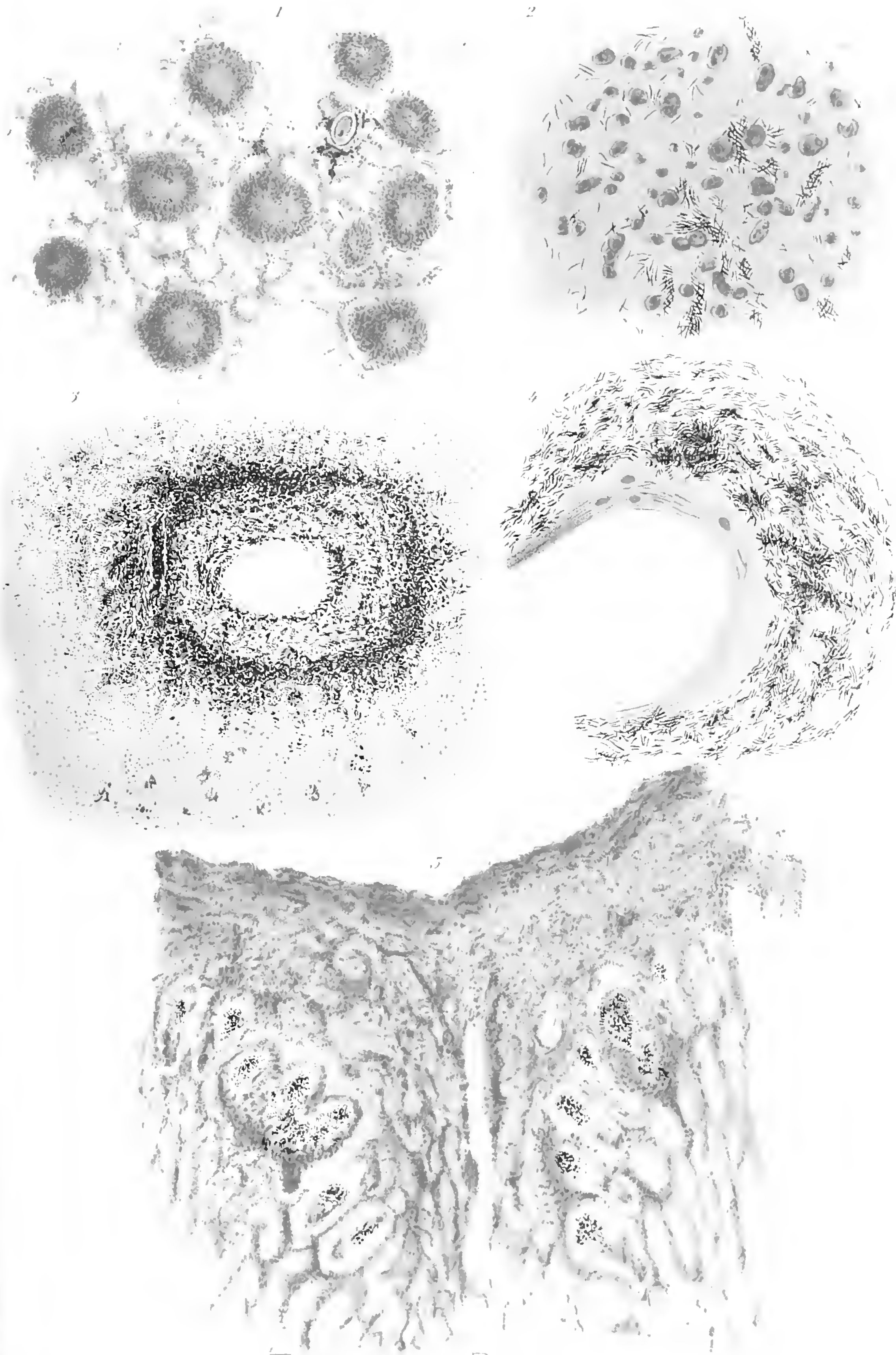
Fig. 2.—The Blue-colored Portion of the Tubercle *a* in Fig. 1. The tubercle bacilli are stained blue, the nuclei of the cells brown. Magnified 700 diameters.

Fig. 3.—A Small Artery surrounded by a Mass of Tubercle Bacilli. From a bronchial gland in a case of miliary tuberculosis. Magnified 100 diameters.

Fig. 4.—A Portion of the Wall of the Artery shown in Fig. 3. Magnified 500 diameters.

Fig. 5.—Section from a Phthisical Lung, showing the Crowding of the Tubercle Bacilli into the Alveoli. Magnified 100 diameters.

Plate LVI.



TUBERCLE BACILLI.

FROM R. KOCH'S "*DIE AETIOLOGIE DER TUBERCULOSE*"

Mittheilungen aus dem Kaiserl. Gesundheitsamte. Berlin 1884

Blood serum remains on the whole the best medium for the growth of the bacilli, especially for obtaining the primary growth. An important addition to the technique of their growth was made by the discovery that glycerin added to the culture media facilitated growth. The bacilli grow readily on agar and bouillon to which glycerin has been added. It is very difficult to obtain a pure growth of the bacillus from sputum, or even from the tissue lesions in man, owing to the liability of contamination with other organisms. Kitasato was the first to obtain a pure culture from sputum. The culture is usually obtained by inoculating an animal and using its tissues for cultivation. The advantage is that the bacilli are abundant, and if the animal has been killed there are no contaminating organisms. Smith has shown that it is better to use considerable portions of the tissues for inoculating the tubes, as the bacilli have become accustomed to growth in such tissue. Growth becomes more easy in every subculture as the bacilli become accustomed to a saprophytic existence. The bacilli in pure culture adhere together in masses which are difficult to separate, so that it is difficult to obtain a homogeneous mixture of them in a fluid. Hesse has strongly recommended, for cultivating the bacilli from a sputum, a medium containing a soluble albumen preparation known as Nährstoff Heyden. He obtained upon agar containing 0.5 per cent. of this substance along with three per cent. of glycerin a characteristic microscopic growth of the bacilli from tuberculous sputum in three days. Even when other bacteria are present, the commencement of the tubercle growth can be demonstrated in contact preparations in five or six hours. This is the best medium for obtaining a primary culture from sputum, though it is not the best medium for their continued growth.

The tubercle bacilli are not saprophytic under natural conditions. They grow only within narrow limits of temperature, and will not find favorable conditions for growth outside of the animal organism. The temperature limits of growth are 30°–42° C. Growth takes place best at a temperature of 39° C. Cultures will usually become sterile after twelve months. Bacilli in dried sputum kept in the dark may remain virulent for from six to ten months. The sputum does not lose its virulence by alternately moistening and drying. The dried sputum in a chamber, exposed to diffuse daylight, may retain its virulence for two months. Putrefaction does not destroy the bacilli, but they are rapidly killed by sunlight. Smith has shown that a temperature of 60° C., maintained for twenty minutes, will kill the bacilli in water, salt solution, bouillon, and milk, but that a membrane formed on the surface contained living bacilli after sixty minutes' exposure to this heat.

Fatty acids are important constituents of the tubercle bacilli, and Unna has supposed that the resistance of the stain to acids depended upon these fats. Aronson has shown that the body which gives the acid resistance is of the nature of a wax, and when this is removed the stained bacilli are no longer acid-proof. The best analysis of the tubercle bacilli is that of Rüppel. He finds in 100 gm. of dried tubercle bacilli: Fat and wax, 26.5; nucleic (tuberculinic) acid, 8.5; protamin, 24.5; nucleo-proteid, 23; mineral substances, 9.2; proteinoid substance, 8.3. According to Behring the nucleic acid possesses in high degree the specific properties of Koch's tuberculin.

Levene found differences in the composition of the bacilli dependent upon the medium on which they were grown.

A substance called *tuberculin* is present in cultures of the tubercle bacilli and in the infected tissue. It may be extracted from the dead bacilli and represents the sum of their proteid substance. It is not known whether it is actually given off from the living bacilli as a secretion, analogous to diphtheria and tetanus toxin, or whether it is exclusively derived from their protoplasm. Koch first described this substance and its action at the International Medical Congress in Berlin in 1900. As first prepared it was known as crude tuberculin. The bacilli are grown in large dishes, which give a large surface to the growth. The culture medium used is bouillon containing one per cent. of peptone and from four to six per cent. of glycerin. The bacilli grow abundantly in this, forming a thick yellowish membrane on the surface. After six weeks growth ceases and the membrane begins to break up and sink to the bottom. The culture is then evaporated to one-tenth its volume on the water bath and the residue filtered through porcelain. Tuberculin as so prepared is a brownish fluid, the color being due to the concentrated color of the bouillon, and contains enough glycerin to preserve it indefinitely. It evidently represents a number of different things, including a concentration of the soluble substances of the bouillon. Later, Koch attempted to purify the product by extracting the pulverized bodies of the dead bacilli. He produced two substances, one soluble in water and one soluble in glycerin. The material soluble in water has the same action as the crude tuberculin. Koch was led to the therapeutic use of tuberculin by the difference which he found in the inoculation of a healthy and a tuberculous guinea-pig with a virulent culture of the tubercle bacilli. In the normal animal subcutaneous inoculation leads to the formation of a tuberculous ulcer, which persists until the animal dies from generalized tuberculosis. If a second inoculation is made five or six weeks after a primary, only induration and necrosis of the tissue at the site of inoculation are produced. The necrotic tissue is thrown off and the ulcer heals by cicatrization. He found the same results from the dead bacilli, and endeavored to obtain the chemical substance which was present in the body, and which caused the second inoculation to take a more favorable course. In his explanation of the action of the remedy he supposes that the bacilli produce substances injurious to the cells, causing them to undergo coagulation necrosis. Such necrotic tissue forms a bad culture medium for the bacilli and they die. A greater amount of this substance causing necrosis will extend the area and still more wall off the bacilli contained in it. The necrotic material may become detached and remove the bacilli contained in it outside of the body. The tuberculin contains the material which produces the necrosis, and when injected in sufficient amounts into a healthy man will cause fever and toxic symptoms. Very small doses injected into a tuberculous subject will cause fever and other symptoms. It also exerts a local action on tuberculous tissue, producing intense hyperaemia with leucocytic invasion and increasing the extent of the necrosis. It has this intense general and local action in the tuberculous subject by increasing the amount of tuberculin in the fluids and in the local lesions, some being always formed by the bacilli in the affected subject. This hardly explains its action because a severe general and local reaction takes place when the tuberculous lesions are so slight as scarcely to be manifest, and it can hardly be supposed that in such lesions, containing only a few hundred bacilli, an appreciable amount of tuberculin can be produced. It is generally considered that the action of tuberculin is specific, that its local and general action in very small doses, 0.1–1 mgm., is exerted only in tuberculous individuals. There are opposing opinions to this view of specific action. Roemer and Buchner have obtained the tuberculin reaction in tuberculous guinea-pigs with extracts of other organisms. Tuberculin reaction has been obtained in man in cases of syphilis and in other infections, and in individuals who were clinically in perfect health. In these cases it is impossible to say that an individual giving the tuberculin reaction has not some focus of latent tuberculosis. Koch regarded the remedy as directly curative in the early stages, the advance of the disease being stopped and the lesions cicatrized. The most enormous literature on tuberculin followed the publication of Koch. Every physician who could obtain any of the precious fluid published his results, however insignificant they might be. The remedy seemed to have a more decided and favorable action in tuberculosis of the skin than in any other forms. Portions of tissue here can be excised and the influence exerted on the lesions followed. Its general action was seen to be the production of acute inflammation in the lesions with leucocytic infiltration and serous and fibrinous exudation. The general results were not favorable to the views of Koch. Numerous autopsies were made on cases of tuberculosis in which the remedy had been used. It was shown that it could be dangerous and even fatal, producing extensive inflammation around foci in important organs and leading to dissemination. The strongest possible reaction succeeded the enthusiasm with which the remedy was first greeted. At present it seems to be the opinion that tuberculin is of great importance in the diagnosis of tuberculosis in animals (cattle) and in man, being far more accurate than any other mode of diagnosis with the exception of the bacteriological and experimental; it is available when these methods are not. It is of therapeutic value in certain early cases, and when most judiciously used. It is a very dangerous agent when considered as a general remedy for the disease.

Differences in Bacilli.—In his first work Koch held that there was but one species of tubercle bacillus, and that all forms of the disease in man and in animals were the same, and due to the same bacillus. Subsequent study has shown that this statement must be greatly modified, and that there are several distinct varieties or strains of the bacilli. These different strains are distinguished from one another less by their morphology and cultural characteristics than by the effects which they produce on inoculation. The general opinion seems to be that they cannot be made to pass one into the other either by cultures or by series of inoculations. Undoubtedly much confusion in the pathology arises from these variations. It will be necessary to repeat a great deal of the work which has already been done, holding in mind these differences and in every case determining the character of the organism which has been used in the experiments. These different strains of bacilli will be considered in the tuberculosis of animals.

Differences in Virulence.—Great differences are found in the clinical course of the disease and in the character of the lesions. In certain cases the disease runs its course, ending in death, in a few weeks or months; in others it takes a very chronic course, and may terminate fatally only after years. Autopsies show an extraordinary number of cases in which infection has been followed by cure or at least by complete quiescence of the disease. In the microscopic study of the lesions the same differences are seen. In one case little or no reparative action of the tissue; in another a formation of fibrous tissue, limiting the extension of the process. These differences are due to a number of factors: The anatomical structure of the organ attacked, which may or may not favor the dissemination of the bacilli or the chemical substances derived from them; the number of bacilli and their mode of entrance into the tissue; peculiar individual qualities of the tissue attacked or of the body generally.

There is undoubtedly a great difference in the organs and tissues attacked as regards their favoring or not the multiplication of the bacilli, this difference being due not to anatomical arrangement, but to peculiarities probably of a chemical nature. It is possible also that there may be differences in different individuals, the bacilli finding all or similar tissues in one more favorable for growth than in another. It is generally assumed also that there are differences in the virulence of the bacilli. There are certainly differences in the virulence of the different strains of the bacilli, the bovine being most virulent, the human coming next. The virulence of cultures also diminishes in the course of cultivation. There is some uncertainty as to the variation in virulence of primary cultures of the human and bovine, and whether we can refer differences in the lesions and in the clinical course of the disease to this. Variations in the virulence of human cultures may be due to infection with other than the human bacillus. Vagedes has studied the virulence in thirty different cultures of the bacilli. Three were from rabbits which had been inoculated, two were from cattle, and the others were obtained directly from the human sputum or from contents of cavities. He tested the virulence by inoculation with a suspension of the bacilli made by rubbing up weighed amounts of the pure culture in a given amount of water. He found three different degrees of virulence, four of the cultures derived from man being as virulent as the bovine. The most virulent culture came from a fifteen-year-old girl, both of whose parents had died of the disease. The autopsy of the girl showed advanced lesions of the lungs and intestines. The less virulent cultures came from the cases which clinically showed a less rapid course. There was very little difference in the character of the growth in the different cultures. One culture of medium virulence resembled the avian type of bacillus, and there was much similarity in the shape of the organisms between those from his most virulent case and the bovine.

Tuberculosis in Animals.—The disease never appears in animals in a wild state. In some it never appears spontaneously, though they may be highly susceptible to inoculation. The same rules for infection govern the disease in animals and in man, being dependent upon the situation of the lesions, this determining the ways by which the bacilli leave the body and the opportunity given by the life of the animal for the entry of the bacilli into the tissue. The disease in animals is of great importance, both from the enormous economic loss it entails and because animals play a certain part, the importance of which is probably overestimated, in the transmission of the disease to man. It is also of importance that the disease can be given to animals, because our knowledge of the disease has been chiefly obtained through animal experimentation. The unity of the disease could have been established only by animal inoculation. Modes of infection followed by preventive measures have been studied in the same manner.

Tuberculosis of cattle is the most common and the most important form of animal tuberculosis. The form of disease differs in many respects from that in man, and the identity of the two has been established only in the last twenty-five years. It is characterized chiefly by the presence of hard, tumor-like masses up to 20 cm. in diameter, on the serous surfaces or in the viscera. The masses are often flat on top and attached to the surface by a pedicle. Several such masses may be united together by small attachments, and hang from the serous surface like a bunch of grapes. The large masses are formed from the confluence of single tubercles, which give the surface an irregular character. The smaller nodules are hard and fibrous on section, later they become caseous, infiltrated with lime salts, and have a peculiar bright-yellowish color. They may undergo partial softening, becoming filled with a yellowish, greasy, gritty material of the consistence of mortar. Microscopic examination of the younger nodules shows a structure composed of single tubercle with epithelioid and giant cells containing bacilli. The lungs contain irregular solidified areas, circumscribed tumor-like masses similar to those first described, and cavities with smooth walls, filled with yellowish, thick, tenacious, often fetid material. The extension along the bronchi is very evident, the separated single lobules are often affected, the single small foci in these resembling the grapes on a bunch, the stems being represented by the bronchi filled with and surrounded by yellow caseous material. The lymph nodes are always infected, and may be the only seat of the disease. Infection seems to take place chiefly by inhalation and the bronchial and mediastinal nodes are those most often affected. The nodes may be enormously enlarged, forming hard caseous or calcareous masses with peculiar yellow pigmentation. The grayish tumor-like masses have given the disease the name "Perlsucht," or pearl disease. Acute general miliary tuberculosis as seen in man does not occur, though miliary tubercles harder and more transparent than in man may be found both on the serous surfaces and in the organs. Ulceration of mucous surfaces is not common, although in the trachea and larynx ulcers may be found which take the form of large projecting masses formed of conglomerate tubercles, and which seem to have burst through the mucous membrane. I have seen one case in which tuberculosis of the peritoneum took the form of a diffuse caseation of the surface with adhesions between the intestines which were filled with communicating ulcers, the whole forming a mass which it was impossible to disentangle. Tuberculosis of the mamma is common and important from its relation to the infection of milk. It may be primary or a part of the general process. It usually commences as a diffuse uniform thickening of the posterior part of the gland. The gland at this time may contain bacilli which are apparently growing in the ducts, since they can be squeezed from it through the udder. Later, the gland becomes filled with fibrous or caseo-calcareous masses, and increases greatly in size. The milk may present a normal appearance, even when there is advanced disease of the gland; later, it becomes thin, bluish, and on standing gives a sediment which contains numerous bacilli. The bones are rarely affected.

The disease ordinarily takes an extremely chronic course, and may remain latent for years. The animals may become fat, appear to be perfectly well, and yet the autopsy shows an advanced tuberculosis of the serous cavities. When the disease takes a more rapid course, cough begins, there are fever, discharge from the nose, and rapid emaciation. The disease is widely spread over the entire civilized world. It increases in a definite proportion with age, and is extremely rare in calves. Most cases are in cattle over six years of age. It is more frequent in cows than in oxen and bulls, which may in part be due to the more confined life of the cows and the greater demands made on their nutrition by pregnancy and lactation; but it is probably due rather to the fact that cows live longer. The disease spreads by contagion and one animal may infect a herd. The opportunities are good for the extension of the infection. The animals are usually in close proximity, they cough forcibly, and can project fine spray particles of sputum containing the bacilli for a considerable distance; they commonly use the same place for drinking, they lick away their nasal discharge, and by the habit of licking each other may transfer the bacilli. The disease is most common in stables where the animals are kept closely confined.

There is much difference in the susceptibility of the different breeds of cattle. The purest breeds where the selection of certain qualities economically valuable has been made are those most affected. The most susceptible races are the Alderneys and the Short Horns. Certain strains of these in England have been threatened with total extinction. Wilson estimates that in Great Britain there are 2,200,000 tuberculous cattle, and that the annual loss caused by the disease is £3,000,000 sterling.

The numbers of bacilli found in the lesions vary. They are about as numerous as in the human lesions, and they may be present in enormous numbers. The greatest number of bacilli I have ever seen in a disease was in a case of intestinal tuberculosis in a cow.

The most important practical question relating to bovine tuberculosis is the part which it plays in the transmission of the disease to man. The danger comes through the use of the milk; the danger of infection through the use of the meat of tuberculous animals is remote. Tubercle bacilli have been repeatedly found in milk and in milk products. They are always present in large numbers in the milk in tuberculosis of the udder, and may be present in tuberculosis of internal organs when the udder is not affected. When we consider the enormous frequency of bovine tuberculosis and the facts that the milk coming from different farms is all mixed before distributing in the cities, and that the bacilli would certainly not be destroyed in the milk, it is evident that they must be frequently ingested. But a small proportion of the milk used in this country is boiled or even heated before it is used. Animals fed on milk containing bovine bacilli become infected, but the opinion is gaining that milk infection is an exceedingly rare source of tuberculosis in man.

Baumgarten (1882) was the first to point out differences in the transmission of the bovine and the human disease. He says that inoculation with material from bovine tuberculosis produced a disease which took a quicker course and led more rapidly to a general infection than inoculation with material from man or dog. He had no results from the inoculation of tuberculous material from chickens and pigeons.

The bacillus of bovine tuberculosis is the common cause of all tuberculosis in mammals with the exception of man. The morphological distinctions between the human and bovine bacilli are not sufficiently marked to enable us to distinguish them. The bovine bacillus is a little shorter than the human and the sizes are more constant. The cultural differences are more marked. The human bacilli from the start grow more vigorously than the bovine, though the bovine are less influenced by slight modifications of the culture media. There are marked differences in the character of the growth on the surface of glycerin bouillon, the growth of the bovine forming a more moist and translucent membrane with less tendency to plication. The inoculation differences are more striking. The bovine is more virulent for all animals and tends to more rapid generalization. When rabbits are inoculated in the ear vein with like amounts of pure cultures of the human and bovine bacilli the bovine inoculation produces general miliary tuberculosis and death in three weeks. With the human bacilli the animal lives longer and may survive the inoculation. A number of inoculations in cattle have been made with pure cultures of both bacilli and with somewhat varying results. But the general result shows that cattle are either completely immune to the human bacillus, or, if they acquire the disease at all, only slight local lesions are produced. The study of the bacilli shows that the characteristics of each form are retained after a series of cultures and animal inoculations. Those opposing the idea that the disease may be transmitted from cattle to man base their belief on a number of conditions. The types of human and bovine bacilli remain constant, and only the human type is found in pure cultures of the lesions in man. Bovine tuberculosis cannot be produced by inoculation of the human bacillus. Were infection by milk common, the lesions in man would show the primary foci in the intestinal canal. Experiments in feeding animals with tuberculous material produce a series of lesions pointing to infection from the alimentary canal. Primary intestinal tuberculosis or even primary tuberculosis of the mesenteric glands is rare in man, notwithstanding the opportunities for infection given in the extended use of milk. Baumgarten has recently reported a series of experiments made twenty years ago, in which inoculations of the bovine bacilli were made in man. Proceeding from the views of Rokitansky regarding the opposition between tuberculosis and cancer a physician inoculated a number of patients having advanced malignant tumors with pure cultures of bovine bacilli, with the hope of effecting a cure of the cancer. No influence was exerted on the cancer, of which the patients died, and at autopsy no effects from the injection of the bacilli could be found. Opposed to this there have been a number of cases reported of local and general tuberculosis in man due to infection with bovine tuberculosis, and some of them do not admit of any doubt. The matter of this mode of infection or the frequency of it is one which must be cleared up by further investigation. The permanence of type of the bacillus must be more accurately determined, and the bacillus must be isolated and studied in a large number of human cases, particularly in those in which infection seems to have come from the alimentary canal. The infrequency of primary tuberculosis of the alimentary canal is by no means opposed to the probability of food infection, because it is possible for the bacilli to enter the tissues without the production of a lesion at the point of entrance, or without any anatomical evidence of the lesion. No effective control of bovine tuberculosis is possible. To use the tuberculin test for its detection and to destroy all cattle which give the reaction would result in economic losses impossible for the state to meet. It would be absurd to condemn as unfit for consumption the meat of cattle which show only a caseous lymph node as evidence of the disease. In Massachusetts an attempt was made to exterminate the disease by destroying all cattle which gave the tuberculin test, but it was soon abandoned. The attempt at extermination of the disease in the present state of our knowledge regarding infection should be undertaken rather as an economic than as a hygienic measure. It might possibly be done by the general Government, but not by the States. At present in Massachusetts State control is limited to inspection of herds and destruction of cattle with evident extensive tuberculosis or with involvement of the mammary gland.

Tuberculosis of the horse is rare; the disease is often confounded with glanders, especially the chronic form of this. It is usually localized in the lungs and abdominal cavity, and resembles the bovine disease. The affected lymph nodes may form enormous tumors. Histologically the disease is characterized by the fibrous character of the tubercles, the less tendency to calcification as compared with cattle, the number of bacilli in the lesions, and their almost constant presence in the giant cells. The symptoms are not characteristic, and are not seen until a late stage of the disease. After cattle swine are most frequently affected. The disease is most often seen in young animals, and is due to infection by the digestive tract caused by feeding them with tuberculous milk or with the refuse of abbatoirs. A peculiar form of intestinal tuberculosis is sometimes seen in very young pigs, consisting in general diffuse necrosis and caseation of the mucous membrane. The lesions closely resemble those of diphtheritic dysentery. The disease often becomes generalized with great rapidity and takes an acute course. The bacilli are usually present in very small numbers. Sheep and goats are rarely affected, although the disease can be conveyed by inoculation. It takes the same form as in cattle. In Prussia in 1894 abbatoir inspection showed only 0.06 per cent. of tuberculosis in sheep. The dog, though relatively immune, may contract the disease. Villemin produced the disease in the dog by subcutaneous inoculation. Both the human and the bovine disease may be inoculated. Strauss has injected pure cultures of the human bacillus into a vein, producing miliary tuberculosis of the organs. Several cases of spontaneous infection of the dog have been reported, infection being due to the animal eating the sputum of a tuberculous master. The bacilli in the lesions are in very small numbers. Shortly after the discovery of the tubercle bacillus I had occasion to examine the tubercles in the liver of a dog for bacilli. The case was an important one at the time because it was regarded as proving the presence of tubercles without bacilli. Forty sections were examined before a bacillus was found. Tuberculosis can be easily transmitted to the cat, but the spontaneous disease is rare. The lesions have nothing characteristic. In one case of spontaneous tuberculosis the liver contained very acute lesions full of bacilli, and in many places there was an actual injection of the capillaries with masses of tubercle bacilli. It has been known for a long time that tuberculosis is frequent in monkeys living in captivity. In this animal, as in man, the pulmonary form is most common, and the lesions are very similar to those in man, though the tubercles have a greater tendency to softening and may resemble abscesses. The bacilli are present in about the same numbers as in man. The guinea-pig and the rabbit, although so susceptible to experimental tuberculosis, are rarely spontaneously affected even when in captivity. It is very rare in the laboratory, even when animals are kept in close relation with those infected experimentally, that an animal killed for any other purpose will show tuberculous lesions. Mice and rats are less susceptible than guinea-pigs and rabbits.

The tuberculosis of fowls has a special interest because it is due to a strain of the tubercle bacillus which is different from both the bovine and the human form. Infection takes place from the alimentary canal, though the mucous membrane shows no ulceration. The lesions take the form of small firm tumor-like masses seated principally on the peritoneal surface of the intestine and in the liver. The tumors are surrounded by a capsule of connective tissue and are easily enucleated. The tubercle bacilli are more abundant than in the lesions in any other animal. Section of a large nodule shows a necrotic centre which is full of bacilli. Around this is a layer of tissue containing epithelioid and giant cells in which the bacilli are less numerous. The bacilli are generally longer than the human bacilli, and the cultures can be distinguished from both this and the bovine. All experimental evidence is opposed to the idea that the human bacillus can produce tuberculosis in fowls. Strauss fed eight chickens with sputum rich in bacilli, and also gave them a chopped-up tuberculous lung. The autopsy showed no trace of tuberculosis, although masses of the tuberculous material were ingested. Martin has inoculated chickens and pigeons in the peritoneal cavity without producing any lesions. Subcutaneous inoculation of the human bacilli may produce an abscess at the point of inoculation. The results of the inoculation of the guinea-pig with the avian bacilli are distinctly different from those produced by either the human or the bovine varieties. An abscess follows subcutaneous inoculation but it does not open and produce an ulcer. The animal usually dies after some months, and at the autopsy abscesses are found at the seat of inoculation, enlargement of the lymph nodes, and a few tubercles elsewhere. The rabbit has an abscess at the point where it was inoculated, and the bacilli are not usually found elsewhere. The injection of the bacilli into the blood produces emaciation and death in the course of some weeks. The liver and spleen are enlarged and the vessels contain numbers of bacilli, but there are no tubercles.

Dubard and Terre discovered in 1897 a form of tuberculosis in carp; it was due to a bacillus, the bacillus tuberculosis piscium, which has the same staining reaction as other varieties of the bacillus, but which will not produce the disease in birds or mammals and grows at ordinary air temperatures. The cultures much resemble the human and avian forms. Frogs are susceptible to inoculation with the bacilli; the lesions are much the same as in other forms of tuberculosis, but caseation is not so evident. This bacillus contains a toxin with properties analogous to those of the tuberculin of Koch. Ledoux prepared these two toxins, making them as much alike as possible. Both the fish and human tuberculin produced a reaction in guinea-pigs inoculated with human bacilli, but the fish tuberculin was not so strong as the human. One cubic centimetre of Koch's tuberculin killed a guinea-pig which had been inoculated twenty-eight days previously. The same dose of fish tuberculin produced the same elevation of temperature, but was not fatal.

Tuberculosis in Man.—Mortality statistics from all civilized countries show that about one-seventh of all deaths are due to tuberculosis. This must be based to a large extent on the deaths in which the form of the disease is obvious. Every pathologist is aware of the frequency of cases in which death from tuberculosis was attributed to some other cause; and if all forms of the disease were accurately diagnosed, the mortality would probably exceed the figures given. There is no immunity in the human race. Certain individuals may appear to be more or less susceptible than others, but the question of greater or less exposure to infection cannot be ruled out. Differences in susceptibility could be determined only by inoculation with the same amount of the same culture. There are of course great differences in the race susceptibility in animals, but the general result of experiments has been to show that susceptibility of individuals of a species of the same age and under the same conditions is about the same. No human race is exempt, and the susceptibility in all is about the same, the relative frequency of the disease being governed mainly by the greater or less chance of infection given by the conditions of life. There may be a difference in the susceptibility of the tissues of the body due to local conditions, which may favor the reception of the organisms. There may also be conditions brought about in various ways which may favor the multiplication of the bacilli when once established. It seems to be a general rule that the young of all species are more susceptible than adults. It is evident from the usual localization of the disease in man and the opportunities which the bacilli have for leaving the body that every individual with tuberculosis is a focus of infection, more or less dangerous according to the locality of the tissues affected and the extent of the lesions. This being so, density of the population and the greater opportunities which this gives for disseminating the bacilli, are the principal factors influencing the frequency of the disease. The disease exists independently of conditions of climate or soil. Wherever the population is dense the disease is frequent; wherever there is a scarce rural population the disease is more rare, and this whether the locality is in the east or west, north or south, whether the altitude be high or low, whether the climate be dry or moist, hot or cold. The disease is rare in high altitudes, but if one compares the tuberculosis curve with the curve representing density of population it is seen that the infrequency is due not to altitude, but to scarcity of population. The increase in tuberculosis in civilized life corresponds with the irresistible movement of the population to the cities, and the substitution of sedentary indoor professions for agricultural occupations in the open air. Paris gives a general mortality from tuberculosis of nearly 5 per 1,000, and from this there is a gradual decline according to density of population to 1.81 per 1,000 in some of the country districts. Density of population means indoor life and factories. These undoubtedly increase the danger of infection because the bacilli in the sputum and discharged in the expiration spray are not exposed to the killing influence of sunlight. Whether crowded conditions and indoor occupations apart from increasing opportunity for infection have any influence on morbidity is uncertain. They probably have an influence on mortality. The frequency of the disease is influenced by the different professions, and this to some extent independently of density of population. Tailors give a high mortality, which may be due in part to the fact that this pursuit is not undertaken by the more robust. The disease is particularly common among those exposed to the dust coming from vegetable and mineral substances. The mortality in Switzerland from stone-cutters is 10.47 per 1,000. It is also high in those subjected to metallic dust, as in the grinders. The cause of this is probably due to opportunities for infection combined with the creation of local conditions in the lungs favoring the lodgment of the bacilli. An exception to this is given in the coal miners in England, who have a low mortality from the disease, notwithstanding the fact that their life in the mines is not under conditions which we ordinarily regard as hygienic. Cornet explains this by the fact that in the mines there is no opportunity for infection, the sputum not becoming dried into dust. In Switzerland the mortality in agricultural laborers is 2.10 per 1,000, railroad employees 1.84, foresters 1.75, locksmiths 7.2, printers and lithographers 5.55, watchmakers 5.19, coopers 5.8, bakers 5.6, tailors 4.90. In Italy there is the high mortality of 4.59 in students and seminarists. Pastors in mountain villages seem to have the lowest death rate from the disease.

When we consider the actual frequency of the disease, as shown by the presence of anatomical lesions which could have been produced only by the action of the bacilli, the figures are colossal. Every pathologist is aware of the frequency of caseous foci in lymph nodes, of cicatrices, nodules or indurations in the lungs, of adhesions between the pleuræ, etc., the greater part of which certainly must be attributed to tuberculosis. In the Boston City Hospital, to which patients with advanced tuberculosis are not admitted, such lesions are found in the ordinary conduct of the autopsy in about one-third of all cases. Where the determining of tuberculous lesions is especially held in view in making the autopsy, and where microscopic examination of organs and animal inoculation are resorted to for diagnosis of obscure lesions, the proportion of cases is much greater. The inoculation of animals with bronchial nodes coming from subjects presenting no macroscopic evidences of the disease has shown that the bacilli may be present without any or certainly without easily recognized lesions. I have shortly had the opportunity to examine the lymph nodes from a cow which seemed both on macroscopic and on cursory microscopic examination to be intact, but a more careful examination showed a few giant cells containing bacilli with scattered epithelioid cells around them and without any caseation. The most carefully carried out investigations on the frequency of anatomical lesions in tuberculosis are those of Naegeli made on 500 autopsies

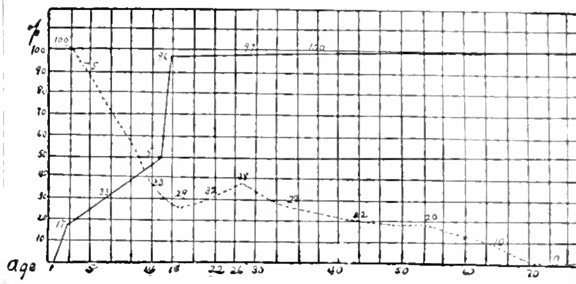


FIG. 4808.—Table taken from Naegeli, *Virch. Arch.*, vol. clx. The black line shows the frequency of anatomical evidences of tuberculosis at different ages; the dotted line, the cases in which the disease proved fatal.

(Fig. 4804). The curve shows the frequency of tuberculous lesions at different ages, reaching at eighteen the astonishing number of 97 per cent. Naegeli regards it as probable that every individual over forty has or has had at some time in his life an infection with tuberculosis. He shows that the infection increases irregularly up to 50 per cent. at fifteen years, and from that there is a rapid rise to 96 per cent. at eighteen. The dotted curve gives the percentage of fatal tuberculosis at the different ages, showing that all cases were fatal up to two and a half years, and from that a gradual decline to 29 per cent. of fatal cases at twenty in spite of 97 per cent. of infection. He argues from this that there is a special disposition in children to the extension of the disease, so that cases of infection are usually followed by generalization and death. This disposition decreases until the age of seventy, when there is practically no mortality in spite of universal infection. The figures with regard to children are misleading, and show that his autopsy material of children did not embrace the acute infectious diseases of children, and are not representative of average autopsies on children. Autopsies on diphtheria cases show a very high percentage of latent tuberculosis in children, and many of the old lesions met with in adults can be referred to infection in childhood. The percentage of lesions must, however, increase with age, for the reason that the longer a soldier remains in battle, the greater the danger of a wound. Tuberculosis was found in 35 out of 220 autopsies on diphtheria at the Boston City Hospital, or in 16 per cent. All but 21 of the 220 cases were under ten years of age. The examinations were not made with special reference to tuberculosis, and it is probable that many slight lesions which could be referred to this were overlooked. In 3 cases miliary tubercles were found only on the routine microscopic examination of the organ, there being no macroscopic evidence of the disease. In 3 cases there was healed tuberculosis of the lungs without lesions elsewhere. Contrary to general statistics which show the greatest frequency of the infection in the bronchial lymph nodes, the mesenteric lymph nodes in our cases were most frequently affected. In 7 cases the only lesions of the disease were found in these. In only 6 out of the 18 cases in which the nodes were affected was there intestinal ulceration. In but few of the cases were there any clinical manifestations of the disease, and in most cases the character of the lesions was not such as would have given rise to symptoms. Other statistics derived from diphtheria autopsies show about the same percentage of tuberculosis. Berliner in Freiburg found 19 cases in 107 autopsies on diphtheria, or 17 per cent. The tuberculous lesions were usually old, and as a rule were

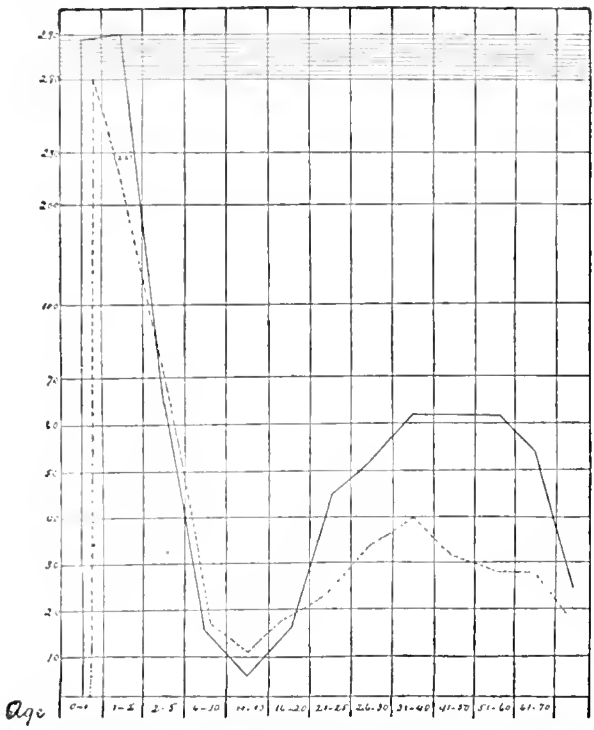


FIG. 4805.—Table of Holste, showing the Death Rate from Tuberculosis in Helsingfors for 1882–1889 for 10,000 inhabitants. The black line represents males, the dotted line females. During this period the death rate from tuberculosis was, for males 5.7 per thousand; for females, 3.8 per thousand.

not influenced by the diphtheria. Cohans in an analysis of 45 cases in Kiel found 95 cases, or 20 per cent. Nearly one-half of his cases could be regarded as definitely healed. The smallest percentage (13.3) was found by Crenemeyer in 459 cases of diphtheria. It is probable that these figures give a fair estimate of the frequency of tuberculosis in children. It is, if anything, too low, because in none of these statistics was any special examination made to determine the presence of tuberculosis; and children who were actually ill of the disease would not be so liable from their surrounding conditions to infection from diphtheria. No fault can be found with Naegeli's methods of estimating the tuberculous character of old lesions. They show in man a high disposition for infection, and a relatively slight disposition for the infection to extend and lead to death (Fig. 4805).

This latent tuberculosis, to which the term healed is often erroneously applied, is of great importance. We can regard a lesion as healed only when the cause which produced it is also destroyed and the lesion is no longer a source of danger for the body. The bacilli in these lesions are not destroyed; they can often be detected on microscopical examination, or, still better, by animal inoculation. They remain a fertile source of future, and often fatal, outbreaks of the disease. Even those which macroscopically appear to be healed may show the contrary on microscopic examination. I once examined a small caseous nodule in the apex of the lung of a young man who died from an accident, and who was apparently in a condition of perfect health. The caseous nodule contained bacilli, and around it were a number of miliary nodules in the cicatricial tissue, each with bacilli. Nothing shows the important part which latent tuberculosis plays more strikingly than the statistics of prison tuberculosis. All who have studied the question have been struck with the high mortality from tuberculosis, reaching in some cases up to seventy-five per cent. of all deaths. It is rare that it comes below fifty per cent. At first this was attributed to greater opportunities for infection in prison life. But this cannot be shown to be the case. The prisoners are generally under better hygienic relations, certainly as regards air and cleanliness, than they would be outside. Investigations of prison dust have not shown bacilli at all, or not in numbers sufficient to explain prison mortality by infection. Moreover, the mortality is greater during the first three years of prison life, and this is too short a time for death to have followed a primary infection in the prison. The study of mortality in cellular prisons, where each prisoner is separately confined and has no opportunity for infection from his fellows, shows about the same mortality as when they live in common. The attempt has also been made to explain it, in part, by the assumption that prisoners as a class are apt to be tuberculous. But the examination of those entering has not shown a percentage of tuberculosis much exceeding the average. The mortality can be explained only by the supposition that prisoners in common with other individuals of a like age have the disease in a latent form, and that the conditions of prison life favor the extension of the primary focus. It is a striking instance of the well-known fact of the influence of conditions of both body and mind on disease. Laënnec gives a striking example of the influence of external conditions on the mortality from the disease. In Paris he attended for six years the house of a religious order which had not the recognition of the religious authorities and was only tolerated. The inmates were depressed in spirits, their thoughts were always on the gloomy side of religion, and they were subjected to a rigorous discipline. The effect was the same on almost all. At the end of one or two months' sojourn the menses stopped and phthisis shortly appeared. In six years he saw two or three times almost complete destruction of the sisterhood, the exceptions being a small number composed of the superior, the door attendant, the sisters who had charge of the garden, and the cook. These were all persons who had more distractions than others, and whose work took them into the open air.

Infection.—The tubercle bacilli are the only source. The bacilli are obligate parasites. They probably never find natural external conditions favorable for their multiplication. They are not spore-producing organisms, and though more resistant than most vegetative forms of organisms, they can easily be destroyed by rational methods of disinfection. Exposure to sunlight destroys them. Individuals with the disease are the source of infection, and infection is in most cases at least confined to the immediate neighborhood of such individuals. The situation of the lesions of the disease particularly favors the extension of the infection. The lungs are chiefly attacked, and the sputum is the chief vehicle by which the bacilli are discharged. In advanced phthisis they are contained in the sputum in immense numbers. They may also be discharged from the body in the fæces in cases of intestinal tuberculosis, and by the bladder in genito-urinary tuberculosis. Tuberculosis of the skin rarely takes a form in which the bacilli are discharged to any extent. In the question of infection only the sputum need be considered. Individuals with the disease, except in the last stages, are not usually confined to rooms, but they mix with their fellows and carry the danger of infection with them. Infection can take place from the respiratory passage, from the alimentary canal, and from the skin. Infection from the respiratory passages is by far the most common. This is shown by the localization of the disease in the lungs and in the bronchial glands, in by far the majority of cases, and by other evidence.

An attempt has been made by some to deny or to minimize infection by inhalation. The bacilli discharged in the sputum when this becomes dry may enter into the dust. Those discharged in the open by the sputum may be disregarded. They are destroyed by sunlight and other conditions in the open. They are not present, or at least not present in a living condition, in the dust of the street. In close spaces (rooms) they have been found in the dust when the rooms were occupied by tuberculous patients. Sputum containing tubercle bacilli has been dried on pieces of carpet, and guinea-pigs have been caused to inspire the dust which came from beating the carpet, with positive results. Strauss has found bacilli in the nose of healthy individuals, by mopping out the nose with pledgets of cotton, washing this out in bouillon and injecting guinea-pigs. Moeller found tubercle bacilli in his own nose after two hours in the consultation room. Flügge thinks that it is not the bacilli in the dried sputum, and which may enter into the formation of dust, which convey the disease, but small particles of fluid containing the bacilli which are projected into the air in the act of coughing and even speaking, and which may remain for some time suspended in the air. Moeller suspended cover-slips in the vicinity of tuberculous patients, and found bacilli on them carried there by spray particles. He thinks the sputa containing the bacilli are with difficulty broken up into dust when dried. The infectiousness of the bacilli contained in the spray he showed by placing guinea-pigs in the rooms with tuberculous patients and having them cough into the cages. Several of the guinea-pigs became infected in this way. Flies may also convey the bacilli from the sputum either by carrying particles containing bacilli to food, or by their excreta. There would seem to be no question that the infection can be extended by inhaling either dust or spray particles, but there is little chance for this mode of infection to occur in the open except in the immediate vicinity of a case of pulmonary tuberculosis. Pigmentation of the lungs by carbon shows that solid particles can be carried into every part of the lungs. The expired breath in calm respiration is free from bacilli. It has also been shown that the bacilli retain a close connection with the sputum which comes from the lungs. The saliva has been found in most cases to be free even when the lung expectoration contains numbers of bacilli. Kitasato has also shown that a large proportion of those contained in the sputum are dead.

There has been considerable opposition to this idea of infection by inhalation. Those opposing have based their belief on the examination of healthy lungs of animals which, it has been asserted, are free from organisms; also on the seeming impossibility of causing solid particles to be carried by air currents along complicated systems of tubes representing the bronchi. The best series of investigations, however, have shown that the lungs of healthy animals may contain organisms. That none was found is by no means proof that the animal had not inhaled them, for they may be taken into the lymphatics and removed from the lung with great rapidity. After injecting the blood into the trachea of an animal it is scarcely possible to kill it quickly enough to prevent the corpuscles from passing from the lung into the bronchial glands. Neninger found that B. prodigiosus was carried into the lungs by the inhalation of spray containing the organisms; also, when the organisms were placed in the mouth and the animal caused to make forcible inspirations, they were found in the lungs.

Infection by dust and sputum particles need not take place solely by inhalation. Articles placed in the mouth or food may become contaminated and infection take place by the alimentary canal. Primary tuberculosis of the tonsils, which is not infrequent, and tuberculosis of the cervical lymph nodes are to be referred to infection from the mouth or pharynx. It is not necessary to assume that every case of primary tuberculosis of the intestine and the mesenteric nodes is due to the tubercle bacilli contained in milk. Bacilli may be taken into the digestive tract in many other ways than in milk. Infection by the intestinal canal, even secondary, is not very common in view of the possibilities. We often find no intestinal lesions in cases of advanced phthisis, notwithstanding the enormous numbers of bacilli which are swallowed with the sputum.

There have been a number of cases reported of infection by the skin. Most of these have been in connection with circumcision, the practice being to suck the wound to stop the bleeding. Other cases have come from tattooing, the saliva of an individual with pulmonary tuberculosis having been used to moisten the pigments. Infection cannot take place by the intact skin even when bacilli are rubbed on the surface.

The most common form of skin infection is that given in the post-mortem wart, the tuberculosis verrucosa. There seems to be a strong local predisposition to this, which is probably due to some anatomical condition of the skin. Some individuals become infected while others under the same circumstances of exposure are exempt.

It is in most cases extremely difficult to say when and how infection takes place. It very often does not occur under conditions which would seem to be the most favorable. In the acute infectious diseases in many cases it is possible to trace definitely the infection. Tuberculosis is a disease of slow development. The infection, when it takes place, may lead only to a latent tuberculosis, which may become the active cause of the disease many years afterward. In the study of tuberculosis in families there are cases which show that one member of a family after another may be attacked, the disease becoming a house epidemic.

The study of marital tuberculosis has shown that infection may not take place under conditions seemingly the most favorable. Leudet has investigated the frequency of infection in 74 marriages where one individual was tuberculous. In 61 cases there was no infection. Of the 13 cases in which the survivor became tuberculous, in 6 of these the ancestors were tuberculous. In 112 cases of widows or widowers, the former partner having been tuberculous, only 7 had the disease. These cases, collected by Leudet, were from the better classes, in which the chances of infection were less. Delacour investigated 54 marriages, in which one individual was tuberculous. In only 4 cases did the survivor die of tuberculosis. The general result of all these inquiries is to show that in marital tuberculosis the female is more apt to be affected than the male. It is probable that the chances of infection in marriage have been somewhat over-estimated. The parties are separated for a greater part of the time, and the chances of infection would not be probably so great as in the case of a mother or of two sisters living in the same house. There are quite a number of cases in which an individual with chronic tuberculosis had communicated the disease to successive wives.

The influence of heredity in the extension of tuberculosis must be considered under two heads. On the one hand, there is a widespread belief that the disease itself is not inherited, but that the offspring of tuberculous individuals have tissues of a peculiar character, in that they offer a better soil for the development of the tubercle bacilli and the extension of the lesions. Some even go so far as to refer such a supposed inheritance to remote ancestors, and see this disposition to the disease affect entire families. This is a widespread belief, and one which it is difficult to prove or disprove, either statistically or experimentally. Experiments on animals give no basis for the belief. The young of tuberculous animals, if they have not undergone an intra-uterine infection, and if they be removed from sources of contagion, are no more susceptible than the young of healthy animals. It cannot be denied that children of parents with tuberculosis, as the children of parents weakened by any disease, are as a class weaker and have less general resistance than children of healthy parents, and when the infection is once established the disease may spread more rapidly in such cases. The disease is so common that if we consider the remote as well as the immediate ancestors as a source of such a predisposition, it is possible to find an inherited source in almost every case of tuberculosis. It is impossible to consider this supposed predisposition to the disease apart from the greater chances for the infection to which children, in families in which some one member is affected, are subjected. Even with the best of care as regards sputum, the surroundings of such individuals must become infected by the sputum spray. The infection of the child may not manifest itself for years; only a latent tuberculosis may develop and the disease afterward appears, giving a supposed example of inherited predisposition.

The other view is that there is an actual inheritance of the disease. True germinal inheritance due to infection of either male or female germinal cell need not be considered, and the inherited tuberculosis is really a congenital disease due to intra-uterine infection of the embryo or fœtus. This undoubtedly may take place, but all the evidence with regard to it tends to show its rarity. It has been demonstrated experimentally, the most important work being that of Gaertner. He inoculated white mice in the peritoneal cavity with tubercle bacilli and then had them fecundated. Mice are less susceptible to the disease than guinea-pigs, a slow form of tuberculosis being developed without any interference with function. The period of gestation is only three weeks, and two or three litters can be obtained before the mother dies of the disease, the later broods being obtained in an advanced stage of the disease in the parent. The skin and alimentary canal were removed from the fœtuses, the entire body was rubbed up in water and injected into the peritoneal cavity of guinea-pigs. Two or three fœtuses were used to inject a single animal. One hundred and sixteen fœtuses so obtained were injected into thirty-six guinea-pigs and two of these developed tuberculosis. This is not a large number when it is considered how favorable the conditions were for infection. He also inoculated canary birds, by way of the peritoneum. These laid nine eggs, which were used for the peritoneal inoculation of nine guinea-pigs, the result being that tuberculosis developed in two of the animals. Gaertner does not think that such experiments represent conditions analogous to those in man. Relatively enormous numbers of bacilli were placed in the peritoneal cavity, and infection of the eggs and young took place through the oviduct. He injected the bacilli into the blood of ten pregnant rabbits. These lived a variable time, and fifty-one young were obtained from them. He took from each fœtus the entire liver, the bronchial lymph nodes, the spleen, and other tissues and injected the whole into the peritoneum of guinea-pigs. Five out of the fifty-one became tuberculous. He also inoculated mice in the trachea with a single drop of culture. The inoculation produced tuberculous foci in the lungs, a large spleen, and a liver containing numbers of bacilli. Gaertner obtained from these mice seventy-four young, which were used for the inoculation of thirty-nine guinea-pigs, with positive results in seven.

A number of cases have been published in which congenital tuberculosis in both animals and man has been demonstrated. The first case was that of Johne, who found tuberculous lesions with bacilli in a new born calf. The bacilli have also been found in the tissues without any lesions. Schmorl and Birch-Hirschfeld investigated the placenta and fœtus from a woman who died of acute miliary tuberculosis in the seventh month of pregnancy. No tubercles were found in either placenta or fœtus. Bacilli were found in the placental sinuses, and animals inoculated with the tissues of the fœtus acquired the disease. Ouche and Chamberlain found both tubercles and bacilli in the placenta of a woman who had acute miliary tuberculosis, and who died shortly after the birth of the child. The child lived for twenty-six days and died of general tuberculosis. We may be warranted in assuming congenital infection in a considerable number of children who died of the disease in the first weeks or months of life, but such cases are rare. It is probable that infection of the fœtus can take place either from the blood or by means of the genital canal, and either the father or the mother may be the source of infection. Jani was the first to show the presence of tubercle bacilli in the testicles and seminal vesicles, and even in cases in which these organs were not the seat of the disease. His work has been confirmed by other investigators. Very few bacilli have been found. Experimentally it has not been possible to transmit the disease by coitus either to the mother or to the fœtus. Friedman successfully infected embryos by injecting the bacilli into the vagina immediately after coitus.

Baumgarten has been the most persistent advocate of the theory of congenital tuberculosis. He was led to advance the theory as an explanation of the rarity of spontaneous infection of laboratory animals when they are exposed to it, and from the difficulty of explaining the situation of many primary foci by the assumption of infection from without. Primary foci are undoubtedly found in bones and other situations, to which the bacilli could be carried only by the blood stream. He thinks the bacilli are transmitted to the fœtus or embryo by either parent. The bacilli enter into the blood and may be deposited in various organs or tissues. The fœtal tissues are an unfavorable soil for the growth of the bacilli and the development of the lesions. The bacilli may remain and the lesions slowly develop and remain quiescent for long periods, becoming cases of latent tuberculosis. He considers this to be the most obvious explanation for primary tuberculosis of the bones.

There is absolutely nothing in favor of Baumgarten's theory that congenital tuberculosis plays any considerable part. It undoubtedly occurs, but it leads not to a latent but to a rapidly generalized tuberculosis. There is no evidence to show that the tissues of the embryo or fœtus are an unfavorable soil for the growth of the bacilli. All statistics which have been collected on the presence of latent lesions have shown that these increase progressively up to adult life. There is no necessity for resorting to the congenital theory for the explanation of tuberculosis in bone or other places where the bacilli could be carried only by the blood current. It is comparatively rare that we find this localization of the disease without an older focus at some place in the body from which the bacilli in small number should have been carried into the blood and deposited in the bones or elsewhere. It is not even necessary to have an older focus. Bacilli may be taken into the circulation without any evidence of a local lesion where they enter the body. Most of these bacilli would be stopped in the filter of the lymph-nodes and develop lesions in these. Ribbert and others explain the frequency of pulmonary tuberculosis not as a primary disease of lungs due to inhalation, but as a secondary blood infection coming from primary lymph-node tuberculosis. Most of the bacilli would be stopped in the lymph nodes, but it is possible under certain conditions that a few of them might get through into the blood without the production of lesions, or of lesions which can be recognized macroscopically. One sees not infrequently tuberculous lesions in the lymph nodes which are apparent only on careful microscopic investigation. The relative frequency and gravity of tuberculosis up to five years of age are due to the greater opportunity of the young child for infection and the relative lack of resistance of its tissues to the bacilli.

The character of the lesions produced by the tubercle bacilli and the histogenesis of the cells entering into the lesions have been the subject of numerous investigations, and by leading men in pathology. Not only has the histology of the tubercle process been cleared up, but much light has been thrown on other infectious processes by the study of tubercles. We may divide the changes produced into two classes: in one, tissue proliferation is produced alone or predominates; and in the other, exudations, which differ only in their ultimate end from exudations produced by a variety of influences. The new formation of tissue which results from the proliferation can appear in the form of small isolated nodules, or of larger nodules composed of aggregations of the small, or as a diffuse formation of tissue of the same character as that composing the nodules. The most numerous cells, and often the only cells, are known as epithelioid cells. These are cells which vary somewhat in form and size, and have, as their name suggests, some similarity to epithelium. The protoplasm is clear or finely granular, the nucleus is vesicular, and usually oval or slightly incurved. Among these epithelioid cells there are larger cells with numerous vesicular nuclei. These giant cells vary in size and shape and in the number and arrangement of the nuclei. They may be round or irregular, with numerous protoplasmic processes extending out among the epithelioid cells. The nuclei are generally arranged around the periphery of the cell enclosing a central space free from nuclei, or the cell is elongated and the nuclei are arranged at either end. The giant cells may be found either at the centre of the nodule or at one side. They may be found singly, without any epithelioid cells about them. Outside of the epithelioid cells, and often among them, there are numbers of lymphoid cells. Between the lymphoid cells there is a fibrous-tissue reticulum, which may extend a short distance between the epithelioid cells, but which does not anastomose with the reticulum formed by the protoplasmic processes of the giant cells. The fibrous reticulum is continuous with the surrounding connective tissue. Such a structure as this is found only in the smallest and most recently formed tubercles. The best examples are found in the tubercles developing in fibrous or granulation tissue and in certain organs, as the liver. The diffuse tuberculous tissue is formed on surfaces under conditions in which ordinarily only granulation tissue would be formed. It is found in joints, at the bottom of tuberculous ulcers, on serous surfaces, and in the lungs. In this formation the general appearance is that of granulation tissue composed of various kinds of leucocytes, formed and forming connective tissue, and young blood-vessels. In this tissue the epithelioid cells with scattered giant cells are not sufficiently circumscribed to be regarded as tubercles. Occasionally such a structure is found only on the surface.

The histogenesis has been chiefly studied experimentally, by injecting tubercle bacilli either into the general circulation or into the vessels of single organs. The epithelioid cells have the same genesis as they have in granulation tissue, and the same marked property of phagocytosis. They are derived from the large mononuclear, homogeneous leucocytes of the blood, the macrophages of Metschnikoff, the epithelium of serous membranes and of certain organs as the lungs, from all varieties of lymphatic endothelium and from the endothelium of blood-vessels, and from connective-tissue cells. They differ from the epithelioid cells of granulation tissue in being somewhat larger and paler.

When the bacilli are injected into the circulation tubercles are formed about collections of them in capillaries. They may be primarily taken into polynuclear leucocytes at these places, but these leucocytes do not enter into the formation of the tubercle. The tubercle begins with the presence of the bacilli in the endothelial cells of the vessels, and the first cells are formed by endothelial proliferation followed by the proliferation of adjoining cells. In the tissues the close relation of the endothelium of blood-vessels cannot be so easily followed. Baumgarten from his studies of the histogenesis of the tubercle believes that all sorts of epithelium as well as the cells of mesodermic structures can form the cells of the tubercle. He supports his view by the presence of nuclear figures in the adjoining cells. The nuclear figures are found, however, around the formed, and not the forming tubercle, and represent regenerative proliferation. There are two views as to the histogenesis of the giant cells. Weigert has always defended the view that they are formed by a proliferation of nuclei of epithelioid cells, the cell being so injured by the bacilli that it stops short of complete division. Metschnikoff also believes they are formed by nuclear division in a single cell, but denies that this is a degenerative process. For him the giant cell is an active phagocyte and one of the means of defence in the struggle between the bacilli and the tissues. The other opinion regards them as formed by the union of single epithelioid cells. The formation of the tubercle and tuberculous tissue is due to the action of the tubercle bacilli themselves. Similar changes cannot be produced by the injection of chemical substances derived from the bacilli. Typical tubercles can be produced by the injection of dead tubercle bacilli. Conglomerate tubercles are formed by the diffusion of the tubercle bacilli into the tissue around a single focus. The bacilli may be carried into the tissue by lymph streams or by leucocytes or the epithelioid cells. Between the individual tubercles forming the nodule there are numbers of lymphoid cells. Around the tuberculous tissue there are changes of a non-specific character due to the presence of the tubercles.

More characteristic even than the structure of the tubercle is the degeneration of the cells composing it. The cells lose their shape, the nuclei disappear, and the centre of the tubercle becomes changed into an opaque, homogeneous mass which may contain nuclear detritus derived from the nuclei of the degenerated cells. This change (caseation) is due to the tubercle bacilli, probably to toxic substances formed by them. Prudden and Hodenpyl have shown that the injection of dead tubercle bacilli into the circulation will lead to the production of nodules similar in structure to ordinary tubercles, the only difference being that caseation does not take place in them. It has been held that the caseation of the tubercle is due to its non-vascularit , but the tubercle produced by the dead bacilli is equally devoid of vessels. The tubercle may not only undergo caseation, but other forms of degeneration. The cells may become converted into a perfectly homogeneous refractive hyaline mass, hyaline degeneration, or the connective-tissue formation may involve the entire structure, giving rise to the fibrous tubercle. Caseation is usually preceded by fatty degeneration of the cells. Fresh sections of tubercle show fine fat drops in the cells outside of the caseous centre, and even giant cells often show fat inside the row of nuclei. As the tubercle increases in size the degeneration extends until it may involve the surrounding tissue. The caseation varies in its extent and in the rapidity of its formation. It is usually more extensive in tuberculosis of lymph nodes than in any other tissue. Lymph nodes may become completely caseous, with little or no evidence of formation of tubercles or of tuberculous tissue within them. Tuberculosis of lymph nodes is usually secondary to a tuberculous focus in their territory of lymph supply. If the caseation is due to the active substances formed by the bacilli, it is evident that such substances can be brought to them from the affected territory as easily as can the bacilli. With the beginning of the caseation polynuclear leucocytes appear in numbers in the surrounding tissue and in the tubercle. The necrotic tissue of the tubercle attracts them as does other necrotic tissue. The number of bacilli in the tubercle varies greatly. They can always be found in young forming tubercles and often in considerable numbers; in the older formations, single bacilli only are found or they may not be demonstrable. They lie in the caseous centre or enclosed in the epithelioid or giant cells. They are more frequently found in the giant cells in animal than in human lesions. Occasionally they are found in the granulation tissue outside of the tubercle, lying between the lymphoid cells and without any specific reaction about them. It is not easy to explain why the tubercle once formed should not homogeneously increase in size by the continued formation of tissue in the periphery and continued central caseation. The large tubercles are never formed in this way, but increase by the coalescence of single centres. The larg solitary tubercles in the brain show centres of caseation with a tissue between them which finally becomes caseous without undergoing the specific change into tuberculous tissue. The large tubercles in bovine tuberculosis show a similar conglomerate structure. Even the diffuse formation of tuberculous tissue does not lead to the formation of large masses. A possible explanation might be that the tissue which lies just outside the caseation has acquired an immunity to the action of bacilli, and these might pass through it without exerting any influence, the tuberculous tissue being formed only where this immunizing influence is not felt. A somewhat different action of the bacilli is seen when numbers of them are distributed over a surface the cells of which can take part in the formation of the tubercle, as in the lung. When the bacilli are injected into the trachea the cells lining the alveoli proliferate and the alveoli become filled with large desquamated cells and giant cells.

A more important influence exerted by the bacilli is the production of exudations. The specific tissue changes are in themselves relatively unimportant; except in cases of acute miliary tuberculosis or in cases of tubercle formation in organs essential for life, the specific tissue lesions are rarely sufficient to destroy life. The bacilli can lead to the production of a serous, fibrinous, or purulent exudation. The formation of such exudations is almost inseparable from the action of the bacilli, and may predominate over the tissue formation. I have seen a case of acute miliary tuberculosis in a child, in which vast numbers of bacilli were found in the lesions and in the vessels without changes in the tissue around them, where the miliary foci in all the tissues really represented miliary foci of exudation. The tubercles, particularly in the liver and spleen, appeared as foci of fibrin. These exudations are seen particularly in organs whose structure permits a great multiplication of the bacilli, as in the lungs, where the bacilli can grow in the walls of a cavity, as on the surface of a culture tube. The ease with which exudation can take place in an organ like the lungs or in a serous cavity facilitates this action of the bacilli. They may be considered among the true pyogenic organisms. Experiments have shown that the subcutaneous injection of avian bacilli into an animal usually leads to the formation of an abscess. The distinctly pyogenic action seems to take place when great numbers of bacilli are present, and when they have little power for the production of those chemical substances which lead to caseation. I have seen small definite abscesses in the lung due to purulent exudation and liquefaction of tissue in which the polynuclear leucocytes were filled with tubercle bacilli. Neither the exudation nor the surrounding tissue showed any caseation. This suppuration must be distinguished from the formation of puriform material due to the liquefaction of caseous tissue and the mingling of the broken-down granular fatty mass in a serous fluid. This is seen in the contents of a psoas abscess, and in this the tubercle bacilli may not be demonstrable. In the meninges the bacilli lead to the formation of an exudation which is chiefly fibrinous, which contains various numbers of polynuclear and epithelioid cells, and which is difficult to distinguish from that of other forms of meningitis. The exudation undergoes caseation just as the tuberculous tissue does. It is difficult to avoid the conclusion that such an exudation may be due to the local action of the chemical products of the bacilli.

Tuberculous ulcers may be produced either in the skin or in the mucous membrane. They may be the result of an infection extending from the surface or taking place in the tissue beneath. The process of their formation is a simple one, and due to the formation of tubercles or tuberculous tissue, with subsequent caseation and liquefaction of the caseous tissue. The ulcer increases in size by the continued formation of foci and their subsequent softening. This gives to the base of the ulcer, which is usually undermined at the edges, an irregular, eroded aspect. As the lymphatics afford the easiest route for the diffusion of the bacilli in the tissue, the ulcer usually enlarges in the direction of the lymphatics. The tuberculous ulcers of the intestine tend to enlarge transversely to the axis, and girdle ulcers, extending completely around the intestine, may be produced.

From a single focus the tubercle bacilli may be carried to other parts of the same organ or throughout the body. The distribution can take place by means of the blood, by the lymphatics, or by natural channels which connect a tuberculous focus with other parts of the organ, as the bronchi in the lung, or with other parts of the body, as the intestine. These methods of distribution give rise to special forms of tuberculosis.

Distribution by Blood.—A few bacilli probably enter the blood in all cases. The lesions which are produced in the different organs are due to the character of the circulation, which in some organs peculiarly facilitates the deposit of insoluble substances suspended in the blood, and to the character of the tissue, which may or may not facilitate multiplication and action of the bacilli. A careful microscopic examination of the liver will show the presence of a few miliary tubercles in almost every case of tuberculosis. The circulation in the liver, giving an enormous capillary stream bed with slow movement of blood in the capillaries, facilitates deposit of suspended particles just as a large body of water facilitates sedimentation. Miliary tubercles are never found in voluntary muscles because the tissue offers unfavorable conditions for their development. There is no other way of explaining the presence of lesions in bones than by blood distribution. It is also possible that tubercle bacilli may enter into the blood without the production of a primary focus. How these few bacilli enter into the blood stream is a matter only of conjecture. In most cases they probably come from a tuberculous lymph node, and in these the lesions may be so slight as to elude observation. When the tubercle bacilli enter into the blood in larger numbers they may be deposited in single organs, determined by conditions of the circulation, or they may be generally distributed, producing general miliary tuberculosis. In this, careful examination of the body will almost invariably show the source of the bacilli either in a tuberculous focus in a blood-vessel or in a tuberculosis of the thoracic duct. The exceptions to this are so few that we are warranted in believing that such a source existed but escaped detection. The tuberculosis of the vessel can result either from the infection of the intima or from the extension into the vessel of a tuberculous focus adjoining it. The former is the more common. In both forms the tuberculosis appears as a thrombus formation. A slow thrombus formation takes place at the point of infection, and in the thrombus the tubercle bacilli grow as in a culture medium. The vessel may be completely occluded, but generally the lumen is open and the thrombus may be partially covered by the endothelium. Such thrombi are most frequently found in the pulmonary veins, and may extend a considerable distance, two or more centimetres, along the wall. They may be distinguished from ordinary thrombi by their opaque white appearance. Microscopic examination of the thrombus shows a finely granular or homogeneous mass, denser in places, not unlike ordinary caseation. In tuberculosis of the thoracic duct the infection can also take place from the intima or by the extension of an adjoining focus into the duct. The duct may be converted into a solid caseous cord, or the lesion may be mural. To the theory of general blood infection by such foci various objections have been raised. Sections of the thrombus may contain very few bacilli, and it may appear so firm that apparently the bacilli contained in it have no opportunity to enter the blood. It is true that sections of the thrombi rarely show large numbers of bacilli in immediate contact with the blood stream. The bacilli were always present in the cases examined by me, and in some cases there were great numbers of them. To show the absence of connection between the bacilli in the thrombus and the blood stream, it would be necessary to examine all parts of it by serial sections. Moreover, it is only necessary for the focus to have been a source of infection; it need not be one at the time the autopsy is performed. We often find all the tubercles at about the same stage of development, showing that the mass of bacilli producing the lesions have entered the blood some weeks previous to the autopsy. The source of the bacilli may be a very unusual condition. In one case of extremely acute miliary tuberculosis in an adult the only old lesion apparent on first examination was a small caseous focus in the apex of the lung, which seemed to be entirely healed. A closer examination of the veins of the lungs and of other parts showed no source of the bacilli in them. On the examination of the aorta a few miliary tubercles were found at a point forming a line leading up to a small opening in the aorta which was at first considered to be the mouth of an intercostal artery. On slitting this up it was found to be a minute aneurism of the vessel, which was filled with a caseous mass more or less broken down and containing great numbers of bacilli. The aneurism was the result of an infection of the adventitia of the artery, the caseous degeneration extending from this up through the media, which had given way before it. The intima extended a short distance into the aneurism. Although it may not be possible to find the source of the bacilli in a vessel or in the thoracic duct, I have never seen a case in which such lesions were not associated with miliary tuberculosis. The source is not only shown in this way, but it is also evident from a careful examination of the tubercles themselves, which will very often be found in relation to the vessels. The miliary tubercles are never formed in certain places, and are but rarely found in others. They are never found in the voluntary muscles, nor in the skin. It is very rare also that any are found in the mucous membranes. Even in the mucous membranes of the alimentary canal, which is so liable to infection from the lumen, we but rarely find any eruption of the nodules. Whether there is any multiplication of the bacilli in the blood in these cases is uncertain, although one occasionally finds cases in which from the number of bacilli this conclusion seems almost inevitable. I have seen such a case in a child in which great numbers of bacilli were found in the capillaries of the liver, both free and enclosed in epithelioid cells, either within or attached to the wall of the vessel. In another case almost an injection of the capillaries with bacilli was found in the liver of a cat. Cases of chronic miliary tuberculosis are seen in which the tubercles are larger and more advanced in caseation. It is usually considered in these cases that small numbers of the bacilli are constantly entering into the blood stream. It is possible that an advanced tuberculosis of a lymph node may give the necessary condition without our being able to follow the bacilli through the sinuses and into the blood stream. When the disease has once been established, the number of bacilli in the blood may be added to by their multiplication in the numerous miliary tubercles in the walls of the vessels.

It is a rule without exception that, wherever the seat of the tuberculous lesions may be, the lymph nodes which receive the lymphatics from the affected regions are tuberculous. In the tuberculous tissue the bacilli are in close relation to the cell spaces and the lymphatics of the tissue. They are carried to the lymph nodes by the lymphatics, either free or enclosed in cells. The lymphatic vessels may be affected and converted into white cords filled with caseous material containing bacilli, or tubercles may be formed within them. Such a lymphangitis is often seen in the lymphatics extending from a tuberculous ulcer of the intestine to the mesenteric nodes. The nodes form a barrier to blood infection; they retain the bacilli in their sinuses. This barrier ceases to be when the node itself is infected, and tubercles develop in the tissue of the sinuses, from which bacilli pass into the blood. Miliary tubercles are formed in the nodes, either in the sinuses or in the follicles. The entire node may be almost filled up with typical miliary tubercles or by the formation of diffuse tuberculous tissue. In other cases we find the nodes enlarged, partly or wholly caseous, and without any evidence of specific tissue formation. Such a process seems very similar to the caseous pneumonia in the lungs. Few or no bacilli may be found in the caseous tissue, and it seems most probable that the caseation is due not to the action of the few bacilli *in loco*, but to the action of toxins which are formed by the disease in the lymphatic territory, and which are carried to the node and continuously act upon it. The lymphatics also play an important part in the distribution of the bacilli around the focus of infection. The infection of tissue leading to the formation of a conglomerate tubercle takes place by means of the lymphatics. Careful examination of the lungs in tuberculosis will often show tubercles or caseous tuberculous tissue in both the periarterial and the interlobular lymphatics. The infection of the large serous cavities of the body, particularly of the pleura, which is so often the apparent primary focus of the disease, takes place by means of lymphatics. The interlobular lymphatics of the lung pass to the pleura, entering into the subpleural lymphatics, which communicate with the pleural cavity. Tubercle bacilli can enter these lymphatics either without producing any lesion, in the same way that the dust particles can enter the lymphatics, or the lymphatic and pleural infection can be secondary to an inconspicuous primary lesion in the lung. The tuberculous infection can extend just as carcinoma often does in a direction opposite to that of the usual lymph current. There are innumerable anastomoses, and the direction of current may be changed by occlusion of certain vessels.

No other way of extension has the same importance as that along natural canals. These offer the readiest means not only for an extension of the disease in the organ affected, but also for carrying it to other organs. The bacilli find good opportunities for growth in these canals. In tuberculosis of the kidney we may find tubercles containing great numbers of bacilli which are growing in the peculiar spindle-shaped masses which are found at the edges of pure cultures.

All these modes of extension and the interrelation of all tuberculous processes can be studied to better advantage in the lung than in any other organ. I shall give a short account of tuberculosis of the lungs, as the disease here is most important both clinically and pathologically. In other organs the study of the lesions is much simpler. The lungs may be primarily or secondarily infected. Infection takes place by means of the bronchi or blood-vessels. The lymphatics play only a minor part in the extension of the disease in the lungs. In no other organ of the body does exudation become so prominent a part of the lesions. It is difficult to separate clearly the lesions produced by blood infection from the infection coming from the bronchi. The blood infection leads to the formation of miliary tubercles, starting in the interalveolar septa and in the other interstitial tissue of the lung. The epithelium of the alveoli takes part in the formation of the miliary tubercle, and bacilli are contained not only in the tissue but in the interior of the alveoli as well. With the entrance of the bacilli into the alveoli the conditions making bronchial infection possible are given. Exudation also takes part in the process, and fibrinous, serous, or hemorrhagic exudation may be found in the surrounding alveoli. This condition is more often found, and to a greater extent, in children than in adults, and it may be impossible to distinguish miliary tubercles coming from blood infection from miliary foci of tuberculous pneumonia coming from bronchial infection. The infection by the bronchi is of infinitely greater importance than infection by the blood-vessels. The primary infection of the lungs takes place in most instances by inhalation, the bacilli in the dust or in the spray reaching the tissue by the bronchi. This is shown by the predominating situation in the apices of the lungs. A great many reasons have been given in explanation of this, without any of them being satisfactory. So far as can be determined by the situation of other lesions due to solid substances conveyed by the blood-vessels into the lung, this situation of the primary lesions in the apices does not speak in favor of blood infection. The tubercles in miliary tuberculosis are more numerous in the lower lobes of the lung, and abscesses and infarctions are also more apt to be found in other places than in the apices. There can be no doubt that the primary infection may be hæmatogenous, and the primary lesions are frequently found in other parts of the lung than in the apices. It is rarely possible to see the early stages of a primary tuberculous lung. We frequently find either an old caseous focus with cicatricial tissue around it, or a focus of slaty induration with radiate cicatrices extending into the tissue; or, rarely, in cases of death from intercurrent disease we may find an earlier condition. I once found in the apex of the right lung of a young man a single focus of tuberculous pneumonia 0.5 cm. in diameter, which differed in no respect from the foci which are so common in advanced tuberculosis, and which must be referred to bronchial infection. Microscopic examination in most cases enables us to determine the character of the old lesions, and one certainly gets the impression that they are pneumonic in character.

It is rare that we find lesions that can be regarded as definitely healed. Around the old caseous foci single tubercles will be found outside of the cicatricial tissue showing a slow infection, probably by means of the lymphatics. In the cicatricial tissue we shall generally find fibrous tubercles which still show some remains of specific structure, or their situation may be shown by calcareous or hyaline foci. Probably in most cases the primary infection is followed by a period of quiescence, in which the process is slow or arrested. The bacilli increase in number, and infection of the surrounding tissue through the lymphatics and bronchi takes place, leading to new foci, which become united into a single caseous mass by the advance of the caseation in the primary focus. There is usually no marked advance of the process until the softening of the caseous tissue gives opportunity for an extensive general infection by the bronchi. There is still much uncertainty as to the immediate cause of the softening. It may be the result of the formation, in the caseous tissue, of a ferment which liquefies it in the same way that the liquefaction of the exudation in lobar pneumonia is brought about. Or it may be due to the action of other bacteria. The softening takes place either in the middle of the focus, or in one or several places, or at the edge, a line of softening separating the caseous mass. I have seen such softening take place both in the lymph nodes and in the lung. In one case there was complete sequestration of a caseous mass as large as a lemon, which lay in a cavity filled with thin purulent material. All around the edge of both the sequestrum and the lung there were great numbers of both tubercle bacilli and streptococci. With the expulsion of the softened mass there remains a cavity in the tissue. The cavity is usually surrounded by a zone of granulation and cicatricial tissue, in which numerous tubercles are found. The extent of cicatricial-tissue formation indicates the rapidity or slowness of the local extension. The interior of the wall may be covered by a layer of caseous tissue of varying extent, or it may have the soft velvety character of the wall of a chronic abscess. Tubercle bacilli are often found growing in masses in the wall with the same form of growth as in a pure culture in a test tube.

The further infection of the lung by means of tubercle bacilli or their products, carried into other parts of the lung by way of the bronchi, gives rise to several forms of the disease.

Tuberculous Bronchopneumonia.—This is due to the action of the bacilli. The foci of the disease are very similar in their situation and extent to the foci of bronchopneumonia met with in the infectious diseases of children, and due chiefly to streptococci. As in the case of the latter disease tuberculous bronchopneumonia has a relation to Miller's lobule of the lung. The infection begins at the bronchial termination in the atrium, and from this extends into the air sacs and air cells. Macroscopically, these foci have the appearance of miliary tubercles. Microscopically, the bronchial passage, the atrium, and parts of the air sacs contain leucocytes, often a small amount of fibrin, and large epithelioid cells. Some caseation of the contents is always found, but it need not be extensive. We may find the infection taking place not at the entrance of the bronchus, but at the bottom. At this point, however, the tubercles can scarcely be distinguished from those arising from blood infection.

Tuberculous Bronchitis.—Either in connection with bronchopneumonia or independently of it there may be an infection of the wall of a bronchus, due either to infection from within or to the extension into the bronchus of a tuberculous focus in the adjoining air cells, just as in the case of the tuberculosis of the vessels. The bronchus at this point loses its epithelium wholly or entirely; it becomes filled with an exudation which later becomes caseous. On section it appears as a round area of caseation more or less separated from the wall, or extending somewhat into the wall.

Tuberculous Pneumonia.—This is by far the most important of all the processes, and has always been recognized as such. The tuberculous infiltration of Laënnec was really a tuberculous pneumonia. The tuberculous pneumonia has more or less resemblance to foci of ordinary bronchiogenic pneumona. It may affect at the same time a large area of the lung, or the large areas may be produced by the confluence of smaller areas. The lung varies in macroscopic appearance. In some cases it has a gelatinous, almost transparent, appearance, with scattered small and opaque areas within it; or it may have the granular appearance of lobar pneumonia, but it is usually more opaque; or it may have on section a homogeneous, opaque character. Microscopically a great variety of conditions may be found. In the parts which present a gelatinous appearance we may find the alveoli filled with a homogeneous or slightly granular material in which are large numbers of epithelioid cells. In the process of hardening this material contracts and so leaves an interval between itself and the walls. This seems to be the result of a serous exudation, which has changed the character of the affected tissues, rendering them more dense than is commonly observed when they are infiltrated with ordinary serum. They present somewhat the appearance of an œdematous lung, but the material does not flow from the lung so easily on section, though it can be squeezed out to some extent by pressure. The walls of the alveoli may be but little changed. There is a varying degree of hyperæmia. The vessels may be distended with blood, but most of them may be empty. In most cases the alveolar tissue appears to be thinner than usual, or it may be infiltrated with cells. Shreds of fibrin may be found mixed with this material in the alveoli, or the fibrin may be so great in amount that the exudation can scarcely be distinguished from that of lobar pneumonia. In both the serous and the fibrinous exudations there is a varying number of polynuclear leucocytes. In some cases they may be so numerous that the exudation has a distinctly purulent character. These foci have often a close connection with the foci of bronchopneumonia and bronchitis. The number of tubercle bacilli in them varies. In the most recent foci, in which there is no softening of the caseous tissue, they may be absent entirely. In cases in which there is a close connection with foci of bronchopneumonia the tubercle bacilli may be found in the bronchopneumonic foci, and entirely absent in the diffuse exudation in the surrounding lung.

The etiology of this tubercuious pneumonia is not completely cleared up. It has been attributed to the immediate action of the tubercle bacilli, or to the influence of other bacteria, representing a mixed infection, or to the influence of products of bacilli. I am inclined to consider it due chiefly not to the bacilli, but to chemical products of bacilli. The tubercle bacilli growing in the walls of cavities must produce there a quantity of tuberculin. We do not know how much products from the advancing necrosis of tissue have to do with increasing the action of the tuberculin. In the advance of the process there is a considerable difference as compared with the extension of bronchopneumonias. Foci of bronchopneumonia do not extend by continuity of tissue, but by the continuous involvement of new bronchial territories. They are often sharply limited by the septa of the lung. In tuberculous pneumonia the process is never so sharply limited; the extension may be by continuity without any reference to bronchial territories. Cultures may show the presence of pyogenic organisms, and they possibly assist the process, but there is no reason whatever for assuming that such infections are primarily due to such organisms. Microscopic examination of the tissue fails to show them, or reveals their presence in very small numbers. We know that the tubercle bacilli are capable of producing these exudations. Exudations similar in character may be found in the meninges of the brain and elsewhere, without any suspicion being excited that their peculiar character is dependent upon the action of secondary invaders. The lesions differ from the ordinary pneumonia lesions chiefly in the changes which they undergo. Even if the action of other bacteria be assumed, the caseation which the tissue undergoes shows that the action of the tubercle bacilli predominates over any other action. Similar lesions cannot be produced by the injection of tuberculin into the lungs of a healthy animal; in animals, it is true, the conditions are different. The tuberculin when injected is rapidly absorbed, and produces generally toxic instead of local lesions. The material which acts here is in a state not capable of ready absorption, and must act locally. It represents the soluble products mixed with mucus, possibly with particles of tissue. In all cases it is in a condition which would not admit of rapid absorption by the lymphatics. I have repeatedly found in the accompanying bronchopneumonia great numbers of bacilli in the bronchi and none at all in the surrounding exudation. Caseation takes place first in the centres of these foci and advances. That the caseation is not due to an absence of vascularity is shown by the fact that it can take place in tissue which, so far as can be judged by the presence of blood in the vessels, still has a circulation, but how active it is, it is impossible to say. Softening takes place with more or less rapidity, and results in the formation of cavities of a different character from the primary cavities in the apices. These cavities are extremely irregular and represent large channels of softening. Their walls are often composed of the caseous pneumonia tissue without any demarcation whatever. Around the periphery of these foci there will usually be found some connective-tissue formation. This shows first as an organization of the process. Beautiful examples of organizing pneumonia may be found. There is a growth of connective tissue into the alveolar spaces, taking the place of the exudation. The connective-tissue formation may be widespread so that a section of a focus may show extensive organization taking place from the periphery and advancing toward the centre, which is represented by exceedingly irregular areas of caseation. When softening takes place, then the cavity will not represent a simple hollowing out in the pneumonic lung; but, however irregular the cavity may be, it will be bounded by cicatricial tissue. The distribution of the areas of pneumonia may be chiefly lobar. Single lobes of the lung are often found chiefly affected, and all parts of the lung are never found homogeneously affected. The infection is due probably not to masses of bacilli which come from the affected portions of the lung and flow on into other parts of the lung, but to spray particles of such material formed in coughing, these particles being formed chiefly, if not entirely, in the larger bronchi. The quick inspiration in violent efforts of coughing is particularly favorable for the injection of the material into the lung. There is always, in connection with these changes, emphysema in the surrounding lung—sometimes of a pronounced character.

Recently an attempt had been made to utilize the agglutination method in the diagnosis of tuberculosis, but up to the present time the success of this does not show it to be a method of practical importance. The agglutination only takes place in such low dilutions as to show its great uncertainty. It is possible that greater success may be attended by the use of certain strains of the bacilli which will agglutinate more rapidly than others.

W. T. Councilman.

TUBERCULOSIS, PULMONARY. See *Lungs, Diseases of: Tuberculosis.*

TUBERCULOSIS: SYMPTOMATOLOGY AND TREATMENT.—Symptomatology.—The general symptomatology of tuberculosis is practically that of all wasting diseases.

In the early history of the malady, often before it is possible to determine the point of its localization, there is a great loss of bodily strength; the patient loses in weight, perhaps even to the point of emaciation; the skin loses its natural color, growing pale; there is marked dyspnœa, due to the anæmia that exists, even though the respiratory organs be not involved; the pulse is habitually accelerated and feeble; the patient suffers from indigestion, either with anorexia, or having a good appetite which is gratified at the expense of subsequent suffering; and finally, sometimes not until later in the disease, there is fever, either constantly or during some part of the day. In addition to these general symptoms, the involvement of individual organs or parts, such as the lungs, the meninges, the peritoneum, the bones, or what not, gives rise to symptoms peculiar to the part involved.

These individual symptoms will be described in detail in the articles which are devoted to the consideration of the diseases of such organs or parts, and therefore need not here be specified. It may be profitable, however, briefly to review the different methods of invasion of the several organs, especially with reference to the presence or absence of the general symptoms enumerated above.

Pulmonary tuberculosis is the most common and the most familiar form of tuberculous disease. It occurs under one of three forms:

First—Acute pneumonic tuberculosis, the onset of which is sudden, with a chill, quickly rising temperature, the physical signs of lobar pneumonia, sputum which may resemble that of lobar pneumonia, but is likely also to reveal the presence of the tubercle bacillus. This form may end fatally, even as early as the second or third week, and is generally mistaken for a severe case of simple lobar pneumonia. The importance of a correct diagnosis may be of more value in protecting others from infection than in saving the life of the patient.

Second—Acute tuberculous bronchopneumonia. This form is more frequent in children, often following other infectious diseases, as measles or whooping cough. The onset may also be sudden, with repeated chills, very high temperature, and death within a few days. Or it may run on for weeks, or even months, terminating in chronic phthisis.

Third—Chronic pulmonary tuberculosis. Here the onset is more gradual and insidious, accompanied with the general symptoms of debility, emaciation, rapid pulse, dyspnœa, pallor, indigestion, and moderate fever during a part of the day, before the pulmonary symptoms are severe, and long before night-sweats or a pulmonary hemorrhage alarm even the unwary.

It goes without saying, that the reverse of this picture may also be seen, when an alarming hemorrhage is the first sign of trouble, or a persistent cough long precedes the more general symptoms.

Tuberculous meningitis occurs more frequently among children than among adults. The prodromal symptoms are loss of appetite, loss of weight, great peevishness and irritability, without fever or local symptoms, until gradually or very suddenly and violently the true meningeal manifestations appear.

Tuberculous peritonitis presents a very varied picture, as a rule showing none of the general symptoms of tuberculosis. It may be entirely unsuspected and has repeatedly been found to exist when the abdomen was opened for the relief of other conditions. It may appear suddenly, with fever, severe pain, and the ordinary symptoms of acute peritonitis. Or the onset may be gradual, with abdominal tenderness, tympanites, and a low grade of fever not unlike the beginning of typhoid fever.

Tuberculous Pleurisy.—The ordinary form of this disease is subacute or chronic in character. The onset is insidious, with no grave general symptoms, and even the local symptoms are so little marked that the diagnosis of a pleuritic effusion, which is usually sero-fibrinous, is often not made until it has existed for some time. Another form is that of *acute tuberculous suppurative pleurisy*. Of this, Professor Osler, in his "Principles and Practice of Medicine," says: "The fact is not so generally recognized that there is an acute, ulcerative, and suppurative disease which may run a very rapid course. The pleurisy sets in abruptly, with pain in the side, fever, cough, and sometimes with a chill. There may be nothing to suggest a tuberculous process, and the subject may have a fine physique and come of healthy stock."

Tuberculosis of the pericardium is not so common as that of other serous membranes. It has been found *post mortem* when nothing during life had led to a suspicion of its existence. In other cases it has been accompanied during life with the ordinary symptoms of cardiac insufficiency or cardiac dropsy.

Tuberculosis of the kidneys and of the genito-urinary tract, as a primary lesion, is not very uncommon. The disease of the kidney gives the ordinary symptoms of pyelitis, with the presence of tubercle bacilli in the urine. It may persist for years while yet the patient enjoys fair health and shows no other signs of tuberculosis.

Tuberculosis of the testis may also, apparently, be primary, although undoubtedly depending on the presence of some other tuberculous focus within the body. It is early associated with the general symptoms of tuberculosis and should not escape recognition.

Tuberculosis of the lymph glands (formerly called scrofula) is one of the most common of the tuberculous affections and the one most likely to result in a spontaneous cure. The cervical glands are the ones most frequently affected. The general symptoms of tuberculosis do not appear, or do so only to a very slight degree. Fever is absent unless the extension of the disease is rapid or suppuration takes place. When the mesenteric glands are involved (tabes mesenterica) nutrition is seriously interfered with and rapid emaciation ensues, with the characteristic enlarged and tympanitic abdomen, diarrhœa, etc.

No reference need here be made to tuberculosis of the larynx, pharynx, nasal cavity, intestinal canal, or other parts, the involvement of which is secondary to pulmonary or other forms of the disease.

Bone Tuberculosis.—With regard to the general symptoms of this form of disease we quote from Tillmann's "Text Book of Surgery": "The general health in tuberculosis of bone is very often but little, or not at all, affected. There is frequently a slight fever, varying with the extent of the process. It is a common occurrence to find that the general health is only slightly disturbed, even when extensive multiple tuberculosis is present. In general the fever is most pronounced before the tuberculous inflammation has extended beyond the bone, but it is usually slight and, as a rule, disappears more or less completely when the inflammation has worked its way to the surface of the body." . . . "Quite often it happens that for a long time symptoms peculiar to bone tuberculosis are absent; severe pain, especially, may long be missed, unless a neighboring joint, the periosteum, or overlying parts, are attacked by the tuberculous inflammation. Symptoms generally do not appear for months."

Acute miliary tuberculosis, of the general or typhoid form, is a disease in which the various organs of the body generally are invaded by the tubercle bacillus and filled with miliary tubercles. The patient presents the symptoms of a most profound infection with few local manifestations of a characteristic kind. After a brief period of general indisposition, not unlike the prodromal stage of typhoid fever, the patient enters on the febrile stage, his temperature quickly reaching a height of 102° to 104° F. One of the main characteristics of the fever is its irregularity, with perhaps a morning rise and an evening fall, or two crises during the day, with a fall below normal, but, as a rule, with no chill. Some cases are said to run their course to a fatal termination entirely without fever. Leucocytosis is usually present. Pulse and respiration are quite rapid. Pulmonary symptoms may appear. Jaundice is not infrequent. Coma usually terminates the scene. In very rare instances tubercle bacilli are found in the blood.

TREATMENT.—Even without treatment, in any strict sense of the term, the restoration to health of people who have suffered from tuberculosis is no very unusual occurrence. As a matter of course this is more likely to occur under favorable hygienic conditions, but it does also occur, at times, under very unfavorable conditions. Much as it has been sought, and often as its discovery has been claimed, there is as yet no specific for this malady. Very much, nevertheless, has been accomplished during the past twenty years in limiting the spread of the disease, in prolonging life, and in effecting cures. When Koch announced his discovery of the tubercle bacillus, and shortly afterward introduced his tuberculin treatment, great hopes were entertained that "the white plague" was to be banished from the earth. Great as our disappointment has been, it must still be confessed that Koch's discovery has placed in our hands the power, to a great degree, of limiting the spread of the plague, and of thus, at least, beginning its extermination.

Prophylactic or preventive treatment, therefore, offers to-day the greatest field for activity, and holds out the best promise for favorable results. This implies, in the first place, the furtherance of everything that contributes to good hygiene; the abolishment of crowded tenements for the poor; the admission of fresh air, and above all of sunlight, into living-rooms and working-rooms everywhere; the limitation and regulation of child-labor and of the hours of labor for old and young; food inspection; instruction in cooking; provision for bathing facilities, and a thousand things besides that go to make healthy living possible. Not only must this possibility be placed within their reach, but the ignorant must be instructed as to the importance of these measures for health and for life. All this and much more belongs to the department of public health in states and municipalities, aided by the efforts of benevolent organizations, supported by the voice of the public press, and ceaselessly agitated by the medical profession everywhere.

In order that the tuberculous, and especially the phthisical, patient may become as little as possible a menace to the health of those about him, such cases should in all municipalities be reported to the board of health, not for the purpose of subjecting them to annoying surveillance, but that they and their friends may be instructed in a few simple rules for the safety of those who are well. Furthermore, after the death of a phthisical patient the room which he has occupied should be thoroughly disinfected.

Patients and friends should be instructed as to the vital importance of the destruction of all sputa of a phthisical person. Such persons should never spit anywhere except into a receptacle containing a germicide solution or into cloths or pasteboard cups which are afterward to be burned. The phthisical patient should, if possible, sleep in a well-ventilated room by himself.

Children or young people who have shown any suspicious symptoms, or those who are suspected of a possible predisposition to tuberculosis, should be brought up, as much as possible, in the open air and the sunlight. They should be hardened against exposure by daily cold sponging, be warmly clothed and well fed, sleep with open windows, and avoid all crowded rooms. The first signs of nose or throat troubles should be vigorously treated. Even the trifling ailments of such subjects should be given attention, and during convalescence from serious illness they should be carefully watched.

In cities and towns, and even in many villages, much of the regulation of public hygiene above referred to belongs to the boards of health. Even here such regulations will fail of their legitimate end unless faithfully and actively supported by the medical profession. But in all rural districts the practising physician is the board of health, the sanitary inspector, the police officer, as well as the friendly counsellor of the family. When the entire medical profession in any land wakes up to the importance of the preventive treatment of tuberculosis, and takes the field in an active and relentless campaign against the spread of the disease, the results will be such as the greatest enthusiast has hardly dared to dream of.

In the treatment of tuberculous patients, where anything may be expected in the way of cure, or of the arrest of the symptoms, our main reliance, again, is on *good hygienic surroundings, proper and sufficient feeding, fresh air and out-of-door life*. By hygienic surroundings we mean absolute cleanliness, the avoidance of all dampness in dwellings, and the free admission of sunshine. The feeding problem is a hard one, since we have to do so often with people of small and capricious appetites. The diet should be simple, varied, and nutritious—milk, eggs, meats, cereals, breadstuffs, vegetables, with as much as possible of fats. Many patients who cannot eat very heartily at any one meal may gain in weight and in strength by eating six times a day—that is, by taking nourishment between meals in the shape of milk, broth, raw eggs, etc. As much of the daytime as possible should be spent out of doors, not in wearing one's self out by undue exercise, but much of the time by sitting or lying in the sunshine. Bedroom windows should be wide open at night, or, better yet, the patient, warmly bedded, should sleep out of doors, on a veranda, or on the roof, if need be, and if the roof happens to be flat. *No tuberculous patient ever died of out-door living, by day or by night, while thousands of lives have been saved by nothing else.*

Because of the difficulty of carrying out the methods above indicated in cities, or in regions where the climate is unfavorable to out-of-door living, we come to the question of the *climatic treatment* of tuberculosis, and of *sanatorium treatment*. Both of these subjects will be fully discussed, under their respective headings, by other writers in this HANDBOOK. Suffice it here to say that the best climate for the tuberculous patient is the one that furnishes pure, dry air, without excessive heat or dust, and the greatest number of days of sunshine during the year. If to this be added a more rarefied atmosphere, such as is found at an elevation of from three thousand to six thousand feet above sea level, and the conditions which supply a reasonable degree of comfort and good food, we have the ideal resort, at least for the consumptive. Such a climate and conditions are to be found notably in Colorado, in portions of New Mexico and Arizona, and in Western Texas.

Because of the extreme difficulty and often the impossibility of carrying out hygienic, dietetic, and other regulations while the patient remains at home, it might be expected that great advantage would accrue from the treatment of such patients at well-regulated sanatoria, whether private or public, and experience has proved that this expectation is realized. Even under unfavorable climatic conditions the results of sanatorium treatment have been most favorable, especially for that class of patients who cannot secure the best conditions at home. There is no charity that will so well pay the community for the capital invested as the establishment and maintenance of such institutions.

Medicinal Treatment.—As before stated, there is no specific treatment for tuberculosis. Tuberculin and all its modifications have, on the whole, proved failures. The same is true with regard to all the antitoxic serums and antiseptic injection preparations from which, one after the other, something has been hoped, but nothing realized. Medicated inhalations benefit a bronchitis, but never cure phthisis. Pneumatic cabinets have had their day. And so one might go on through a long list of disappointments.

Cod-liver-oil, that old stand-by, still does good where the stomach will tolerate it, and helps much in maintaining the general nutrition, which is a most vital point. It is undoubtedly of most marked value in bone and gland tuberculosis, especially in the young. It is best digested when administered in connection with malt extract.

Arsenic is the most valuable general tonic that can be given to the tuberculous, whether or not the claim holds true, which has been put forth by some, that it tends directly to make an unfavorable soil for the development of the bacillus.

Creosote and *guaiacol* have had the same claim advanced on their behalf, probably with no very good reason. It is not probable that any drug which is administered ever reaches the tissues in sufficient amount to modify their value as a culture ground for bacteria. But there is no denying the fact that these drugs lessen the amount of expectoration and relieve cough, without disturbing digestion or constipating the bowels, and so are a source of great comfort and benefit to the phthisical patient.

Iodine preparations are of undoubted value in gland tuberculosis. Lugol's solution, administered internally, iodide of potassium, or iodide of iron, are the forms most commonly used.

Surgical interference at certain stages of glandular involvement and in bone tuberculosis is imperative, and will be treated of elsewhere. Of late years operative procedures, in bone and joint tuberculosis, have been largely superseded by injections with or applications of *iodoform emulsion*, with most admirable results. In these cases iodoform seems to hav :a direct anti-tuberculous action. It is not too much to hope that before long similar injections into tuberculous lung cavities or areas may yield better results than they have in the past.

Details with regard to the treatment of individual symptoms of pulmonary or other forms of tuberculosis, however, do not belong to this article and will be given elsewhere. The general principles laid down above are applicable to all forms of the disease. It has been within the experience of the writer to see cases of tuberculosis of glands, of the urinary tract, and of the testis (the latter of which did not seem to have been arrested by operative removal), as well as of pulmonary tuberculosis, apparently cured by a change of climate, change in methods of living, good hygiene, and an outdoor life.

Edward W. Schauffler.

TUMENOL.—This compound, which is very similar to thiol, has also been proposed as a substitute for ichthyol. The mineral oils obtained by the fractional distillation of coal-tar are supposed to contain a class of unsaturated hydrocarbons, which are readily acted upon by sulphuric acid. These hydrocarbons, treated with concentrated sulphuric acid, constitute the active ingredients of tumenol. The hydrocarbons undergo sulphonation and are separated as a dark, thick liquid, containing sulphone and sulphonic acid, known as *commercial tumenol*. It is a dark brown, almost black fluid of a syrupy consistency, acid in reaction. *Tumenol-sulphone* and *tumenol-sulphonic acid* may be separated from the commercial tumenol by the addition of soda lye, which combines with the acid to form a soda salt. The tumenol-sulphone is a dark yellow, thick liquid. Tumenol-sulphonic acid is a dark powder having a peculiar, faintly bitter, taste. The therapeutic uses are the same as those of ichthyol and thiol. The commercial tumenol is that which is generally used. From this two forms of solution are prepared for use, one containing ten per cent. of tumenol in equal parts of ether and rectified spirit and water, and the other containing glycerin in the place of the water. It may also be used as an ointment. The tumenol sulphonic acid is employed as a powder, or in solutions, of the strength of one or two per cent. *Beaumont Small.*

TUMORS.—(Synonyms: Common synonymous terms are new growths, neoplasms, malignant disease, blastomata.)

DEFINITION.—It is difficult to give a clear, exact definition which will apply to the term *tumor* under all conditions, because the word, which etymologically simply means increase in size, has a clinical and a general as well as a strict anatomical use. For example, clinically, increase in the size of a part has been and is now designated as tumor, as when we say that the four classical symptoms of inflammation are rubor, calor, tumor, dolor.

The word is employed in a vague general way when we apply the term acute or chronic splenic tumor to a spleen which is enlarged in consequence of an acute or chronic inflammatory process.

In the narrow sense of the word a tumor may be defined as a more or less circumscribed new formation of tissue, for which no cause can be assigned, and which, either in its growth, or in its relations, or in the character of its elements, departs more or less from the type of the normal tissues of the body. It possesses independent or autonomous growth without physiological limitations and serves no physiological purpose.

Tumors approach on the one hand the processes of regeneration and repair, and, on the other, certain inflammatory processes (sometimes called infectious tumors), which are due to definite causes. They also stand in close relationship with certain embryonic displacements of tissue, malformations, and inclusions from which it is not always easy to distinguish them.

The principal difference between infectious tumors and true tumors is this: In a metastasis of an infectious tumor the parasite which has caused the new growth is carried elsewhere and incites the tissue where it lodges to the formation of new tissue, which resembles that in the primary growth: in the metastasis of a true tumor a cell or group of cells of the original tumor is carried elsewhere and by its own growth produces a secondary nodule which resembles the primary growth.

Tumors vary much in *size*, from microscopic nodules to masses weighing more than the body itself. They also vary greatly in *shape* because they are influenced by many conditions. A tumor growing in the interior of a solid organ, and growing equally on all sides, is round, but if it projects into a cavity, it usually adapts itself to the shape of that cavity if the latter is small enough to exert pressure. Tumors situated near the surface of an organ usually find less opposition to growth above the surface, and hence may project more or less above it, or even be connected with it only by a slender pedicle bearing blood-vessels. Tumors developing in the wall of the uterus remain there, or project into the peritoneal cavity or into the cavity of the uterus, according to their situation in the centre or near either surface of the wall.

The majority of the tumors are grayish to white in *color*, but many other colors, such as yellow, pink, red, brown, black, and green, are sometimes seen, and a few of them are fairly characteristic, as the green of the chloroma and the brown and black of the melanoma.

The *consistence* of tumors varies from the hardness of bone and the density of fibrous and myomatous tissue to the flabby toughness of the œdematous fibroma and the soft juiciness of a rapidly growing sarcoma.

Structure.—All simple tumors consist of two parts,—of the tumor cells, which may or may not secrete an intercellular substance, and of a stroma furnished by the tissue in which the tumor grows, in consequence of a physiological demand for nutrition and support made by the tumor cells. The stroma consists of blood-vessels which usually are accompanied by a varying number of connective-tissue cells and their intercellular substances. The blood-vessels are often of the simplest type, and in some tumors may consist of endothelium only.

A few examples will make this difference between tumor and stroma clear. In an adenoma or carcinoma the epithelial cells are the tumor cells; they alone are necessary to form metastases. All the cells of the connective-tissue stroma and of the blood-vessels present both in the original growth and in the metastases are intimately associated with the tumor cells, but they are furnished by the tissue in which the epithelial cells are proliferating. They do not invade surrounding tissues or give rise to metastases.

In a glioma the neuroglia cells, with their characteristically staining fibrillæ, can readily be separated from the stroma, *i.e.*, from the blood-vessels and accompanying connective tissue. But in many connective-tissue tumors, such as a fibrosarcoma, for example, it would be difficult to say whether certain cells along a blood-vessel were true tumor cells or only connective-tissue cells of the stroma. In a myoma it is impossible to say at present whether the reticulum that surrounds all of the muscle cells is the product of the connective-tissue cells of the stroma or of the smooth muscle, *i.e.*, tumor, cells themselves. The latter conception seems the more probable one.

In some tumors, such as carcinomata, the cells of the stroma often show such marked proliferative tendencies that their increase must be regarded—partly at least—as a reactive inflammatory rather than a simple physiological growth.

Growth.—Tumors start from a single cell or group of cells and grow by proliferation of those cells. They do not infect other cells and cause them to turn into tumor cells. In their growth they follow the same laws of cell proliferation that hold in normally growing or regenerating tissues. Hence in all rapidly growing tumors mitotic figures are very common, and the number of them present in a given tumor furnishes the best means of judging its rapidity of growth. Irregular and multiple mitotic figures are common, but are not characteristic of tumors, as it has been shown that they occur also in active regenerative processes.

A tumor has two modes of growth. In the one, which is called *interstitial expansive growth*, the tumor grows simply as a mass, pushing aside the tissues with which it comes in contact. Such tumors are very frequently surrounded by a sort of capsule of connective tissue which separates them from the surrounding tissue and through which pass the vessels of the tumor.

The other method of growth is by *infiltration*. In this case the tumor does not grow as a mass, but, probably because it finds better nutritive conditions or less resistance to growth in certain places, the cells of the tumor press into these places and infiltrate the surrounding tissue. In these cases a naked-eye examination cannot determine the limitation of the tumor; for a tissue which appears normal to the naked eye may be infiltrated with rapidly growing cells of the tumor.

The effect of tumors on the surrounding tissues is often to cause degenerative, inflammatory, and regenerative processes.

Metastases.—A tumor developing in a certain organ or tissue may remain solitary. In other cases a number of tumors of similar structure may develop later in other parts of the body. The tumor in the place of origin is called a primary tumor. The tumors in other parts of the body, which are derived from and develop in consequence of the primary tumor, are termed metastases. These metastases are due to cells or parts of the tumor being carried by the lymphatics or by the blood-vessels into other parts of the body, where they develop, forming tumors similar in character to the primary growth. It is not at all uncommon to find tumors growing into the vessels or lymphatics. They may fill up and grow along them, or the single cells may be carried in the current. Where these metastases take place will depend upon the blood and lymph circulation, and also to some extent on the tissue in which the cells lodge. If the tumor grows into a lymph vessel, then the cells will be carried into the lymph nodes connected with the part from which the tumor arises, and the metastases will develop in them. We have an example of this in carcinoma of the axillary lymph nodes following carcinoma of the breast; or in metastases in the pelvic lymph nodes following carcinoma of the uterus, etc. When the tumor cells enter into the blood, they are carried into the nearest capillary circulation, where they remain and develop metastases. Thus we have metastases in the lungs when the cells enter the systemic circulation; metastases in the liver when the cells enter the portal circulation. In case the tumor growth takes place in a large space, such as the pleural or peritoneal cavity, the cells of the tumor may get free and be carried to various places over the surface, giving rise by *implantation* to secondary tumors. This is seen often in tumors of the ovary, which may rupture into the peritoneal cavity and produce numerous small tumors over its surface. These secondary nodules, due to implantation, are also common secondary to carcinoma of the stomach. The cells are distributed by the movements of the intestine.

Recurrence of a tumor in the original site is due to incomplete removal of the primary tumor. This is sometimes due to the fact that the tumor is so situated that it is difficult to get at. A good example is offered by fibromata of the nasopharynx. If a tumor shells out easily, the surgeon is likely to think that he has the whole of it, when, as a matter of fact, the surrounding tissue may be invaded in various places.

The danger of recurrence, in the case of carcinoma, is so well known and feared that a generous margin of apparently normal tissues is always removed with the tumor.

Multiplicity.—Most tumors develop in but one situation in the body at once, but following this primary tumor there often are secondary new growths, due to metastases. Certain tumors, however, frequently are multiple and each nodule is independent of the other in its origin; for example, multiple myomata of the uterus and multiple fibromata of the skin. Less commonly lipomata and angiomata may be multiple. Tumors of the kidneys and ovaries are not infrequently bilateral in origin. Some tumors, such as the malignant lymphomata, spread so quickly that they seem to have a multiple origin, but probably do not.

Multiple tumors of different structure occurring at the same time in one individual are rare and must be regarded as accidental coincidences.

The *nutrition* of tumors takes place by means of blood-vessels which are developed from the blood-vessels of the part in which the tumor arises. The development of blood-vessels and the enlargement of the old blood-vessels from which the new ones arise take place according to the laws of nutrition. Wherever there are numbers of multiplying cells demanding greater nutrition new blood-vessels will develop to supply this demand.

In general the vessels of tumors have the same character as the normal vessels, but in certain of the sarcomata the blood-vessels are more irregular in character and may be represented by mere fissures lined with endothelial cells.

The vascular supply of a tumor is dependent largely on the rapidity of growth. A tumor which is growing rapidly has a much larger vascular supply than a tumor which is growing slowly.

A tumor is able to make greater demands for its nutrition than the normal tissues of the body. It is not at all uncommon to find rapidly growing tumors developing in people of advanced age in whom the general nutrition of the body is poor, and in whom the processes of regeneration and repair are at a low ebb. Tumors composed of fat tissue may develop and may grow in individuals in whom, owing to disease, the subcutaneous and other fat of the body has almost entirely disappeared. Conditions of malnutrition, which may influence the nutrition of all other tissues of the body, have no effect in retarding the growth of the tumor.

Phagocytosis.—The cells of some of the rapidly growing tumors are often phagocytic for other cells, particularly leucocytes. The partially digested remains of these cells lying within vacuoles in the protoplasm form inclusions of various shape and size which have often been mistaken for protozoa, especially in carcinomata.

In the malignant lymphoma many of the tumor cells are taken up and destroyed by the large endothelial cells lining the reticulum.

Various forms of *degeneration* are common in tumors. In consequence of the often extreme rapidity of growth of the cells the blood-vessels may become compressed, leading to fatty degeneration or necrosis. The veins passing out from a tumor may become constricted so that intense congestion and hemorrhage may occur in certain parts, or hemorrhage may follow the rupture of imperfectly developed vessels. The necrotic tissue in tumors has the same attraction for leucocytes as in normal tissues. Ulceration is not at all uncommon in tumors on the surface of the body, especially where they project more or less, and it almost invariably occurs in tumors involving mucous membranes. Invasion of tumors by suppurative and other bacteria is fairly common.

Certain tumors tend to produce in the body a state of marked malnutrition, which is termed cachexia. The cachexia may be accompanied by such definite forms of metamorphosis as the amyloid. This malnutrition is due to a number of causes. In the first place, it may be brought about by the presence of tumors in certain places where they will interfere actively with the general nutrition; for example, tumors may lead to stricture or to closure of the alimentary canal. Secondly, tumors by the products of their own degeneration, or by toxic products due to invasion by bacteria, may produce retrograde changes. Thirdly, pain, loss of sleep, and the anxiety produced by a malignant tumor will interfere with nutrition.

The *diagnosis* of a tumor cannot be made from isolated cells alone: there are no cells which are characteristic, for example, of carcinoma or of sarcoma. The diagnosis of a tumor depends on the arrangement of the cells of which it is composed with relation to each other.

The *classification* of tumors is a subject of much difficulty. This is due chiefly to three causes: to our lack of knowledge regarding their etiology, to the great diversity in their structure, and to the present incomplete histological study of them. There is unquestionably a large field for future discoveries in the microscopic study of tumors.

It is often convenient to divide tumors into those which are *malignant* and those which are *benign*. Clinically, the division may have a certain justification, but it can never be made exact, because any tumor may be malignant in consequence of its situation in the body, although ordinarily in consequence of its slow growth, its encapsulation, and its lack of metastases, it would be classed as benign.

Virchow divided the true tumors into the following three groups:

1. *Histoid tumors*, those into whose structure only one tissue of the body enters (fibroma, osteoma, etc.).
2. *Organoid tumors*, those into whose structure several tissues enter (adenoma, carcinoma, etc.).
3. *Teratoid tumors*, those into whose structure whole systems of the body enter.

These divisions were further systematically subdivided and the tumors classified according to the normal tissues which they resembled.

From another point of view tumors are sometimes divided into the two following classes:

1. *Homologous tumors*, those which resemble the tissue from which they arise.
2. *Heterologous tumors*, those which are unlike the tissue from which they arise.

Both histoid and organoid tumors may be homologous (a chondroma from the cartilage of a joint or an adenoma from the mammary gland) or heterologous (a round-cell sarcoma from the peritoneum or a carcinoma from the stomach). It is important to bear in mind that homologous and heterologous are not synonymous with benign and malignant.

Virchow's classification of tumors into three groups is practically followed by many pathologists at the present day, although the headings of the groups are usually changed into the following:

1. *Connective tissue tumors.*
2. *Epithelial tumors.*
3. *Mixed tumors.*

The objections to this classification are that the word epithelial is used partly to refer to the character of the cells, partly to refer to a tissue derived from the ectoderm, as when a glioma is said to be of epithelial origin.

As a matter of fact, some epithelial tumors may originate from any one of the three embryonic germ layers. In like manner the term connective-tissue tumors, as generally employed, refers to tumors derived from the mesoderm, when it should include only a part of those derived from the mesenchyma. Moreover, many writers include gliomata under the connective-tissue tumors.

A few writers attempt no classification of tumors, while others believe that they should be divided according to the organ or tissue from which they arise.

Unquestionably, the proper classification of tumors must be like that of normal tissues. It must be

1. *Embryological*, based on the origin of the various cells from the three primitive germ layers and the various structures to which they give rise, and

2. *Histological*, based on the differentiation of the cells and their intercellular substances.

For this reason a list is given of the three embryonic germ layers and of the tissues and organs derived from them.

The Three Embryonic Germ Layers.

A. Ectodermal.

1. *Epidermis*, including:
(*a*) Epidermal appendages.
(*b*) Lens of eye.
2. *Epithelium* of:
(*a*) Cornea.
(*b*) Olfactory chamber.
(*c*) Auditory organ.
(*d*) Mouth, including oral glands, enamel organ, hypophysis.
(*e*) Anus.
(*f*) Chorion, fœtal placenta.
(*g*) Amnion.
3. *Central Nervous System:*
(*a*) Brain, optic nerve, retina.
(*b*) Spinal cord.
(*c*) Ganglia.
(*d*) Peripheral nerves.
(*e*) Ependymal cells of ventricles and neural canal.
(*f*) Neuroglia cells.
4. *Sympathetic Nervous System*, including part of the adrenal glands.

B. Mesodermal.

1. *Mesothelium.*
(*a*) Epithelium of peritoneum, pericardium, pleura, urogenital organs (Wolffian body, kidney, ovary, oviduct, uterus, vagina, epididymis, testicle).
(*b*) Striated skeletal and cardiac muscle cells.
2. *Mesenchyma.* (The primitive type of mesenchymal cell is preserved with slight modifications in the lymph nodes, and in the mucous membranes of the intestine and uterus)
(*a*) Connective-tissue cells (with fibrillar, reticular, and elastic intercellular substances).
(*b*) Supporting tissues (cartilage and bone).
(*c*) Smooth muscle cells.
(*d*) Fat cells.
(*e*) The so-called endothelium of the blood-vessels and lymphatics, and of the arachnoid, synovial, bursal, and corneal spaces.
(*f*) Pigment cells
(*g*) The epithelium of the adrenal.
(*h*) Nerve sheaths.
3. *Mesamaboids.*
(*a*) Red blood corpuscles.
(*b*) Leucocytes.
(*c*) Myelocytes

C. Entodermal.

1. *Notochord.*
2. *Epithelium* of:
(*a*) Digestive tract, viz.: œsophagus, stomach, liver, pancreas, small intestine, yolk sac, large intestine, cæcum, vermix, rectum, bladder (from allantois).
(*b*) Pharynx, Eustachian tube, tonsils, thymus, parathyroids, thyroid.
(*c*) Respiratory tract (larynx, trachea, lungs).

From the embryological point of view the principal types of tumors can be classified as follows:

A. Tumors Derived from the Ectodermal Germ Layer.

1. Adenoma, including cysts and other tumors from epithelium of tooth papillæ.
2. Carcinoma.
3. Syncytioma from fœtal placenta.
4. Neuroma.
5. Glioma.
6. Epidermoids (cholesteatoma) and simple dermoids due to inclusions of epidermal cells.

B. Tumors Derived from the Mesodermal Germ Layer.

(*a*) *From the Mesothelium.*
1. Adenoma, adenocystoma.
2. Carcinoma.
3. Rhabdomyoma.
4. Teratoid tumors (ovary, testicle).
5. Congenital tumors of urogenital tract.
6. Tumors of testicle with embryonic type of cells.
(*b*) *From the Mesenchyma.*
1. Fibroma, fibrosarcoma, spindle-cell sarcoma.
2. Myxoma, myxosarcoma.
3. Chondroma, chondrosarcoma.
4. Osteoma, osteosarcoma.
5. Leiomyoma, malignant leiomyoma.
6. Lipoma.
7. Melanoma.
8. Hypernephroma.
9. Angioma, angioendothelioma.
(*c*) *From the Mesamaboids.*
1. Lymphosarcoma.
2. Chloroma.
3. Myeloma.
4. Leukæmia (lymphatic, myelogenous).

C. Tumors Derived from the Entodermal Germ Layer.

1. Chordoma (from notochord).
2. Adenoma.
3. Carcinoma.
4. Thyroid and parathyroid tumors.

From an examination of the above classification it is evident that certain tumors, such as adenomata and carcinomata, can arise from all three of the germ layers, while many other tumors, such as gliomata and myomata, can arise only from differentiated parts of single germ layers. It is possible that the epithelial growths derived from the different germ layers may eventually show some differences in structure or in chemical properties, but at present no marked differences are recognizable. Therefore, for the sake of convenience, it is customary to consider all epithelial tumors of a similar structure—as, for example, carcinomata—under a single heading, and to distinguish only those of which the cells or cell products are so characteristic that they can be readily recognized, as, for example, adenomata of the thyroid or carcinomata of the adrenal.

In taking up tumors in detail it is customary, as in dealing with normal tissues, to group together, largely for practical purposes, those that in the character and arrangement of the cells, and in the production or nonproduction of intercellular substances, are morphologically most closely related. Just as carcinomata are considered together without reference to the germ layer from which they arise, so other tumors are grouped together—as, for example, the gliomata—with certain new-growths of mesenchymal origin, because of the production of fibrillar intercellular substances.

One fault at present universally made is the grouping together of certain rapidly growing tumors and the separation of them from the slower-growing forms to which they are related. I refer particularly to the sarcomata.

A carcinoma is treated as an entity; it represents a certain type of tumor. The two extremes in its rapidity of growth are distinguished as scirrhous and medullary carcinomata: all intermediate stages occur.

A glioma is a definite tumor of which the extremes in rate of growth are represented by the dense fibrous and the soft cellular forms, while all intermediate forms occur.

The same method should be adopted in the discussion of tumors arising from smooth muscle cells (leiomyoma, malignant leiomyoma), from connective-tissue cells (fibroma, fibrosarcoma, spindle-cell sarcoma), from endothelium (hemangioma, hemangio-endothelioma), etc.

Unquestionably, the reasons for grouping the rapidly growing tumors of different origins together have been at least three: First, the common properties of rapid growth and of malignancy, due partly to infiltration of surrounding tissues and partly to giving rise to metastases; second, the difficulty of determining the origin of certain sarcomata owing to the lack of differentiation of the cells; and third, the fact that several of the tissues are very closely related (connective tissue, cartilage, bone) and are often present together in a single tumor. The two latter difficulties have not yet been entirely overcome, but it is believed that with better histological technique and more careful observation they may be.

It does not matter much in what order tumors are studied, but as a rule those most closely resembling simple normal tissues are taken up first because most easily understood by beginners.

It is not claimed that the following list of tumors is complete, but it includes the most characteristic types and permits of the insertion of others as their distinguishing characteristics become recognized and generally accepted.

I. Non-epithelial Tumors.

A. Tumors of which the Cells Secrete an Intercellular Substance.—(*a*) *Fibroma, Fibro-sarcoma, Spindle-cell Sarcoma.* These names are applied to tumors originating from connective-tissue cells, and represent the three rates in the rapidity of growth under which they are all grouped. These cells produce two kinds of fibrils which are chemically and morphologically different (see *Sarcoma* for staining methods). One variety is intercellular and corresponds to white fibrous tissue. The other variety of fibrils bear the same relation to the cell that neuroglia fibrils bear to neuroglia cells; they touch the surface of the protoplasm and continue indefinitely in two directions. They are numerous in the cellular forms of tumors and very scarce in the fibrous forms.

(*b*) *Myxoma, Myxosarcoma.* Myxomatous tissue consists of connective-tissue cells with branching protoplasmic processes: between the cells are numerous intercellular fibrils more or less separated from each other by a fluid containing an excess of mucin. The term myxoma is applied to a slow-growing tumor composed of myxomatous tissue, and the term myxosarcoma to a rapidly growing one.

(*c*) *Chondroma, Chondrosarcoma.* The first name is applied to the slow-growing, the other to the rapidly growing tumors which produce the homogeneous substance characteristic of cartilage. Connective-tissue fibrils may occur in any of these tumors, but elastic fibrils are found only in the more slowly growing ones.

(*d*) *Osteoma, Osteosarcoma.* Tumors of which the cells produce a homogeneous intercellular substance in which lime salts are deposited are classed according to their rapidity of growth as osteomata or osteosarcomata. An *osteoid sarcoma* is one in which the ground substance of bone is formed without the deposition of lime salts in it taking place. The *giant-cell sarcoma* probably represents, in the majority of cases at least, a further differentiation of the cells of this type of tumor in an attempt to form osteoclasts.

(*e*) *Lipoma.* This is a tumor composed of fat tissue. Two forms occur: in the common form each fat cell is enormously distended by a single drop of fat, the protoplasm is reduced to a thin envelope, the nucleus is flattened and pressed to the periphery of the cell. In the rarer form the fat occurs in numerous large and small droplets scattered fairly uniformly in the protoplasm, and the nucleus remains in the centre of the cell. This type of fat cell occurs to some extent in normal human fat tissue and is quite common in some of the lower animals. The fat cells in lipomata are held together by intercellular connective-tissue fibrils which possibly are produced by the fat cells.

(*f*) *Leiomyoma, Malignant Leiomyoma.* Smooth muscle cells have two sets of fibrils: the coarse or myoglia fibrils are situated at the periphery of the protoplasm, run from cell to cell, and can easily be stained differentially; the fine contractile fibrils are situated between the nucleus and the periphery of the cell. Between the muscle cells and surrounding them closely is a network of intercellular fibrils probably produced by the smooth muscle cells. In the ordinary leiomyoma, all three kinds of fibrils are produced. In the more rapidly growing malignant leiomyomata the intercellular fibrils are formed in great abundance and so far as my experience goes many or practically all of the smooth muscle cells are sufficiently differentiated to produce the coarse myoglia fibrils.

(*g*) *Glioma.* The neuroglia is the connecting and supporting tissue of the central nervous system and is of ectodermal origin. It is composed of cells and of fibrils. The fibrils are in intimate contact for a part of their course with the cell from which they arise and then continue away from the cell in two directions running between the other cells. The fibrils of neuroglia cells have characteristic chemical properties which permit of their being stained by certain differential methods. A glioma is a tumor composed of neuroglia tissue. All gradations occur between dense fibrous forms containing few cells and many fibrils, and soft cellular forms with few fibrils.

Chordoma. This is a tumor derived from remains of the notochord. It consists of large pale cells surrounded by a homogeneous intercellular substance and containing vacuoles in the protoplasm.

B. Tumors of which the Cells are Embedded in a Reticulum.—(*a*) *Malignant Lymphoma.* This term is applied to a series of tumors derived from the lymphocyte series. The cells vary from undifferentiated lymphocytes such as fill the germinative centres of Flemming to the typical differentiated lymphoid cell found in the circulation. The cells vary not only in histological differentiation but also in size. They lie in the meshes of a connective-tissue reticulum which is furnished by the tissue in which the tumor cells grow. Tumors of this series vary much in rate of growth.

(*b*) *Chloroma.* This tumor is closely related to the malignant lymphoma, but is distinguished by the fact that some or all of the nodules of new growth are, for some reason yet unknown, of a greenish color. The tumor arises from cells in the bone marrow.

(*c*) *Myeloma.* This is a tumor which likewise arises from cells of the bone marrow, and which is closely related to the malignant lymphoma. The cells are characterized by having basophilic protoplasm. They resemble plasma cells except that they possess distinct nucleoli.

(*d*) *Leukæmia.* It is not impossible that both forms of leukæmia are true tumors, of which the cells find the conditions in the blood favorable for growth and multiplication.

C. Non-Epithelial Tumors Having an Alveolar Structure.—(*a*) *Melanoma.* Chromatophores or pigment cells are certain differentiated cells of mesenchymal origin which occur normally in the choroid and iris of the eye, and in certain situations in the pia and in the skin. They are also present more or less abundantly in the congenital soft warts or nævi (abnormalities, not true tumors) of the skin. Tumors arising from these pigmented cells are called melanomata or melanotic sarcomata. The cells do not produce an intercellular substance, but like the cells of the carcinomata are arranged in alveoli more or less separated by a connective-tissue stroma containing blood-vessels.

(*b*) *Alveolar Sarcoma.* This group of tumors must be regarded with suspicion. Some included in it may have been slightly pigmented melanomata; others were unquestionably carcinomata. Possibly rapidly growing tumors, arising from striated muscle cells, possess an alveolar arrangement and may have been included under this heading.

D. Tumors Arising from Endothelial Cells.—(*a*) *Hæmangioma, Hæmangio-endothelioma.* The congenital vascular nævi of the skin and the cavernomata of the liver are abnormalities, not true tumors, but they may give rise to autonomous vascular tumors. A hæmangioma is a slow-growing tumor composed of blood-vessels, which exhibits the characteristics of true tumors. The vessels often dilate and become cavernous in type. Rarely the tumors are multiple. The term hæmangio-endothelioma is applied to rapidly growing tumors arising from the endothelium of blood-vessels. As the lumina of the new-formed capillaries often become occluded by intravascular proliferation or by rupture of continuity, rows of anastomosing cells and concentric cell masses are usually formed in parts, at least, of the tumors. There is a gradual growth of connective tissue between the cells separating them from each other.

(*b*) *Lymphangioma, Lymphangio-endothelioma.* These names are applied to the slowly and rapidly growing tumors arising from the endothelium of lymph vessels.

(*c*) *Dural Endothelioma.* Tumors distinguished by this title arise from the endothelium lining the arachnoid space. They vary in rate of growth from slow to rapid. The structure of the tumors varies greatly; it may be cellular like a sarcoma or more or less fibrous like a cellular fibroma. The cells may have an alveolar arrangement with the cells often grouped in whorls, or the cells may be more or less uniformly distributed in the stroma.

E. Tumors Arising from Nerve Cells.—(*a*) *Neuroma.* This term is often applied to a tumor-like mass which follows amputation of a limb, and is due to an attempt at regeneration made by the axis cylinders of a cut nerve. As an axis cylinder is only a process of a cell it cannot give rise to a true tumor. A true neuroma is a tumor composed, in large part at least, of ganglion cells which may produce medullated or non-medullated nerve fibres. Neuromata are rare, and arise chiefly from the sympathetic nervous system.

2. Epithelial Tumors.

In this group of tumors epithelial cells play as a rule the more important part. Like the cells in the tumors already described they cannot exist by themselves, but are always accompanied by a certain amount of connective tissue and blood-vessels on which they depend for support and nutrition. In some of the tumors the stroma is slight in amount; in others it is abundant, rapidly growing, and suggests active inflammatory tissue; in still others the connective tissue accompanying the epithelium is very abundant, and cannot be regarded as stroma but as part of the tumor formation.

A. From surfaces covered with epithelium tumors arise which are divided into two groups, according as they are elevated above the lining epithelium or invade the tissues below it.

(*a*) *Papillary fibroma*, a tumor composed of papillary outgrowths of connective tissue and blood-vessels, covered externally with a single layer of epithelium, or with a pavement epithelium. Sometimes the connective tissue is very slight in amount, sometimes very abundant.

(*b*) *Carcinoma*, a tumor composed of branching and anastomosing columns and masses of epithelial cells which invade the tissue beneath the lining epithelium, from which the tumor arises and which give rise to metastases.

B. From the epithelium lining glands, two general types of tumors arise.

(*a*) *Adenoma*, a tumor composed of new-formed glands which do not invade the surrounding tissue. Closely related to the adenoma are on the one hand the *adenocystoma*, an adenoma in which some of the glands dilate to form cysts, and the *papillary adenocystoma*, an adenocystoma with papillary projections from the wall. This latter tumor sometimes approaches the carcinoma in malignancy, and is even classed by Ribbert as one form of it. On the other hand, the connective tissue surrounding the glands may play an equal or even more important part than the epithelium, and then we get the *adenofibroma*, or, if papillary ingrowths occur, the *intracanalicular papillary adenofibroma*.

(*b*) *Malignant adenoma, adenocarcinoma, carcinoma.* A closely related group of tumors, morphologically somewhat different, biologically alike, which are often included under the term carcinoma. They also correspond biologically with the carcinoma of the first group of epithelial tumors.

The term carcinoma is unfortunately employed in two ways—biologically as a designation for all malignant epithelial tumors, and morphologically to distinguish in malignant epithelial new growths the epithelium growing in solid masses from that which grows in the form of glands or cysts.

There is a certain tendency to give a special name to all epithelial tumors coming from a certain organ, such as malignant hypernephroma for epithelial tumors of adrenal origin, provided the cells or their secretions are very characteristic.

In the above classification those tumors in which epithelium and connective tissue play an essentially equal part are often separately considered under the heading fibro-epithelial tumors. This would include papillary fibromata of the skin and the adenofibromata of the breast.

It is to be noted, however, that adenomata of any organ imitate that organ not only in regard to the glands, but also in regard to the amount and character of connective tissue which is between the glands. In the liver and adrenal there is very little connective tissue and adenomata of these organs exhibit the same condition. But in the mammary gland, where there is always a great amount of dense connective tissue between the glands, the adenomata arising there have much connective tissue associated with them. It would seem as if the two tissues worked together in an attempt to form mammary-gland tissue.

C. Cysts Lined with Pavement Epithelium.—Cysts lined with a single layer of epithelium belong in one of two classes. The first are due to dilatation of pre-existing glands or cavities under the influence of retained secretions. The second are true tumor formations and begin as adenomata, of which some of the glands dilate and fuse to form cysts.

There is another class of cysts which are lined with epidermis. Those due to the dilatation of the ducts of sebaceous glands (wen, atheroma) are certainly not tumors. There is another group, however, which is usually included among the new growths. These are the simple dermoids occurring chiefly along the lines of closure of the embryonic fissures and the cholesteatomata which are found almost exclusively in connection with the central nervous system. They are probably both to be regarded not as true tumors, but as embryonic inclusions and displacements. The dermoid cysts enlarge as sebaceous cysts do under the influence of retained secretions. If the secretions could escape they would not enlarge any more than do the fistulæ originating from branchial clefts.

The cholesteatoma is due to the inclusion within the central nervous system of ectodermal cells, which would normally form epidermis. The apparent tumor is due to the gradual accumulation of dead desquamated epidermal cells.

The simple dermoids and the cholesteatoma belong in the same class with aberrant adrenal rests. They are unquestionably under the physiological control of the body. They can give rise to tumors, but are not themselves true tumors. They have been classed with the tumors largely because under the influence of retained secretions they often attain a considerable size.

3. Mixed Tumors.

There are three principal groups of mixed tumors which require attention. It is possible, however, that the fibro-epithelial tumors should be added to them as the simplest type of mixed tumors.

A. *Mixed Tumors of the Salivary Glands.*—They develop most commonly in or near the parotid. They are nodular tumors of varying size which are usually benign, but may become malignant. They are composed of tissue elements derived in part from the ectoderm, in part from the mesoderm. The latter germ layer may give rise not only to connective tissue, but often to cartilage and more rarely to bone, fat, and lymphoid tissues, and even to striated muscle cells. The epithelium of ectodermal origin may occur in the form of glands or in solid masses as in a carcinoma.

These tumors probably arise from embryonic displacements of cells of the ectoderm and mesoderm during the formation of the branchial arches and of the parotid and submaxillary glands.

B. *Mixed Tumors of the Genito-Urinary Tract.*—They occur most commonly in the kidney, but arise sometimes in the uterus and vagina, and even in the wall of the bladder. They are congenital tumors which are always malignant, and may give rise to metastases. They are composed of rapidly growing connective tissue which resembles sarcomatous tissue, of embryonic striated muscle cells, of tubular structures lined with epithelium, and occasionally of fat tissue and cartilage. These tumors unquestionably arise from the displacement, at an early stage of embryonic development, of undifferentiated cells, which under normal conditions are capable of giving rise to differentiated cells such as occur in the tumors.

C. *Teratoma.*—This group of tumors can be divided into two subdivisions.

(*a*) *Embryoma.* In the ovary and to a less extent in the testicle tumors occur which vary from a simple to a very complex structure. They may contain practically all the different tissues present in the body, *i.e.*, all three embryonic germ layers are represented. It is probable that these tumors arise from undifferentiated cells which under normal conditions are capable of giving rise to embryos, *i.e.*, from ova or more probably from cells which give rise to ova.

(*b*) *Fœtus in Fœtu.* Very complicated tumors, more or less similar in structure to those occurring in the ovary and testicle, sometimes occur in other parts of the body. They are probably due to the inclusion in a fœtus of an ovum or of cells developed from an ovum, which under normal conditions would give rise to another fœtus.

Origin of Tumors.—A certain number of tumors unquestionably arise from cells which during embryonic development are displaced from the site where they belong. Some of these cells are displaced at an early stage of cell differentiation, and hence are capable of producing tumors of a complex nature, containing a variety of tissues, as for example the mixed tumors of the kidney. Other cells are displaced at a later period of development when they are more or less completely differentiated, and in consequence they give rise to tumors consisting essentially of a single kind of cell, as for example the tumors of adrenal origin.

Of these displacements of embryonic cells the commonest and most easily recognized are the aberrant adrenals or hypernephromata. Their size probably corresponds to the amount of gland tissue which they would have produced if they had remained in their proper situation. Small, misplaced spleens are not at all uncommon. Displaced bits of pancreatic tissue are less frequent. The so-called cholesteatomata found in connection with the central nervous system, the remains of branchial clefts and of the lower end of the neural canal, and the gland like structures so common in the wall of the oviduct are all examples of cells or groups of cells displaced during embryonic development. Pigmented and vascular nævi are still other examples which should, however, probably be classed as abnormalities rather than as displacements. Some of these "fœtal rests" become so large in consequence of the accumulation of retained secretions (the cholesteatoma and the simple dermoid) that they are usually classed as tumors.

It is probable that all of these displaced tissues are under the normal physiological control of the body. They can give rise to tumors, but are not themselves new growths.

Certain displacements of embryonic tissue are recognized only by the tumors to which they give rise, as for example those from which come the mixed tumors of the genito-urinary tract and of the salivary glands.

The adenofibromata of the breast may be derived from displacements in post-embryonic life, at the time when the mammary gland is developing. They certainly suggest an attempt at the formation of mammary-gland tissue.

The important point to bear in mind in regard to these tumors which unquestionably arise from embryonic displacements of tissue, such as the malignant hypernephromata, and the mixed tumors of the urogenital tract, is this, that they are as malignant as any tumors which exist, and that they give rise to metastases.

Etiology of Tumors.—In regard to the cause of tumors we know absolutely nothing. Bacteria, protozoa, and blastomycetes have been claimed to be the active agents in the production of some of them, particularly of carcinoma. It must be acknowledged that blastomycetes produce a curious form of tissue proliferation containing great numbers of endothelial cells, which to an unskilled observer might suggest an epithelial growth, but the result is granulation tissue, not a true tumor. It has been claimed that trauma (acute injury and chronic irritation) may so stimulate the cells of a part that a tumor formation is the result, but it is impossible to regard this as a general cause, although in certain cases it is possible that it is the exciting cause.

We thus come back to displaced cells as a possible solution of the question. In many cases, certainly, tumors arise from them, but the reason for it we are unable to understand, because most of these tissue displacements persist throughout life without leading to anything abnormal. Possibly a series of experiments with displaced tissues of various sorts might throw some light on the subject. Certainly at present such experimentation is the most promising field for investigation.

F. B. Mallory.

TUNNELLING, DANGERS OF.—The scope of this article is to deal with such explosives as are generally used in public or private works of improvement, the effects of the explosion upon the workingmen employed, and the way in which accidents with such explosives frequently occur.

I. Explosives Used in Blasting.—There are numerous kinds of explosives: Gunpowder, guncotton, nitroglycerin, dynamites, picrates, fulminates, etc. It is not the purpose of this article to deal with all of the different kinds of explosives, but simply with those which come into common use.

The principal ingredients of the various explosives are potassium nitrate, sodium nitrate, ammonium nitrate, potassium chlorate, nitric acid, sulphuric acid, sulphur, the hydrocarbons, benzene, toluene, naphthalin, carbohydrates, cellulose, alcohols, glycerin, ethers, acetone, camphor, vaseline, paraffin, kieselguhr, randanite, tripoli, coal dust, and the alkaline carbonates.

Gunpowder is of two kinds—nitrate and chlorate. Ordinary black gunpowder belongs to the *nitrate* class, and is composed of potassium nitrate, 75 parts; charcoal, 15 parts; sulphur, 10 parts. There are many special powders of this class which vary, not so much in their composition as in their shape, size of the grain, density, and hardness, such as hexagonal, perforated, prismatic, etc. Other powders vary only as to the nitrate used, whether barium nitrate, strontium nitrate, or sodium nitrate.

The results of the explosion of these powders vary. The greater part of the product is represented by sulphate of potash, carbonic acid, and nitrogen, but there is also to be found potassium carbonate, sulphide, hyposulphate, and sulphocyanate, ammonium carbonate, carbon monoxide, carbon dioxide, hydrogen, hydrogen sulphide, and marsh gas.

There are quite a number of *chlorate* mixtures or powders, most of which—as Harvey's, Davey's, Hill's, etc.,—are used for fuse composition; but, as they are attended with great danger in handling, they are of no great practical value.

The picrates are made with a basis of picric acid, or trinitro-phenol. These powders are used almost exclusively in France.

Borlinetto's powder is composed of potassium picrate and potassium nitrate with charcoal.

Brugère's powder is composed of ammonium picrate with potassium nitrate.

Melinite is composed of a mixture of fused picric acid and trinitrocellulose dissolved in a mixture of ether and alcohol; in other words, guncotton dissolved in ether, to which is added picric acid.

Lyddite, the English explosive, is identical with melinite. If fully exploded, these powders deflagrate into nitrogen, carbonic oxide, or carbonic acid, hydrogen, carbonate of potash, etc.; therefore the gases produced by them are not very injurious in character.

Other explosives of the nitro-substitution class are mono-, di-, and trinitro-benzene. *Bellite* and *Securite* (both composed of ammonium nitrate with meta-dinitrobenzene) are very powerful and yet safe to handle. Finally, there are nitrotoluene, mono-, di-, tri-, and tetranitronaphthalin, *Volney's powders* (mixtures of nitrated naphthalin, saltpetre, and sulphur), *Favier powders*, *Emmensite* (similar to picric acid), *Gelbite*, and *Roburite*.

Roburite is composed of ammonium nitrate with chlorinated dinitrobenzol, and is a yellow-brown powder with an odor of bitter almonds. It cannot be exploded by concussion, pressure, friction, shock, or fire, but only by a powerful detonator, such as 1 gm. of the fulminate of mercury.

Nitroglycerin is the most powerful of all explosives. But on account of the danger in handling it, it is not used as much in blasting operations to-day as formerly, but is the base of other high explosives. It is composed of nitric acid, sulphuric acid, and glycerin. It is an odorless, colorless (or slightly yellow) liquid, with a sweetish taste, insoluble in water, but soluble in ether or wood alcohol (methyl alcohol). Mixed with wood alcohol it loses its explosive property, but by adding water to the mixture it separates and can again be used as an explosive. It evaporates at 212° F., and freezes at about 30° F. Some of its incompatibles are muriate of ammonia, sulphate of iron, and the sulphides generally. It is decomposed by sulphuretted hydrogen and sulphur is precipitated; it is also decomposed by calcium sulphide. I mention these as they can be used as antidotes for poisoning by nitroglycerin.

Nitroglycerin explodes from pressure, or from a blow, or at 306° F. Properly to explode nitroglycerin great heat and pressure are needed. If it is exploded by means of gunpowder the explosion is not general and a part is not exploded. The method now in vogue is to use fulminating caps, and if these are of sufficient size and properly made they effect a complete detonation.

A cause insufficient to explode nitroglycerin in wood or paper will explode it in tin or other metals. Confinement or compression makes nitroglycerin and its compound explode more easily.

The result of the explosion of nitroglycerin gives water, 20 parts; carbonic acid, 58 parts; oxygen, 3.5 parts; nitrogen, 18.5 parts. And according to Nobel, 1 litre of "blasting oil" gives 10,400 litres of gases.

In point of rapidity the explosion of nitroglycerin is practically instantaneous. The characters of the products of explosion of many of the compounds are alike, but in the case of some they vary according to circumstances and condition, such as the method adopted for producing a high temperature, pressure, expansion, etc.

By mixing nitroglycerin with some porous substance it is readily absorbed, and produces an explosive comparatively safe to handle. These mixtures of nitro-compound are what is commonly known as *dynamite*.

The names of the various dynamites are Giant powder No. 1 and No. 2; Dualin, Atlas A and B, Vulcan, Judson, Rendrock, Hercules, American Safety, Carbonite, Stonite, Horsley, Dynamite de Trauzl, and Gelignite.

For the purposes of study there are practically two classes of dynamite, which might be termed inorganic and organic, according to the absorbent used. As a type of one class is that made with infusorial earth, kieselguhr, a soil found in Germany and which is composed of siliceous diatoms; and of the other, that made with ground wood pulp or sawdust. Others still are made from a combination of both kinds. The results of the explosion, however, are practically the same in either case, except that the dynamite made with an organic absorbent yields an additional amount of carbon.

As a type of the first class we have Giant powder No. 1: nitroglycerin, 75 parts; kieselguhr, 24.5 parts; sodium carbonate, 0.5 part. And as a type of the second class, we have the American safety powder: Nitroglycerin, 68.81 parts; sodium nitrate, 18.35 parts; wood pulp, 12.84 parts.

Dynamite is safe or unsafe to handle, according to the amount of oil (nitroglycerin) that is absorbed. The capacity of the absorbent varies with the temperature. Thus, a powder that is comparatively safe at 50° F. may be leaky at 100° F.

When dynamite is frozen it is more difficult to explode, and one cap will rarely make it deflagrate.

Guncotton is made by putting ordinary cotton in nitric and sulphuric acids. The cotton is first steamed with caustic potash, and then immersed in a mixture of sulphuric and nitric acids in the proportion of three to one by weight; and then it is washed until free from every trace of acid, and dried in a cool chamber.

Guncotton is harsher to the touch than ordinary cotton and is insoluble in water. It is soluble in ether, ammonia, and acetone. If a flame is applied to it, it burns with a flash, but without explosion. It is one of the safest of explosives. When properly exploded *in vacuo* the resultant gases are carbonic oxide, carbonic acid, marsh gas, olefiant gas, nitric oxide, nitrogen, hydrogen, aqueous vapor. Guncotton in itself is not used for blasting, but is sometimes mixed with other ingredients.

Tonite is composed of guncotton 52½ parts, barium nitrate 47½ parts.

Potentite is composed of guncotton 66.20, potassium nitrate 33.80.

Explosive gelatin is made by dissolving guncotton in nitroglycerin by the aid of heat, the result being a jelly-like mass. It is of a dark-yellow color. Unconfined it will burn without exploding. If confined and heated to 399° F., it explodes violently. It is more sensitive when frozen than in the unfrozen state, and can be readily detonated by the impact of a bullet. In this it differs from dynamite, which is less apt to do so.

Forcite is a gelatin dynamite largely used in the United States, and is gradually supplanting all other forms of dynamite. As this is the dynamite now most commonly used, I give its full composition:

Nitroglycerin	98 parts	Gelatin	50 parts.
Nitrocotton	2 parts		
Sodium nitrate	76 parts	Dope	50 parts.
Sulphur	3 parts		
Wood tar	20 parts		
Wood pulp	1 part		

The smokeless powders are composed principally of insoluble and soluble nitrocellulose.

Cordite, the explosive adopted by Great Britain, is composed of nitroglycerin, guncotton, and mineral jelly (vaseline). The gases evolved by explosion are carbonic acid, carbonic oxide, nitrogen, and hydrogen. Other powders of this class are Ballistite, Maximite, Schultze powder, Wetteren Indurite, Ritleite, Leonard, etc.

Other explosives belonging to no especial class are *Rack-a-rock*, composed of potassium nitrate and mononitrobenzene.

Hellhoffite, composed of metadinitrobenzene and nitric acid.

Oxonite, composed of picric acid and nitric acid.

Panclastite, composed of nitrogen tetroxide and carbon disulphide.

Romite, composed of ammonium nitrate, nitronaphthalin, paraffin oil, and potassium chlorate. It explodes spontaneously.

Fulminate of mercury is used for exploders, percussion caps, and detonators. It explodes violently when compressed or struck or rubbed between hard surfaces, or when touched with concentrated sulphuric acid or any ignited body. When used in a percussion cap it is, as a rule, mixed with potassium chlorate in the proportion of 75 parts of the fulminate to 25 of potassium chlorate.

There are many fulminates, but the fulminate of mercury is the only one in general use, except for toy caps, which contain fulminate of silver.

When it is exploded the following reaction may occur:
$5\,HgC_2N_2O_2 + 4KNO_3 = 5Hg + 8\,CO_2 + 7N_2 + 2\,K_2CO_3$.

II. Dangers Encountered.—Asphyxia, or partial asphyxia, with a general poisoning and consequent disturbance of the system, is frequently met with in the construction of tunnels in the present day, and is due to the use of these "high explosives"; for in the removal of rock, in construction work of this nature, dynamite or nitroglycerin is used in considerable quantities.

When the blasting is done in open-cut work, as on railroads, the gases, after the explosion, immediately distribute themselves in the atmospheric air, and no effect has been noticed on the workmen employed. But when the explosions take place in tunnels, or in mining or other partially closed cavities, and the gases or residue are slow to escape from the mouths of the tunnel or up an air-shaft, serious deleterious effects are produced.

There are two classes of cases of poisoning produced by breathing the products of the explosion of such materials: First, acute cases, in which a considerable quantity of the residue is inhaled at one time; and secondly, chronic cases, or those in which a small amount is constantly breathed for a long time. The acute cases vary according to the amount inhaled.

Where the amount of dynamite used is not large, or where after the explosion a considerable quantity of fresh air has been mixed with the products of the combustion, or where the workman has, after a few breaths, become giddy and is pulled away by others and sent to the surface, the effects produced are the following: a trembling sensation, flushing of the face, succeeded sometimes by pallor, frequently nausea, sometimes vomiting, with throbbing through the temples, and fulness in the head, as if it would burst, followed by an intense headache characteristic of poisoning by nitrites—similar to that of nitrite of amyl, only not so violent, but more persistent, frequently lasting forty-eight hours. The heart's action is increased, and the pulse is full and bounding, though somewhat compressible, and varying in rate from 100 to 140. The condition is described by the workman as a "dizziness." He feels as if drunk, or as if his head is swelled.

In the second class of acute cases, in which a man goes into the tunnel immediately after the explosion, and is brought in contact with a large percentage of the poisonous materials, the effects are giddiness, immediately followed by unconsciousness, and the patient presents the usual appearance of asphyxia.

Sometimes in these cases the pulse is full and bounding, though very compressible, but in most of the cases it is alarmingly weak. Generally there is a great pallor, though this may be partially due to working underground. The comatose condition soon passes away, and is succeeded by drowsiness, languor, cold perspiration, intermittent pulse, and generally nausea and vomiting. Sometimes the breathing is spasmodic, and frequently there are hiccough, and after a time a severe headache.

Nearly all of these cases, however, no matter how serious they seem at the time, end in recovery. In the few cases in which death does occur, it is usually several hours after the patient has been removed from the tunnel, and is due to paralysis of respiration.

In the chronic cases, in which only a small amount of the gaseous products of the explosions is breathed daily, there are four prominent symptoms. These are headache, cough, indigestion, and disturbances of the nervous system. The headache is usually a continuing one, and varies in degree from a mere sense of fulness to a throbbing pain. The cough is similar in character to the cough of pertussis, or of malaria, and as cases of malaria are frequent among men engaged upon such works, one may easily mistake the cause.

Next in prominence to these symptoms come disturbances of the nervous system, as trembling, irritability, neuralgia. In fact, nearly, if not all, of the symptoms are attributable to this cause. Even the cough is in all probability due to the poisonous effect produced on the pneumogastric nerve.

With this nervousness is also associated indigestion, probably due to the same cause. Of course, with this latter symptom, the character of the food and the manner in which it was eaten must be taken into consideration; but as soon as a man with these chronic symptoms is taken from the tunnel and placed at work on top he steadily improves, and finally entirely recovers.

It is also noticeable that those who have previously suffered from dyspepsia, or from tic douloureux, or sciatica, or other form of neuralgia, are made worse by the dynamite smoke.

What are these symptoms due to?

The formula for nitroglycerin is $C_3H_5N_3O_9$. And the products from the combustion of this are written:
$4\,(C_3H_5N_3O_9) = 10\,(H_2O) + 12\,(CO) + 6\,(N_2O_2) + O_2$.

In other words, the products are water, carbonic oxide, and nitrogen dioxide, none of which would produce the symptoms above described with the exception of asphyxia.

A comparison of the above symptoms in the acute cases, with the phenomena produced by various-sized doses of nitroglycerin, shows them to be identical. This similarity between the symptoms from inhalation of the products of the explosion of dynamite, and those produced by the nitroglycerin itself, is so well marked that even miners themselves have noticed it. Frequently, when dynamite is frozen, a miner will place a cartridge in his boot to thaw it out, and the absorption of nitroglycerin through the skin will produce precisely the same symptoms as in the mild acute cases of the inhalation of the products before described.

Again, as another instance, I may cite the case of a miner who used his knife to cut a cartridge and afterward ate an apple cut with the same knife. In this case, according to his statement, the symptoms were similar to being "knocked out by powder smoke," only more severe; the headache persisting three weeks. On another occasion this same miner cut up some tobacco to smoke with a knife that he had used for dynamite, and he was again similarly affected. Here the heat from the tobacco smoke volatilized the fine particles of nitroglycerin on the tobacco below, and poisoning was produced by absorption through the lung tissue. No other conclusion can well be reached than this: that there are mixed with the gases produced unexploded particles of nitroglycerin in a volatile state; and these particles inhaled by the miners produce the effect described.

This fact can be conclusively proved by waving in the fumes, immediately after an explosion, a cold sheet of glass, and thus collecting upon it by condensation a small percentage of the nitroglycerin itself.

There is no doubt that the explosion of a large quantity of dynamite would produce sufficient gases of CO and N_2O_2 to produce asphyxia. Here we get the cyanosis and other symptoms of simple asphyxia, and we may get nausea and vomiting; but not the same disturbance of the sympathetic system, nor the continued chronic spasm of the vagus, nor the persistent headache pathognomonic of nitroglycerin poisoning.

Treatment.—In the way of prophylactic treatment the use of such apparatus or machinery, whether by blowing or by sucking, that will rapidly clear the tunnel or cavity from noxious gases or fumes, is to be recommended. When steam drills that are worked with an air compressor are used, they contribute largely to this end. It has also been found that the use of a large cap will explode a greater percentage of nitroglycerin than a small one, and this, to a certain extent, obviates the trouble. In certain cases, however, a cartridge—for some reason or other—does not explode, but burns like a candle, with considerable spluttering. In such an instance the amount of nitroglycerin volatilized is much greater than if an explosion had taken place, and consequently the effects are more deleterious.

For immediate treatment, such measures as are generally used in cases of asphyxia are of service. In addition, the use of cold to the head or the subcutaneous administration of atropine, ergotin, or other vaso-motor stimulant, is of necessity indicated and very efficacious. There is little doubt that the effects of nitroglycerin are produced by its decomposition and the formation of a nitrite in the body. "Treatment with ammonia restores normal color and normal functional power to nitrite-poisoned blood." So the carbonate and aromatic spirits of ammonia should be used internally, and it is also well for those in charge of such works to recommend to the workmen employed to carry with them small vials of this remedy for use in such cases.

The effects of nitroglycerin are also antagonized by sulphur. I have therefore given to many of the workmen sulphide of calcium, and these seemed to do better than those to whom it was not administered. This result, however, may have been partly due to the beneficial effects of the sulphide of calcium *per se*.

III. Manner in which Accidents Occur.—The methods by which accidents occur, and their effect upon the workmen employed, can be best understood if I narrate a few actual occurrences. Thus, the fulminate of mercury will explode violently when compressed. As an illustration of such explosion one of the workmen under my care endeavored to bend a cap so that he might more easily attach it to a dynamite cartridge; and, being ignorant of the conditions under which it would explode, he tried to bend it between his teeth. The result was that he lost half of his teeth, his cheek, and a portion of his ear.

Exploders or caps will also explode when struck a slight blow. Sometimes they are not properly attached to the dynamite cartridge or to the wire connected with the electric battery, and therefore the charge is not exploded. Under these circumstances the cartridge must be removed from the hole and a new cartridge and exploder put in its place. The removal of this cartridge with the exploder in it is attended with great danger. It is done with a long rod, sharp on the point, and with a little cup near the end. Thus with the point the cartridge is broken up, and with the cup it is drawn out of the hole. Should, however, the point of the rod happen to strike the fulminative mercury cap, it is almost sure to explode.

Numerous accidents of this kind occur. One particularly more gross in carelessness or ignorance than the others I will relate.

In firing, in the heading of a tunnel, it frequently becomes necessary to break up the large rocks that are brought down with a blast, so that they can be handled by the workmen. To do this, a single hole is drilled in the centre of the rock and a cartridge placed therein. This is fired when the heading is fired; but sometimes the cartridge becomes loosened and does not go off. On one such occasion a Norwegian seeing one of these holes in a rock that had not been broken up, he placed a bar in the hole and told his companion to hit it to see if there was a cartridge inside. He happened to strike the exploder, and both men were instantly killed, while a third lost his eyesight.

Compression in other ways may explode both the cap and the nitroglycerin; thus, on one occasion when a charge failed to explode, the foreman took a hose attached to the air compressor, and turning it into the hole endeavored to blow it out; the result was that it immediately exploded, his companion was instantly killed, and he himself died later from the injuries received.

Dynamite will not easily explode when frozen, but it can be made to explode even then under some circumstances. As an illustration, the powder man at one of the shafts on the Croton Aqueduct left half a cartridge in a pail of warm water in which he had been thawing it one evening. On the following morning, as it had been a cold night, the water in the pail was frozen with the cartridge at the bottom. Wishing to get the cartridge out of the ice in the pail, he placed it over the blacksmith's fire and blew upon it with the bellows. Both he and the blacksmith were thrown from the building, and from the powder man I removed more than eighty pieces of zinc from the pail.

Under proper conditions in the open air a dynamite cartridge will burn like a candle; but if heated rapidly beyond 306° F. it will explode. Thus, in the Park Avenue tunnel a number of papers, the packing from the boxes, and other inflammable articles were around the powder house. By some means these caught fire and a hot flame was instantly developed about the dynamite, the result being that the whole deflagrated.

A similar accident occurred at Spuyten Duyvil, where some powder, intended for use in making a new road, was stored in a small house. Some children playing in the neighborhood set fire to the grass near the powder house, and the result was an explosion.

In some parts of the country, as in certain mines in the West, where it is not desired to use a large amount of dynamite at any one time, instead of firing with electricity it is customary to use a powder fuse. Where the climate is warm the fuse is often kept with the dynamite, and then it sometimes happens that the nitroglycerin will exude from the cartridges and as a result the fuse which is kept with it will become soaked. Such a fuse will explode instantly, and sometimes even when kept separate from the cartridges they will get covered with machine oil and will then burn more rapidly than is intended. In an accident of this character in Arizona the explosion followed so rapidly the lighting of the fuse that one man could not get away at all, and his assistant had just time to turn his back, from which I later extracted many small pieces of stone.

In the case of nitroglycerin perhaps more accidents occur with the empty can than in any other way. Thus the foreman in a tunnel, who had just filled some holes with nitroglycerin and had emptied the can, set it down in such a manner that the tin in the bottom of the can bent with a slight snap. An explosion immediately followed, and it then became evident that sufficient nitroglycerin had remained in the can, adherent to the sides and the bottom, to drive the major part of the metal into his thigh and hip.

Illustrations of such accidents might be recorded indefinitely, but from many such the following rules have been formulated:

Always remember that the function of an explosive is to explode.

That accidents as a rule are due to carelessness and ignorance.

Workmen who handle nitroglycerin and dynamite should be provided with rubber gloves, to prevent absorption.

Powder for transportation should not be enclosed in a tight or metallic case.

Explosives should be stored at a sufficient distance from works not to be affected by concussion or by flying débris.

Tools and fuse or caps should be stored or transported separately.

The floor of the powder house should be covered with sawdust and sulphur to absorb and decompose any nitroglycerin that has leaked from a cartridge.

Smoking should not be allowed.

Explosives and powder house should always be marked "dangerous."

Caps must always be examined before attaching them to a cartridge.

In firing by electricity be sure that the wire is disconnected from the battery before attaching the cap or fuse.

Never attempt to remove a charge that will not explode.

Wooden ram rods should be used for charging holes.

Other rules can be formulated from the above article.

Thomas Darlington.

TURMERIC. See *Curcuma.*

TURNIP, WILD or **INDIAN.**—*Arum, Jack-in-the-Pulpit.* The corm of *Arisæma triphyllum* Torr. (American arum) and of *Arum maculatum* L. (European arum). Both these species are very common vernal plants in their respective countries, growing in swamps, along streams, and in other damp and shady places. The American corm is depressed, globose, very much wrinkled, and has a dense circle of curly roots, which arise from the top, around the stem, and descend about the corm. The European is oblong or ovoid, and has the roots at the base. Both usually are found in the market cut into transverse slices, which are white and very starchy. Both are pervaded by an intensely acrid and stinging juice when fresh, but which gradually disappears with drying and keeping, and is dissipated by heat. Small doses of the drug, before this change occurs, act as a very powerful abdominal stimulant, but afterward it is nearly inert. The dose is 0.5–1 gm. (gr. viij.–xv.). It should be given well diluted with mucilage or honey, to mitigate its sharpness. Its use has almost ceased.

Henry H. Rusby.

TURPENTINE.—*American Turpentine* (*Terebinthina*, U. S., P. G.; *Thus Americanum*, Br., *Galipot*, Cod. Med.). A concrete oleoresin obtained from *Pinus palustris* Miller, and from other species of *Pinus* (fam. *Pinaceæ* or *Coniferæ*). The species of pine here referred to form large forests in the Altantic and gulf belts of the Southeastern United States, where the turpentine is collected on an enormous scale. By the carelessness of the Government in permitting the present ruinous methods of collection, the destruction of the sources of this article is a question of a very short time only.

Deep gashes are cut in the trunks of the trees, near the ground, and hollowed out at the bottom so as to hold a pint or more of liquid, and, above these, slight cuts are made in the bark, from which the turpentine flows, and, running down, is collected in the "boxes," as the excavated gashes are called; from these it is ladled out from time to time as the boxes fill, and fresh hacks are occasionally made in the bark above to keep up the flow. The freshly collected turpentine is then filled into barrels and carried to the still, where the oil is distilled off, being the spirit of turpentine, as it is commonly called, of commerce.

Turpentine is described as occurring in yellowish, opaque, tough masses, brittle in the cold, crumbly-crystalline in the interior, of a terebinthinate odor and taste. The alcoholic solution has an acid reaction.

As indicated in its definition, turpentine consists of oil of turpentine and resin. A small amount of bitter substance is also present. Its properties, medicinally, are wholly those of the oil, considered below, which is present to the extent of from fifteen to thirty per cent., weakened by the resin, also considered below. The uses of all three of the articles, as well as their preparations, are considered together at the close of this article:

Oil of Turpentine (*Oleum Terebinthinæ*, U. S.; Br., *Spirit of Turpentine*) is defined as a volatile oil distilled from turpentine, and is thus described:

A thin, colorless liquid, having a characteristic odor and taste, both of which become stronger and less pleasant by age and exposure to the air.

Specific gravity: 0.855 to 0.870 at 15° C. (59° F.).

It boils at 155° to 170° C. (311° to 338° F.).

Soluble in three times its volume of alcohol, the solution being neutral or slightly acid to litmus paper; also soluble in an equal volume of glacial acetic acid.

Bromine or powdered iodine acts violently upon it.

When brought in contact with a mixture of nitric and sulphuric acids, it takes fire.

If a little of the oil be evaporated in a small capsule on a water bath, it should leave no more than a very slight residue (absence of *petroleum, paraffin oils,* or *resin*).

There is a rectified form of it (*Oleum Terebinthinæ Rectificatum*, U. S., P. G.) made by shaking up the crude oil with six times its amount of lime water and redistilling, which is thus described:

A thin, colorless liquid, having the general properties mentioned under oil of turpentine (see *Oleum Terebinthinæ*, above).

Specific gravity: 0.855 to 0.865 at 15° C. (59° F.).

Boiling point: about 160° C. (320° F.).

Its alcoholic solution should be neutral to litmus paper.

If about 10 c.c. of the oil be evaporated in a capsule on a water bath, no weighable residue should be left.

Upon treatment of oil of turpentine with hydrochloric acid, and some similarly acting substances, a kind of camphor, closely resembling ordinary camphor, can be produced.

Rosin (*Resina*, U. S., Br.; *Colophonium*, P. G., *Colophony, Common Resin*, or *Rosin*) is defined as the residue left after distilling off the volatile oil from turpentine, and is described as a transparent, amber-colored substance, hard, brittle, pulverizable; fracture glossy and shallowly conchoidal; odor and taste faintly terebinthinate. Specific gravity 1.070–1.080. Soluble in alcohol, ether, and fixed or volatile oils; also in solution of potassium or sodium hydrate. Rosin varies considerably in its appearance, according to the extent of its distillation. If the water with which it was distilled has not been entirely boiled out, it is opaque and yellow; if it contains no water, it is clear; if overheated, it is dark brown or black, if not, it is bright and clear. The abietic acid in the opaque "thus" is a product of hydration of rosin, and may be produced in ordinary rosin by treating with diluted alcohol.

Action and Uses.—Oil of turpentine is one of the most irritating of its series. Applied to the skin and prevented from evaporating, it quickly causes smarting and redness, and after a quarter of an hour or more is liable to destroy the surface and cause ulceration. In large doses, 10 or 15 gm., taken internally, it is a quick irritant, causing prompt action, but is unsafe. Used with suds or other vehicle, as a rectal injection, it is promptly rejected, and in consequence is a useful stimulating evacuant of the lower bowel. Oil of turpentine is readily absorbed in vapor by the lungs, as well as in its liquid condition by the stomach. It is excreted also by the lungs as well as by the skin and kidneys, the latter principally in the course of its elimination; it is, if in large quantity, an irritant to the whole urinary system, causing strangury, frequent micturition, hæmaturia, etc. The urine has a rather pleasant violet-like odor. Like all essential oils it is an antiseptic. In small doses (a few drops) it is stimulant and hæmostatic, and is frequently given with good effect in the hemorrhage of typhoid and phthisis. In large amounts, 2 or 3 gm. and upward, there are mental exhilaration, intoxication; and in poisonous doses dulness, coma, and convulsions, with muscular weakness and heart failure.

The oil is frequently employed as an irritant application (turpentine stupe); a flannel pad wrung out from hot water, and freely sprinkled over the surface with oil of turpentine, acts the same as a mustard paper. It is also a very useful injection (15 gm., in a litre or less of warm soapsuds, and stirred in while being administered). Internally, as above indicated, it may be given in doses of from three to ten drops.

Turpentine itself is not much employed in this country, but may be given for chronic diarrhœa, ulceration of the bowels, chronic rheumatic joints, sciatica, etc., as well as in leucorrhœa and gonorrhœa, under conditions indicating copaiba, over which it probably has no advantages; it may be made into pills and a gram or two be given at a time.

Resin possesses but little activity. It is employed only externally and occasionally.

PREPARATIONS.—Of turpentine there is no official preparation unless the oil and the resin might be so considered. Of the oil we have the *Linimentum Terebinthinæ* or *Turpentine Liniment*, of 65 parts of resin cerate dissolved in 35 parts of the oil. This is a very irritating application. *Resin Cerate* (*Ceratum Resinæ*, U. S.) is made of 35 parts of resin, 15 of yellow wax, and 50 of lard. *Resin Plaster* (*Emplastrum Resinæ*, U. S.) is made of 14 parts of resin, 80 of lead plaster, and 6 of yellow wax. *Cantharides Cerate* (*Ceratum Cantharidis*, U. S.) contains eighteen per cent. of rosin and fifteen per cent. of oil of turpentine.

ALLIED PLANTS AND PRODUCTS.—The genus *Pinus* is the most important of its family and comprises about seventy living species, distributed through the cooler regions of the earth. Turpentines are found to some extent in all species, and they agree closely in their general properties. Similar substances, some of them known commercially as turpentines, are found in related genera. *Venice Turpentine* is the product of *Larix Larix* (L.) Karst. (*Pinus Larix* L.; *Larix Europæa* D.C.) of southern Europe. *Strassburg turpentine* is obtained from *Abies Picea* (L.), Lyons (*Pinus Picea* L.), the European Silver or Strassburg pine. *Pitch*, *Canada* and *Burgundy*, as well as their turpentines, have been considered under those titles. *Tar*, *cade*, and *juniper oils* have also been duly considered. All agree in their general composition and properties with the subject of this article.

Besides these, a number of oleoresins derived from other families (copaiba, Chian turpentine, etc.) are commercial and medicinal products of similar nature.

W. P. Bolles.

TUSCAN SPRINGS or **LICK SPRINGS.**—Tehama County, California.

POST-OFFICE.—Red Bluff. Hotels and cottages.

The Tuscan Springs, about fifty in number, are located about eight miles northwest of Red Bluff, two hundred miles north of San Francisco and one hundred and thirty-five miles north of Sacramento. They cover an area of about ten acres, and are situated at an elevation of 900 feet above the sea-level. No complete analysis seems to have been made, but the waters resemble in medicinal properties those of the Kentucky Blue Lick Springs. A partial analysis of the Red Spring water was made by Dr. F. W. Hatch a number of years ago. It contains: Sulphuric acid,* hydrochloric acid, lime, sodium chloride (20.72 grains per United States gallon), lithia, iodine (4.50 grains per United States gallon), carbonic acid, iron bicarbonate, potassium chloride, magnesia, alumina. Temperature of water, 78° to 80° F.

The White and Black Springs are also in use, but they have not been analyzed. Most, if not all, of the springs contain sulphureted hydrogen in considerable quantities. The temperature of the springs varies from 67° to 94° F. Their action is tonic and alterative, laxative or cathartic, according to the amount taken. Ample facilities for bathing are furnished to guests. There is also a plunge bath thirty by sixty feet, four feet deep at one end, and thirteen feet at the other. The waters have considerable reputation on the Pacific coast in the treatment of syphilitic skin affections, scrofula, rheumatism, liver and kidney troubles. They are used commercially, having a considerable sale on the coast. *James K. Crook.*

* Probably in combination. J. K. C.

TUSCARORA LITHIA SPRING.—Juniata County, Pennsylvania.

POST-OFFICE.—McCoysville.

We are informed by Mr. W. A. Middleton, mineralogist, of Harrisburg, that this valuable lithia water was discovered by prospectors a few years since while boring for oil. The spring flows about four hundred gallons per hour, and is heavily charged with carbonic acid gas. It contains the following solids: Potassium bicarbonate, calcium bicarbonate, lithium bicarbonate, magnesium bicarbonate, magnesium sulphate, sodium sulphate, silica, alumina. The water is of the alkaline class, and is free from nitrates and nitrites. As far as can be learned, the spring is not yet fully developed as a resort, but the water is sold. *James K. Crook.*

TUSSILAGO. See *Coltsfoot.*

TUSSOL—antipyrin mandelate, antipyrin phenyl-glycolate, $C_{11}H_{12}N_2O.C_6H_5.CHOHCOOH$—is a salt of antipyrin which is especially recommended in the treatment of whooping cough. To a baby four weeks old Kennedy gives 0.03 gm. (gr. ss.) twice a day, and to a child of seven years 0.2 gm. (gr. iij) four times a day. Rehn and Blum speak of its efficiency in pertussis, notable change in the cough ensuing in from three to ten days after beginning the treatment. *W. A. Bastedo.*

TYPHOID FEVER.—(τῦφος, smoke; secondarily, stupor.) (Synonyms: English, *Enteric Fever*; German, *Abdominaltyphus*; French, *Dothiénentérie* or *Dothiénenthérite*, or *Fièvre Typhoïde*; Italian, *Tifo Enterico*; Spanish, *Fiebre Continua, Tifo.*)

HISTORY.—There can be no doubt that this disease has prevailed extensively from very remote periods, but its authentic history, like that of so many other infectious diseases, is of quite recent date. Indeed, for this there are especially good reasons in regard to typhoid fever, for the intestinal lesions are the essential and distinguishing characteristics of the disease, and these would be described carefully only after frequent autopsies. Ingenious attempts have been made to associate passages in the works of Hippocrates with this disease, but such have hardly carried conviction to others than their originators. Typhoid fever, as we know it, is not distinctly recognizable in any of these descriptions, and it is not until the seventeenth century that the clinical conditions ending in death, and followed by autopsies revealing intestinal lesions, are to be found in medical literature.

Spigelius, Lancisi, Baglivi in Italy; Friedrich Hoffmann in Germany; Willis, Sydenham, and Huxham in England, all described cases of typhoid fever with such exactness as to leave no doubt of the identity of the disease. Morgagni in France, in the eighteenth century, gave a particularly clear delineation of the course of the disease, and of the intestinal lesions. It still remained, however, for the nineteenth century to define its distinguishing characteristics, and to differentiate typhoid fever from all other diseases.

The Germans are disposed to attribute priority of recognition and determination of the distinctions between typhoid and typhus fevers to Hildenbrand, of Vienna, who published a treatise on "Contagious Typhus" in 1811 (translated into English by Dr. S. D. Gross in 1829). It is true that he distinguished between "contagious typhus" and what he calls "originary typhus," but his ideas about his "originary" typhus were extremely misty, and I think the impartial reader of his treatise will find much difficulty in identifying it with typhoid, although the "contagious" disease answers fairly well to typhus fever.

Bretonneau, Petit and Serres, Louis and Chomel in France, during the first thirty years of this century, did more, by their careful observations at the bedside and their patient labors in the autopsy room, to elucidate the symptoms and course of the disease, to connect these with the pathological lesions, and to place the whole in the clear light by which we regard this very important disease to-day, than any or all of their predecessors. Even after the publication of their observations a good deal of confusion prevailed for another ten years between typhoid and typhus fevers, the one being more common in France, the other in England, the symptoms being by no means very dissimilar in exceptional cases, or at least sufficiently alike to throw doubt upon the recently promulgated pathology.

This doubt it was the privilege of American pupils of Louis to be instrumental in dispelling. James Jackson, Jr., of Boston, published in 1830, 1833, 1834, personal observations confirming the occurrence of intestinal lesions as the result of typhoid fever. Gerhard, of Philadelphia, in 1835, reported cases of typhus fever occurring during an epidemic at the Philadelphia Almshouse, which marked out plainly the characteristics of that disease; and in 1837, in association with Pennock, Gerhard established clearly the fact that typhoid and typhus were distinct diseases. This was further brought out the following year (1838) in Paris, and in 1840 in this country, by George C. Shattuck, of Boston, as the result of observations in the London Fever Hospital, at the request of and following the teaching of Louis. Stillé, of Philadelphia, who had previously been under Gerhard at the Philadelphia Hospital during the typhus epidemic, and who was in Paris at the same time with Shattuck, was also instrumental in establishing before the Société Médicale d'Observation the anatomical and clinical distinctions between the two diseases.

As a result of these and subsequent studies and reports, the non-identity of typhoid and typhus fever was early recognized and accepted in the United States—earlier and more generally than in England. Dr. A. P. Stewart, of Glasgow, who, after studying fevers in the Fever Hospital of that place, resorted to Paris for the same purpose, accurately described the chief features of these two diseases before one of the Paris medical societies, in 1840, and was the first of his countrymen who did so. It was not, however, until ten years later (1849–51) that a general recognition of the quality of the two diseases, of their specific characteristics, was enforced in Great Britain by the authority of Sir William Jenner. Since that time typhoid fever has been everywhere accepted as a distinct morbid entity, and all difference of opinion as to its special characteristics may be said to have disappeared.

Etiology.—No sooner were the problems of the semeiology and pathology settled, and the conclusions generally accepted, than the equally important question of the etiology of typhoid fever took their place, and a discussion arose which lasted thirty years. The medical world divided into two parties: (*a*) those who held that typhoid fever is not only a distinct disease, but a specific disease having a specific poison, which is only produced by itself, and only reproduces itself; (*b*) those who though acknowledging its distinct symptomatology and pathology, still held that it at times arises autochthonously or spontaneously; that mere filth, or according to some who embraced this view, even depressing emotions which derange the digestion, may give rise to these special results. These two theories were propounded and actively supported by Drs. Budd and Murchison, respectively, and from the year 1850 were largely identified with their names. Both of these theories were of practical benefit, for it was largely due to the efforts of Murchison that the foundations of modern hygiene were instituted, and the influence of Budd was felt both in the care of the patient and his excreta and in the incentive to determine the specific poison. As early as 1871 attempts were made to identify definite organisms as constantly occurring with the disease, but not until 1880 was the germ discovered by Eberth, which has since been found to answer the requirements of a specific organism.

The Eberth-Gaffky bacillus, or bacillus typhosus, was of constant occurrence in typhoid fever and absent in health. It was finally isolated, and after much experimentation grown in pure culture. Owing to the apparent insusceptibility of animals to the disease all attempts at inoculation of animals with typhoid have been unsuccessful, though lately Remlinger has claimed to have caused the disease in rabbits, but his work has not yet been confirmed. The organism has, however, been accepted. Its viability in the human body, before and after death, and its duration in different media, liquid and solid, under varying conditions of heat and cold, have been more or less definitely determined.

It is a short, thick rod, about three times as long as wide, and with rounded ends. The length equals one-third the diameter of a red blood corpuscle. It is somewhat variable under different conditions, and may be thicker or thinner according to circumstances, and may become arranged end to end, forming threads. In hanging drop it has motility due to numerous flagella, which may be seen by careful staining. The other characteristics and growth under different conditions belong to bacteriology and need not be discussed here. It is of practical importance, however, to know that these bacilli may live indefinitely under favoring circumstances, and they have been shown experimentally to exist as long as three months in milk, water, and in a dead body, and five and one half months in soil, and to resist freezing, though they succumb quickly to a temperature of 167° F. The practical value of these facts will appear.

By this discovery of the bacillus typhosus by Eberth in 1880 the etiology has been placed upon a definite basis.

Predisposing Causes.—Age. This is the most important of the predisposing causes. It is essentially a disease of youth, the great majority of cases occurring between fifteen and thirty years of age, and this holds true in general of all countries. Statistics on this and other points are generally made up from hospital patients, but would probably not vary much as to age if applied to those treated at home. Murchison deals with the largest figures, extending over a period of twenty-three years at the London Fever Hospital. He states that persons under thirty years of age are more than four times as liable to typhoid fever as persons over thirty. Of 5,911 cases admitted to the London Fever Hospital, between the years 1848–70 (twenty-three years), 56.70 per cent., more than one-half, were between fifteen and thirty years of age; 28.58 per cent., more than one-fourth, were under fifteen; 13.30 per cent. were over thirty; while only 1 in 71 cases exceeded fifty. The contrast between typhoid and typhus fevers in this respect is shown by the same tables, only 24.87 of the typhoid cases being over twenty-five years of age during a period of years when 50.66 per cent. of the typhus cases were over that age.

For five years preceding 1870 in Berlin, Zuelzer reports the following table of cases of typhoid among every 10,000 inhabitants of all classes:

From 8 to 10 years of age.....	18	From 35 to 40 years of age.....	13
" 10 to 15 " " ".....	22	" 40 to 45 " " ".....	16
" 15 to 20 " " ".....	32	" 45 to 50 " " ".....	13
" 20 to 25 " " ".....	31	" 50 to 55 " " ".....	27
" 25 to 30 " " ".....	20	" 55 to 60 " " ".....	7
" 30 to 35 " " ".....	11	" 60 to 65 " " ".....	10

This table gives the usual ratio up to thirty years, but betrays some singular discrepancies in the later years. Liebermeister found that seventy-seven per cent. of the typhoid patients in the hospital at Basle, from 1865 to 1870—a period of five years—were between fifteen and thirty years of age; and Fiedler reported that in Dresden eighty-one per cent. of all the typhoid patients were between those ages.

The average age of 291 cases which occurred at the Massachusetts General Hospital was about twenty-two years. Other statistics in this country are of the same tenor.

It should not be forgotten that typhoid fever does occasionally occur in the aged, and by no means infrequently in the very young. Undoubted cases in infants under a year old are on record. In fact, recent investigation tends to show that typhoid fever in infants is much more common than is generally acknowledged. Even in the fœtus undoubted cases of typhoid fever have been recognized. In these cases the mothers were suffering from the disease, and the infection probably took place through injury or infarct in the placenta, which was in some cases demonstrable. Some of these fœtal cases near term had fever, diarrhœa, and positive Widal reaction, and some showed at autopsy ulcerated Peyer's patches, enlarged spleen, and typhoid bacilli were found in the organs. A considerable number of cases of very probable typhoid fever in the first, second, and third years of life has also been collected. Griffith and Ostheimer have collected 139 cases in the first year, 187 in the second, and 325 in the third. Many of these cases had positive Widal reaction, and in some typhoid bacilli were found post mortem. The symptoms often are so little marked in the very young that the nature of the trouble is liable to be overlooked. Subsequent immunity to exposure, it is fair to suppose, is sometimes due to an early unrecognized attack. The susceptibility is greatest between the ages of fifteen and twenty-five; next between ten and fifteen; and next between twenty-five and thirty.

Sex: If guided by hospital statistics, one would conclude that the disease is somewhat more common among men than among women. On the other hand, men are more likely to resort to hospital treatment, and the difference may perhaps be explained in this way. As a fact, either sex is probably about equally liable.

Locality: Typhoid fever is no respecter of locality, although having its places of predilection. It prevails alike in cities, in towns, in villages, in hamlets, and in solitary houses; among the poor and the well-to-do; on high and on low ground; over a sandy or over a clayey soil. It is, perhaps, of all infectious diseases, the most constantly to be found, under the greatest variety of conditions.

Seasons of the year: In all countries of the northern temperate zone the last six months of the year, from July to December, are those in which typhoid fever is most prevalent, and in the southern temperate zone the corresponding months, from February to July, are similarly prominent. September, October, and November are three months in which the largest number of cases occur, as shown by tables from various localities.

A statement of the deaths from typhoid occurring in Basle during fifty years gives the following for the different months. January, 192; February, 143; March, 137; April, 121; May, 160; June, 169; July, 186; August, 202; September, 237; October, 237; November, 236; December, 193.

Murchison's 5,988 cases at the London Fever Hospital, during twenty-three years, were distributed through the different months as follows: January, 433; February, 306; March, 318; April, 209; May, 232; June, 335; July, 431; August, 721; September, 803; October, 839; November, 819; December, 539—27.7 per cent. of the entire number were admitted in the two months of October and November, and only 7.3 per cent. in the two months of April and May.

Of 621 cases treated at the Pennsylvania Hospital during ten years, 89 were admitted during spring, 259 during summer, 182 during autumn, and 91 during winter. So marked is the prevalence of typhoid in the months of September, October, and November that it is often spoken of popularly as "fall" or "autumnal" fever. Owing to exceptional causes, epidemics may occur at other seasons of the year. In the older cities the disease has a tendency to become endemic, and to last through the winter months.

Notwithstanding that typhoid fever is more prevalent in the autumn months, statistics show that the mortality is much greater in the first quarter or first half of the calendar year. The reason of this greater mortality in the spring is probably not that the infection is more virulent at that season, but that human vitality is probably lower, and fatal complications are more frequent. The fallacy of statistics must also be remembered, and the fact that there are so many mild cases in the autumn would naturally lower the mortality rate.

Moisture and temperature, level of ground water: These do not seem to have any constant relation to the prevalence of typhoid. It is found to be active during and after both cold and hot seasons, dry and damp weather, although it is said that a warm, dry summer favors abundant typhoid in the autumn. Murchison regards warmth, with moisture and but little rain, as the most favorable combination of circumstances. Von Pettenkofer and Buhl succeeded in establishing a relation between low ground water and increasing typhoid for a time at Munich, but this does not hold good for other places and other countries. Such a connection is far from being invariable for every year and for all places. Wet seasons as well as dry, are followed by, and coincide with, abundant typhoid. In Berlin it has been shown that the inhabitants most exposed to the influences of the ground air are not those most affected by the disease.

In this connection Sedgwick's and Winslow's very recent and thorough statistical studies on seasonal variations in temperature and on the prevalence of typhoid fever in various countries deserve notice. These investigators have brought together statistics of the monthly variations in temperature and in the prevalence of typhoid fever for thirty communities, representing four continents and both hemispheres, and a very wide range of climate. While not asserting that the typhoid bacillus multiplies in the environment during the summer months of a temperate climate, they do consider that it is the absence of the destructive influence of cold, rather than any stimulating influence of heat, which permits the rise culminating in the autumnal maximum. They postulate their conception of the probable mechanism of the seasonal changes as follows:

The bacteriology and etiology of typhoid fever both indicate that its causal agents cannot be abundant in the environment during the colder season of the year. The germs of the disease are carried over the winter in the bodies of a few patients, and perhaps in vaults or other deposits of organic matter where they are protected from the severity of the season. The number of persons who receive infection from the discharge of these winter cases will depend, other things being equal, upon the length of time during which the bacteria cast in these discharges into the environment remain alive and virulent. The length of the period during which the microbes live will depend largely upon the general temperature; as the season grows milder, more and more of each crop of germs sent at random into the outer world will survive long enough to gain entry to a human being and bear fruit. The process will be cumulative. Each case will cause more secondary cases; and each of the latter will have a still more extensive opportunity for widespread damage. In our opinion the most reasonable explanation of the seasonal variations of typhoid fever is a direct effect of temperature upon the persistence in nature of germs which proceed from previous victims of the disease.

Individual idiosyncrasy plays a part as a predisposing cause in this as in other infectious disorders. Some persons and some families seem proof against the poison, even in an active form, while others contract the disease upon slight provocation. An inherited predisposition has sometimes been suspected as reappearing through several generations. Notwithstanding the immunity usually conferred by one attack, some persons have been known to pass through several distinct attacks at different periods. Phthisis, pregnancy, and lactation have been supposed to confer some degree of immunity, but this is doubtful.

The robust are quite as likely to be attacked as the feeble, and in the opinion of some are even more prone. Intemperance, fatigue, and mental emotions can only be admitted as predisposing causes very indirectly.

Exciting Causes.—Since the identification of the specific micro organism causing the definite disease, typhoid fever, the etiology in relation to exciting causes has to do principally with the mode of entrance of the bacilli into the human economy.

Because the bacilli are capable of resisting drying to a certain extent, and may therefore be blown about in the air, the possibility that they may gain entrance through the respiratory organs cannot be ruled out, though this is probably infrequent, and even then some of the organisms could also be swallowed. Dr. Eduardo Germano concludes from experiments that typhoid bacilli cannot resist thorough drying, and therefore cannot be transmitted by air currents through dust to man. Undoubtedly the commonest mode of entry is by ingestion. Formerly it was supposed that water was the only vehicle of practical importance. That it was frequently the means of infection was so satisfactorily proved and is so generally recognized that it need only be mentioned, and space need not be occupied by the now familiar details of convincing instances, the latest and one of the most unfortunate of which is that at Ithaca, N. Y., the home of a university supporting scientific departments and a medical school.

It may not, however, be generally realized, even by physicians, who recognize typhoid fever as largely a water-borne disease, that the death rate from typhoid fever has declined steadily in direct ratio to the introduction of well-managed public water supplies, or to what extent this has taken place. Massachusetts may be taken as an example, for in that State the provision for public water supplies has reached its highest development in this country—over ninety per cent. of the population being now supplied with water under public control. The number of deaths from typhoid fever in Massachusetts in 1901 was smaller than in any single year since the beginning of registration in 1842, and at that time the population of the whole State was about equivalent to that of Boston and its suburbs today. The death-rate percentage from this disease in 1901 in thirty-three Massachusetts cities was only one-fourth of what it was in these same cities thirty years ago. In 1865 only twenty-five per cent. of the population used public water, and the death rate from typhoid at that time was 92.9 per 100,000 inhabitants. In 1875 forty-one per cent. of the population had public water and the death rate had decreased to 80 per 100,000. In 1901 over ninety per cent. of the people were supplied from public water systems, and the death rate from typhoid had fallen to 19.5 per 100,000 inhabitants.

Milk.—Epidemics due to milk have also been thoroughly traced. Sometimes the infected milk has been contaminated by polluted water which was used in washing the vessels or in diluting the milk. In some cases the milk was directly infected by those who were sick or assisting in the care of the sick and at the same time doing dairy work.

Kober recently has tabulated 195 epidemics of milk-typhoid. In 148 of these epidemics there is evidence of the disease having prevailed at the farm or dairy; in 67 instances it is probable that the infection reached the milk by soakage of the germs into the well water, with which the utensils were washed, and in 16 instances the intentional dilution with polluted water is a matter of evidence. More recently butter, fruit, fresh vegetables, and salads, which may have been moistened with infected water, have been shown to be the starting-points of epidemics.

Oysters and Shell Fish.—Shell fish are another source of infection, especially oysters which have been fed or fattened in contaminated beds. In 1894, at Wesleyan College in Middletown, Conn., many students who ate raw oysters were affected with typhoid fever, while those who ate them cooked escaped. It was found that the oysters had been temporarily kept in fresh water contaminated by sewage containing also the discharges of typhoid patients. This outbreak was worked out with much care by H. W. Conn, professor of biology at Wesleyan, for the seventeenth annual report of the Connecticut State Board of Health. The details are very convincing, and leave no reasonable doubt as to the relation of cause and effect between the oysters and the typhoid fever. Other authentic cases have been published, and in some instances the typhoid bacilli have been found in the oysters. As a rule, undoubtedly, the oyster or mollusk is simply a common carrier, the passive, indifferent vehicle or intermediary between the contaminated water and the human organism. It has been demonstrated (Foote) that typhoid cultures introduced within the shells of oysters and kept at 57° F. give active organisms at the end of a month.

Drs. Morny and Bulstrode have presented elaborate reports on the relation of shell fish and oysters to disease to the French Government and to the English Local Government Board respectively.

Dr. Fraser, medical officer of health of Portsmouth, England, where outbreaks of typhoid fever traceable to oysters have occurred, suggests the following propositions [1] as essential to establish proof against the oyster:

1. That the oysters had been eaten at such a date previous to the onset of the disease as would be consistent with what we know as to the time typhoid fever takes to develop in man.

2. That there was no other condition common to all or a large proportion of the cases which could be regarded as playing a causal part in the disease.

3. That the oysters had not only been exposed to sewage contamination, but that this sewage actually contained the specific infection of typhoid fever.

Ice.—Ice has at times been suspected and accused of harboring and conveying the typhoid-fever poison. Sedgwick and Winslow have recently published very elaborate investigations and experiments as to the effect of cold upon the bacilli of typhoid fever. Without going into details, their conclusions may be briefly stated, both because they are the result of careful work and because they are reassuring. Moreover, they harmonize with previous work done by the Massachusetts State Board of Health. Exceptionally, artificial ice made from impure water and used quickly after manufacture may conceivably be a menace to the public health. In the same way natural ice, if increased in thickness by cutting holes and flooding, and if served within a week or two, might allow sufficient of the virus to persist to excite the disease. Yet such instances must be very exceptional; and the general result of human experience, the absence of epidemics of typhoid fever traced conclusively to ice, the fact that cities like New York, and Lowell and Lawrence in Massachusetts, have used the ice of polluted streams, and have yet maintained low death rates from typhoid fever, all tend to support the conclusion that natural ice can very rarely be a vehicle of typhoid fever.

The following are the conclusions of the Massachusetts State Board of Health on this subject as given in its annual report for 1889:

"While clear ice from polluted sources may contain so small a percentage of the impurities of the source that it may not be regarded as injurious to health, the snow ice and any ice, however clear, that may have been formed by flooding, is likely to contain so large a percentage of the impurities of the source, and with these impurities some of the disease germs that may be in the source, that the board feels bound to warn the public against using ice for domestic purposes that is obtained from a source polluted by sewage beyond that which would be allowable in a drinking-water stream or pond; and that, in general, it is much safer to use for drinking-water and for placing in contact with food that portion of the ice that is clear."

In 1898 and 1901 the Boston Board of Health conducted, through Dr. H. W. Hill, investigations of the Boston ice supply with especial reference to danger from typhoid fever.

The conclusions arrived at practically accord with those of the State Board and with those of Sedgwick and

[1] Brit. Food Journ., January, 1903, p. 4.

Winslow, and are thus summed up: "On theoretical grounds the danger of infection from ice is very small. Practically, and under the conditions of the present Boston supply, danger of infection through natural or artificial ice is almost *nil*. . . . Careful search of the records has shown that but one presumably authentic case of transmission of typhoid fever through ice is on record. The fact that there is such a case shows the possibility of such infection; the fact that there is only one shows its extreme rarity."

Notwithstanding the experiments and conclusions of the authorities previously quoted, Drs. Hutchings and Wheeler of the St. Lawrence State Hospital at Ogdensburg, N. Y., have since, and very recently, reported an epidemic of typhoid fever due to infected, clear ice which involved thirty-nine inmates of that institution. It is scarcely possible to impugn the accuracy of the details or the conclusions of this report.

Flies.—That flies may carry the contagion is proved by finding the bacilli on different parts of their bodies, but

Cases of less than a week's incubation are open to suspicion, and those reported instances in which immediate illness has followed the sudden opening of drains, etc., are probably, in their inception at least, due to septic or miasmatic poisoning. On the other hand, the instances of very long incubations, over four weeks, are but little better authenticated. The number of cases with a period of incubation not included between ten days and three weeks is probably small.

During this period the patient is able, as a rule, to pursue his ordinary occupations, though generally with less vigor, and there is apt to be diminished appetite.

Period of Invasion.—This stage begins with the first feelings of malaise, which are often accompanied by a chill or chills. There are headache, dulness, and listlessness, general soreness and chilliness, sometimes epistaxis, often diarrhœa, sometimes moderate abdominal tympanites, with tenderness and gurgling in the right iliac fossa, and the tongue presents a thin, whitish coat, not extending to the tip and edges, which may be rather red.

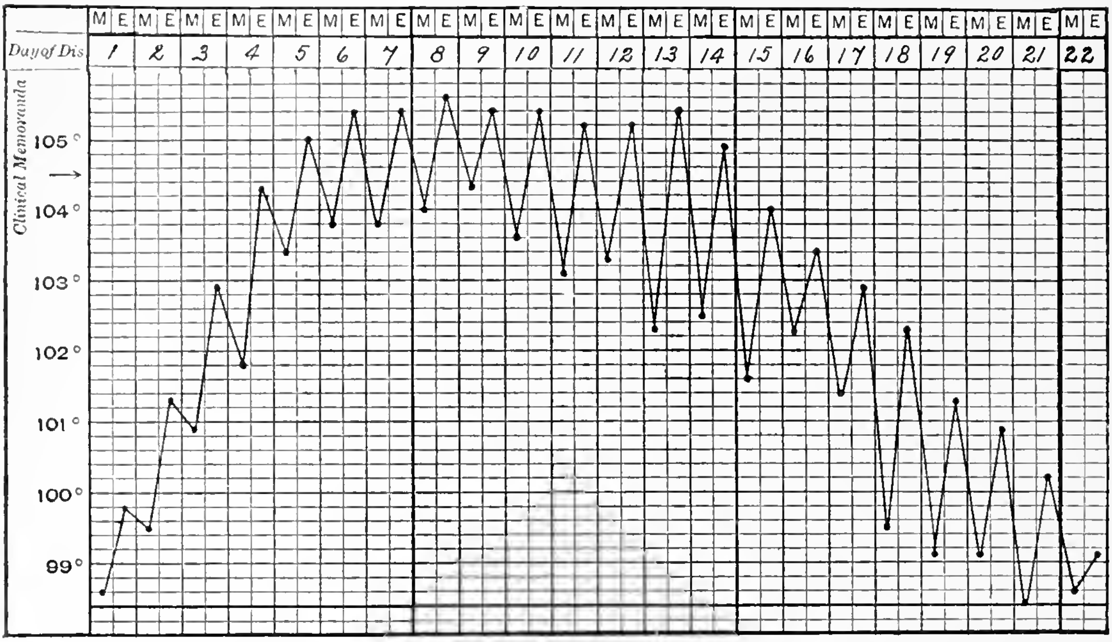


FIG. 4886.—Temperature in a Typical Mild Case of Typhoid Fever from First Day of Attack. (After Wunderlich.)

whether in sufficient quantity to be of grave importance in the dissemination of typhoid fever in civil life is still a somewhat open question. That sporadic cases have such an origin probably must be admitted, and this may have some influence upon the seasonal variations of typhoid.

All of these modes of infection have their practical importance in teaching the care of the patient and the prevention of the spread of the disease. Contamination of any article of food by those caring for typhoid patients is a constant source of danger, which, however, can generally be prevented by caution.

COURSE OF THE DISEASE.—*Incubation.*—The period of incubation, as with other infectious diseases, is a variable one, and probably depends as much on the susceptibility of the individual, as shown in idiosyncrasy or constitutional condition, as on the concentration and activity of the poison. From hospital patients it is difficult to draw any conclusions of value, either as to the period of incubation or as to the duration of the disease. But cases have been recorded in which there is little room for error as to the time of invasion, and from which maximum, minimum and average periods may be fixed in a general way.

All or only some of these symptoms may be present, but are hardly pathognomonic, as many of them may be present in the early stage of other febrile affections. In the temperature, however, we find an important aid to diagnosis.

If, in addition to the above systemic symptoms, the temperature rises step-like steadily from day to day, and from morning to evening, and reaches from 103° to 104° F. by the fourth day, there will be less reason to hesitate as to the diagnosis. By this time the fæcal discharges will begin to exhibit the characteristic light-yellow color and pea-soup consistence. By the end of the first week the temperature will have reached the maximum point which it is likely to hold during the disease, and the *stage of invasion* may be considered to be at an end.

Second Week.—From the end of the first week the temperature pursues a fairly steady course from the highest point, rising from morning to evening, and falling from evening to morning, from 1° to 2.5° F., the chart developing the characteristic zigzag appearance; the countenance becomes more dull; the eyes more suffused; the face more flushed; the tongue more coated; the intestinal discharges thinner and more frequent; the abdominal tenderness and tympanites more marked; the skin drier, congested, and showing evidence of paresis of the vaso-motor nerves in the ready production of Trousseau's *taches cérébrales;* both skin and breath exhale a peculiar odor; the pulse increases in frequency—rising, perhaps, from between 80 and 100 to between 100 and 120—and is more in proportion to the temperature; the characteristic rose spots—small pink papules the size of a pin's head, slightly elevated above the surface and disappearing upon pressure—present themselves upon the abdomen and back; scattered sibilant râles are heard over the chest; the splenic area is enlarged; the urine is diminished in quantity, high-colored, slightly albuminous; a mild form of delirium or of coma vigil is developed. With these conditions the end of the second week will be reached.

Third Week.—At this stage the remissions in temperature from evening to morning will begin to be somewhat more marked, and the morning temperatures a little lower from day to day; the pulse and respirations, however, keep up their former frequency and may be even more rapid; the pulse is softer and weaker, and is apt to exhibit a slight dicrotism, due to the diminished tension of the arterial walls; the tongue is dry, brown down the centre and red at the tip and edges; the teeth are covered with sordes. The frequency of the alvine discharges presently begins to diminish, and the consistency to improve. The patient, however, exhibits the exhausting effect of the disease more than in the previous week; he lies generally upon his back, and presents a dull, stupid appearance, from which he can usually be easily roused; muscular tremor is shown upon attempts to move, speech and the protrusion of the tongue are attended with slowness and hesitation; a smart tap upon one of the large muscles is followed by a swelling due to the contraction of the degenerated muscular fibres, the heart sounds are feeble; the emaciation is pronounced; the rose spots begin to disappear. This brings the disease to the end of the third week.

Fourth Week.—About the end of the third week, or within a few days thereafter, the temperature will touch normal in the morning, although there will be a difference of from 2° to 4° F. between the morning and evening temperatures; the pulse and respirations will diminish in frequency, the former falling from between 120 and 100 to between 100 and 80, at the same time improving in character; the sibilant râles in the lungs and the signs of hypostatic congestion—if such have existed—will gradually disappear; the tongue will begin to clear and to become moist at the tip and edges; the dejections, from having been five or six in the twenty-four hours, and perhaps at times passed in bed involuntarily, will not occur oftener than once or twice in that time, or even in forty-eight hours; they will also begin to be more formed. The signs of nervous exhaustion are less striking, and the patient begins to enjoy hours of quiet, natural sleep.

By the end of the fourth week further progress is made in this direction; the temperature varies but little from normal either morning or evening; the pulse finds the level of health; the tongue is clean and moist, and the patient may be fairly pronounced a convalescent.

Such is the course of a typical case of typhoid fever of average severity, treated on the so-called "expectant" plan, ending in recovery; but individual cases vary from this in an infinite number of ways. In fact, there is no disease presenting a more diversified picture clinically. Any of the above symptoms may be exaggerated or absent altogether. The patient may not take to his bed at all, as in the so-called ambulatory typhoid; the period of convalescence may supervene rapidly upon a febrile course of not more than ten days or two weeks; and, on the other hand, instead of terminating in three weeks the pyrexia may continue for five or six weeks, or even much longer, and that without any genuine relapse. Some authorities used to explain these variations in duration by the statement that we have in typhoid two forms of fever to deal with—a primary, due to the infection of the

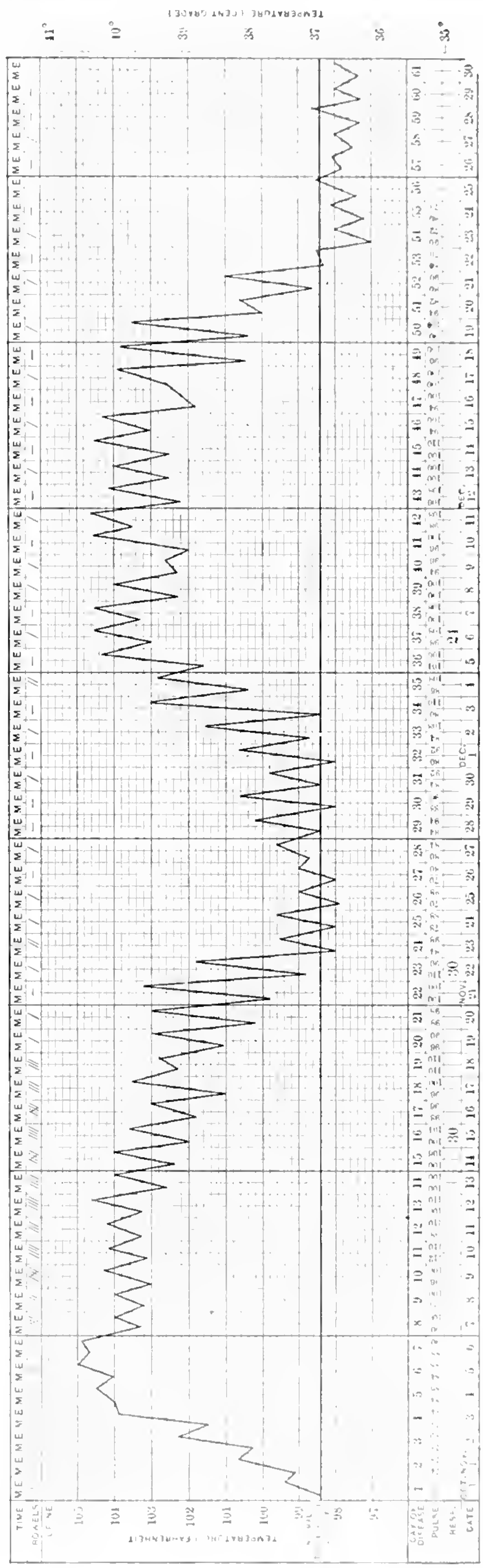


FIG. 1867. Temperature in a Somewhat More Severe Case of the Disease, with Relapse. (From the author's own experience.)

system by the typhoid poison, and a secondary, caused by the gangrene and ulceration of the intestine, and consequent septicæmia. Delirium, again, instead of being of a mild, stupid type, may be very active and acute, the patient requiring watching to prevent his getting out of bed or jumping from a window.

Diagnosis.—The diagnosis in a typical case of typhoid fever is comparatively easy. The gradual onset, with backache, headache, loss of appetite, and general malaise, occasionally with chills and vomiting, with gradually increasing rise of temperature, and frequently a progressive apathy, in conjunction with flushed face, dry tongue, and often an early enlarged spleen, and early rose spots, make a picture which is very characteristic of the disease. There is, however, as has been already stated, every variation in these symptoms, and sometimes the evidence is so slight that diagnosis is very difficult. In these cases certain laboratory tests may make the diagnosis possible.

Leucocytosis.—The leucocyte count is of somewhat negative value, as in typhoid fever, uncomplicated by any inflammatory process, the leucocyte count is usually normal or may be less than normal. It is apt to become less during the acute stage of the disease, and may become high on the advent of any suppurative process. For this reason a leucocyte count early in the disease may be of great relative value and should always be done as a routine measure.

Widal Reaction.—The Widal reaction was discovered in 1896 from the converse of the theory that certain organisms could be identified by their agglutinating under the action of serum from animals immunized to their influence. If, then, the serum had this effect on identified organisms, it would probably be from an immunized animal. This was found to be true in a large percentage of typhoid-fever patients, and the test is now applied as a routine in all hospital and many private cases, and should be in all cases.

The most practical way of applying the test is as follows: From a bouillon pure culture of typhoid bacilli with a sterilized platinum loop take ten drops, place this fluid on a clean slide and cover with a cover glass. On another slide place ten more loopfuls of the culture and one loopful of the suspected serum and stir well. On still another slide place five or ten more loopfuls of this culture and one loopful from the second slide, and mix thoroughly. This gives for examination one specimen of the typhoid culture for a control, one of suspected serum diluting the culture 1 to 10, and the third diluting the serum 1 to 50 or 1 to 100, according as five or ten drops are used on the third slide. These three preparations may be made with care on different parts of the same slide. The first two of these preparations are watched occasionally under the microscope, and if in fifteen minutes, or at most within half an hour, the bacilli in the second specimen lose their motility and become clumped together in numerous colonies, the reaction is presumably positive. This process should occur also in greater dilution, and for this purpose the third preparation should also be examined if clumping has occurred in the second.

The clinical importance of the Widal reaction as a pathognomonic sign of typhoid fever is very great in spite of some of its disadvantages. In the best statistics from very large numbers of cases a positive Widal reaction has been obtained in over ninety-five per cent. In some of these series of cases the reaction is present in ninety-nine per cent. In diseases other than typhoid the reaction is obtained in less than two per cent., and probably with the more proper high dilution (1 to 50) this proportion would be still less. From the blood of some cases resembling typhoid fever with persistent negative Widal reaction organisms, called paracolon bacilli, closely allied to Eberth's bacillus, have been isolated, and with cultures of these organisms an agglutination reaction has been obtained from the serum from the patient. It is possible that other similar organisms exist, and probably when they are identified a positive serum reaction will be obtained in a still larger proportion of cases.

The principal disadvantage of the Widal reaction is that it does not usually occur early in the disease. Though it has been found as early as the third day, it occurs in the first week in only about twenty-five per cent. of the cases. In the majority of cases it is present in the second week, but it may be much delayed, perhaps occurring during a relapse or convalescence as late even as the sixtieth day.

Diazo Reaction.—The diazo reaction, suggested by Ehrlich in 1882, may be of some help in the diagnosis of typhoid fever. A small quantity of the patient's urine is mixed thoroughly with an equal quantity of a freshly prepared solution containing one part of a one-half-per-cent. solution of sodium nitrite and fifty parts of a saturated solution of sulphanilic acid (2 gm.) in hydrochloric acid (50–1,000 c.c. water). This mixture is then made alkaline with ammonia, and if the diazo reaction is present, the solution and foam become carmine red, otherwise they are brownish-yellow. This reaction occurs usually early in typhoid fever, often before rose spots or the Widal reaction. It also usually disappears early in the defervescence and may reappear in relapse, but not in recurrence of fever due to other causes. The objections to this test as a diagnostic aid are that it does not occur in ten per cent. or more of the cases, and it may occur also in tuberculosis, typhus, pneumonia, and acute exanthemata, especially measles.

Other laboratory aids in diagnosis, which are, however, at present of somewhat less practical value, are the obtaining of typhoid bacilli in cultures from the stools, urine, sputum, blood, and rose spots. They may be obtained very early from the stools, and in pure culture from the urine, blood, and rose spots before a positive Widal reaction is present, but the technique of these procedures makes them as yet somewhat difficult of general application.

Differential Diagnosis.—In differentiating typhoid fever of a more or less atypical form, or with misleading complications, the laboratory aids to diagnosis may be very helpful. The leucocyte count may serve to distinguish cerebro-spinal meningitis and pneumonia, and an examination of the blood may show a malarial parasite. The disease from which it is most difficult to distinguish typhoid fever is acute miliary tuberculosis. The absence of remittency in the fever and the presence of rose spots are the most characteristic evidence of typhoid fever, but in the absence of a positive Widal reaction, if the bacilli were cultivated from the stools, urine, or blood, the diagnosis would be certain. Tubercle bacilli may be demonstrated in the blood or may be obtained from the sputum. The two affections have been found together.

Paratyphoid is referred to already in connection with the paracolon group of bacilli, and is described elsewhere.

Anatomical Lesions, Morbid Anatomy, Pathology.—For a complete description of the various pathological lesions, and they are numerous—such as parenchymatous degeneration, cloudy swelling of the vital organs, fatty degeneration of the substance of the heart, hypostatic congestion of the lungs, ulcerations of the larynx and œsophagus, enlargement of the spleen, thrombosis, abscesses, diphtheritic affections, etc.—common to typhoid fever and other wasting febrile diseases, the larger treatises should be consulted. The changes in the intestinal glands, and especially in the solitary and agminated glands (Peyer's patches) of the ileum, constitute the characteristic lesions of typhoid fever; these are invariably present, and in the later stages are peculiar to this disease; they are generally most pronounced in the neighborhood of the ileo-cæcal valve, the patches being most numerous in this part of the ileum. The process may extend to the solitary glands in the large intestine. The individual glands forming a Peyer's patch number from one to four hundred, and give the mucous membrane in health an unequal and roughened appearance. The patches are elliptical, situated on the free borders of the intestine opposite the insertion of the mesentery, their long diameter being parallel with the longitudinal axis of the intestine. They number from thirty upward, are confined to the small intestine, and, as before said, are most numerous and least scattered in its lower third.

These glandular lesions are usually described as passing through four stages: (1) The stage of swelling and

FIG. 4808.—Peyer's Patch and Solitary Lymph Nodules. Peyer's patch shows marked swelling with some loss of surface due to necrosis and beginning ulceration. (From Mallory.)

hyperplasia of the intestinal and mesenteric glands; (2) necrosis and sloughing; (3) ulcerations; (4) healing. In general terms, it may be said that during the *first week* the glands become gradually enlarged and the mucous membrane undergoes the usual changes of catarrhal inflammation; during the *second week* necrosis of the superficies of the glands sets in; during the *third week* there is sloughing of the necrosed glandular tissue, forming ulcers which from the end of the third week begin to clean, and then pass on to the stage of healing. At whatever period of the disease a patient dies, some of the intestinal glands will generally be found in the first stage, and at most autopsies some will be found in the first three stages. The process less often passes on to the second and third stages in the solitary glands.

Since the discovery in 1880 of the specific micro-organism causing typhoid fever, this bacillus has been demonstrated as occurring in every part of the body of patients dying with this disease, viz., the heart's blood, the lymphatic system, the bile, rose spots, etc. In fact, it has been demonstrated in life occurring in the blood, in the urine, in sputum, and in rose spots. Thus from one point of view typhoid fever may be regarded as a systemic affection; but the mode of entry is by ingestion, and the most important and the characteristic lesions are those of the intestine and mesenteric lymph nodes. Though there have been a number of cases of typhoid fever reported in which the diagnosis was made bacteriologically and clinically, but in which no intestinal lesions were found, yet it cannot be proved that no such lesions had existed.

By a series of very early autopsies at different stages of the disease, Mallory showed in 1898 (and his work has since been confirmed by others) that the lesions are due to the action of the diffusible toxin of the typhoid bacillus, which causes a proliferation of the endothelial cells of the lymphoid tissue, lymphatics and blood-vessels of the intestine, of the mesenteric lymph nodes, and of the liver and spleen, and to some extent of other organs. The cells become phagocytic and include lymphoid cells and red blood corpuscles. They lead to necroses in the intestine, mesenteric lymph nodes, liver and spleen, and occasionally other organs, by blocking up the blood-vessels and capillaries.

Necrosis and Sloughing.—The hyperplasia of the lymph cells having reached a certain degree, resolution is impeded, the vessels become choked, an anæmic necrosis or venous thrombosis is induced, a slough forms, which must be separated and thrown off. This process may be superficial, affecting only the mucous tissue or even only a part of this; or it may be, and usually is, deeper, extending to and involving the submucosa. It is always more intense toward the ileo-cæcal valve. The solitary glands may be capped with small sloughs. They have a yellowish-brown color from the bile pigments. The depth to which the necrosis extends depends on the intensity of the lymphoid infiltration; it may be deep in the muscular coat, and even reach the serosa, when perforation becomes imminent. The retrograde process advances more rapidly in the follicles than in the interfollicular tissue, and pigment is deposited in the depressions thus formed.

Ulceration.—The separation of the sloughs is gradually effected from the edges inward, and entails among other

FIG. 4809.—Peyer's Patch and Solitary Lymph Nodules just below Ileo-cæcal Valve. Appendix is curled around the lower end. Shows same condition as Fig. 4808. (From Mallory.)

dangers that of opening blood-vessels and perforation of the coats of the bowel. The size of the ulcer is directly proportionate to the depth and extent of the necrosis. The entire thickness of the mucosa may not be affected, and small, shallow losses of substance may frequently be seen in swollen patches. Generally the slough, in separating, exposes the submucosa and muscular coat, particularly the latter, which forms the floor of a large majority of typhoid ulcers. It is unusual for an entire

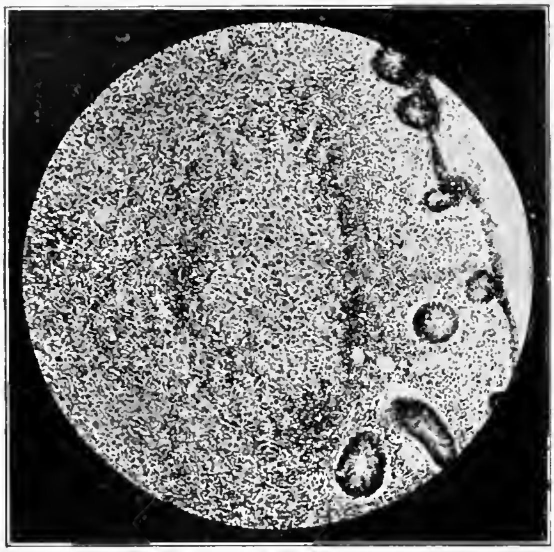


FIG. 4810.—Lymph Nodule in a Peyer's Patch showing the Presence of great Numbers of Phagocytic Cells which have replaced nearly all of the Lymphoid Cells. (From Mallory.)

patch to slough out, and the perfectly ovoid ulcer opposite the mesenteric attachment is rare. More commonly the sloughing commences in different portions of a patch, and small irregular losses of substance result, which may gradually extend and thus form one large ulcer. A large patch may present three or four ulcers divided by septa of mucous membrane. Very often the terminal six or eight inches of the ileum is one large

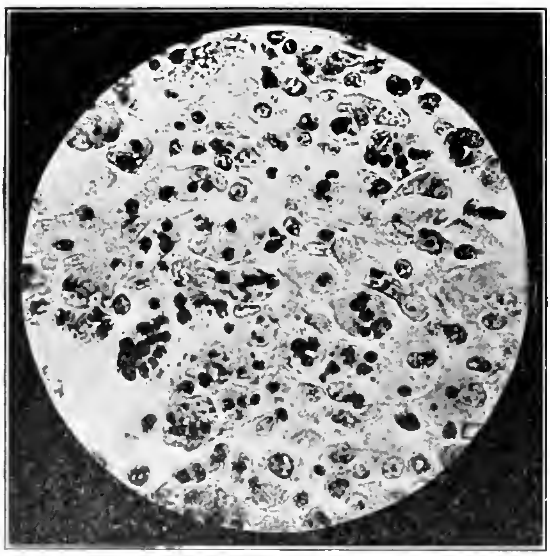


FIG. 4811.—High Power from Fig. 4810 showing Formation of Phagocytic Cells in the Lymph Nodules in a Peyer's Patch. (From Mallory.)

ulcer, with islets of mucosa left here and there. Those originating from the patches naturally affect an oval form with the long diameter in the direction of the gut, and those originating in the solitary glands affect a spherical form. In rare cases the ulceration may extend slightly beyond the confines of the glands. The sloughing or disintegration of the new tissue being completed, there is no induration or thickening of the base or edges of the ulcer. The base of a typhoid ulcer is smooth and clean, and is usually formed of the submucous or muscular coat of the intestine—occasionally of the peritoneum alone. The edges are thin and undermined, and consist of a well-defined fringe of congested mucous membrane, as may be seen by floating the gut in water.

Healing, or *cicatrization*, is the fourth stage. The majority of deaths occur before this stage is reached. The process begins with the development of thin granulation tissue, which covers the base of the ulcer and gives it a soft, shining appearance. The undermined edges approximate to, and unite with, the floor of the ulcer,

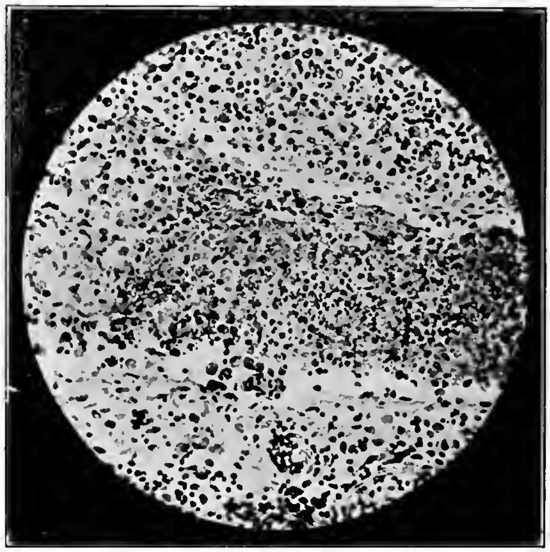


FIG. 4812.—High Power from Fig. 4810 showing Formation of Phagocytic Cells in the Lymph Nodules in a Peyer's Patch. (From Mallory.)

and from its margin new epithelial covering is gradually formed. The gland structure is not regenerated. The site of a healed ulcer is slightly depressed, is less vascular than the surrounding mucous membrane, and is pigmented.

In some cases, especially of relapse, the floor of the ulcer becomes the seat of a secondary ulceration; or occasionally an ulcer heals in one part and extends in another; and again, there may be ulcers healing in one part of the intestine, with fresh ulcers and patches in a state of hyperplasia elsewhere.

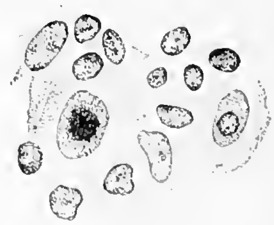


FIG. 4813.—From Periphery of Lymph Nodule, showing a Large Cell of the Reticulum in Mitosis. (After Mallory.)

The secondary ulceration is said to be more apt to cause profuse hemorrhage and perforation than the primary sloughing of the glands.

The Mesenteric Glands.—The changes in these glands are comparable with those in Peyer's patches. The distribution of those affected usually bears a relation to the involved part of the intestine, but is more extensive. The process is also similar and practically synchronous with that in the intestine. These glands likewise are the seat of an acute hyperplasia, which usually undergoes a gradual process of resolution. Softening and suppuration may exceptionally occur, or, the capsule of the gland being destroyed, the softened matters may escape into the peritoneal cavity, causing peritonitis.

Liver and Gall Bladder.—The constant changes (focal necroses) always occurring in the liver in typhoid are of no practical value. Rarely, however, abscess of the liver may occur, and more often a cholecystitis or cholelithiasis may be due to this infection, for which surgical interference may be required. Typhoid bacilli have very often been found in the gall-bladder (Chiari found them in twenty-two out of twenty-four cases), and they are known to persist there for a very long time, seven years in one case. They are supposed frequently to form the nucleus of calculi.

FIG. 4814.—From near the Periphery of Lymph Nodule, showing Newly Formed Cells Beginning to Incorporate the Lymphoid Cells. (From Mallory.)

Spleen.—Changes in the spleen are comparable to those of a Peyer's patch. Except in cases with previous disease of the organ, or in elderly persons, or in cases with much distention, the spleen is generally sufficiently enlarged to be felt. The enlargement is due to hyperæmia and hyperplasia. In the second week it is smooth and tense, dark-red on section. In the third week it is larger, softer, and darker. With defervescence these changes subside and the organ becomes of tough consistence. Infarcts and abscesses very rarely occur. Perisplenitis is rather more common.

Urinary Organs.—The kidneys are almost always enlarged in the second week and hyperæmic on section. Febrile albuminuria is the rule. Following this is parenchymatous degeneration. Infarcts and abscess of the kidney with typhoid bacilli in pure culture have occurred.

Cystitis may occur, but there may be large numbers of bacilli in the urine without causing symptoms; 170,000,000 per cubic centimetre have been estimated by Petruschky, which indicates the importance of disinfection of urine as well as other discharges.

FIG. 4815.—From Centre of Lymph Nodule, showing the Newly Formed Cells Filled with More or Less Digested Lymphoid Cells. Several red blood globules have also been incorporated. (From Mallory.)

TREATMENT.—Treatment properly includes the whole management of the patient. In those not uncommon cases in which the evening temperature does not rise above 102° F., nor the pulse advance beyond 110, and there are no complications, the actual "treatment" may not go beyond rest in bed and a modified diet.

A patient being fairly suspected of typhoid fever should be ordered to bed. The physician should immediately inform himself, when practicable, of the condition of the house drainage and water supply. The origin of the disease should, if possible, be discovered and corrected. The ventilation and regulation of the temperature of the sick room should be secured. Carpets, curtains, window hangings, and unnecessary furniture, it is well to remove. The bed is best in the middle of the room, certainly not in the corner; a second bed or movable couch is very desirable. The mattress should be neither very soft nor very hard—hair is the best material, and upon it a rubber cloth should be placed. The bed covering should be light; fever patients are apt to be too warmly and weightily covered. The patient's pulse and temperature should be taken at least twice a day, say between 6 and 8 A.M. and between 6 and 8 P.M. and recorded on a chart; if they can be taken oftener, so much the more accurate picture is given of the course of the disease. A three-hour chart is always instructive, and sometimes most desirable. The temperature in the axilla is sufficiently accurate for practical purposes in this disease, if proper precautions—such as wiping out the axilla and keeping the arm close to the side—are observed.

During the first week of typhoid fever many patients undoubtedly get out of bed to evacuate the bowels, and it is very seldom that any ill result can be traced to this; it is, however, safer and in the end more convenient to insist upon the use of the bedpan from the first, although to some its use is very uncomfortable, and regard should be had to the form most convenient to the individual. The *dejecta should be persistently and unfailingly disinfected; too much stress cannot be laid upon this point.* They should be passed into a disinfectant solution, another portion of which should be added after their passage, and the whole thoroughly mixed. The same injunction applies to the urine, and in less measure to the sputum. These points will be referred to again under the head of Disinfectants.

FIG. 4816.—Lymphatic Vessels of Mucous Membrane containing Phagocytic, Lymphoid, and Plasma Cells. (From Mallory.)

Soiled bedding, clothing, linen, etc., should be placed in a disinfecting solution before being taken from the sick-room, and when taken thence placed, as soon as possible, in boiling water.

It is desirable, even when there is no hyperpyrexia, that the patient be sponged morning and evening. Water at any desired temperature, with or without the addition of vinegar, alcohol, bay rum, toilet vinegar, etc., may be used. When the fever is pronounced, the water should be cool, about 75° F., and the sponging repeated more frequently. The process is best carried out by placing an old blanket under the patient and going over different portions of the body successively.

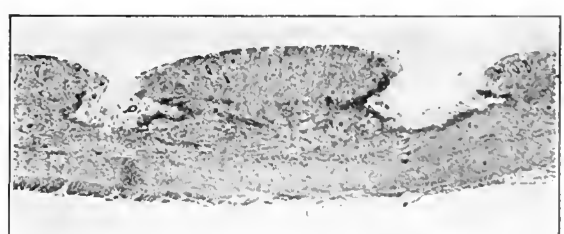


FIG. 4817. Two Ulcers in Large Intestine Following Typhoid Lesions of Solitary Lymph Nodules. (From Mallory.)

DIET.—These details attended to, the regulation of the diet is of prime moment. The general principles to follow are that it be easy of administration; that it be suitable in amount; given at proper intervals; easily digested, unirritating in its passage through the alimentary canal. Good pure milk may be made to meet these requirements better than any other one thing. The individual as well as the disease is to be considered; but, in general, from two to four ounces of milk every two to four hours, or two to four pints in the twenty-four hours, will be indicated during the first three weeks. If too much is given at a time, hard curds are formed in the enfeebled stomach; if too much is given in the twenty-four hours, large and distending masses of pultaceous fæces are formed in the bowel, unless diarrhœa prevents this. The inclination of the patient may often be consulted with advantage; but a certain minimum amount of nourishment is to be insisted on through the early weeks. When milk in small quantities disagrees, lime water, aerated waters, or boiling may be resorted to as diluents. A few patients cannot, or will not take milk in any form. And even for those who can, for whom it is the staple, a variety is needed. Albumen water, prepared by straining the whites of eggs and adding an equal quantity of water, with proper flavoring, is a good

FIG. 4818. Typhoid Swelling and Necrosis of Appendix. (From Mallory.)

FIG. 4819. Two Lymphatics Beneath Peritoneum, Over Appendix; Filled Partly with Phagocytic Cells, Partly with Serum. (From Mallory.)

substitute at times. Broths of beef, of veal, of chicken, or of mutton, given twice a day in addition to milk, four to six ounces each time, or oftener and in somewhat smaller quantities without milk, are useful, and often agreeable. Barley or rice may be boiled in the water, and the whole should be well strained. An egg, if really fresh, may be dropped in and stirred up. Beef juice, if not increasing the activity of the bowels, may be given with advantage; the stimulation thus provided is very useful, and nourishment may be secured in other ways. For increasing the digestibility of milk, broths, beef teas, etc., the peptonizing process may be resorted to. Chocolate boiled in milk or water, if finely ground and not highly flavored, and cacao deprived of fat and treated in the same way will sometimes prove useful and acceptable adjuvants to other diet. The Germans give fruit soups, made by boiling fresh or dried fruits in water, flavoring with sugar, lemon peel, etc., and straining; these are refreshing, but have little nourishment. Wine whey made with sherry or Madeira, milk punch made with brandy or rum, eggnog, Bordeaux if really good, may be given in addition to the above articles if required. There are now to be had a great variety of non-irritating starchy foods or cereals which, properly prepared, may be useful. Koumyss and matzoon should be mentioned. A few of the forms of nourishment most suited to the early weeks of typhoid fever have been suggested, the practical experience of each practitioner will doubtless suggest others. A state of solution, requiring only absorption and not digestion, would be the ideal one for the admin-

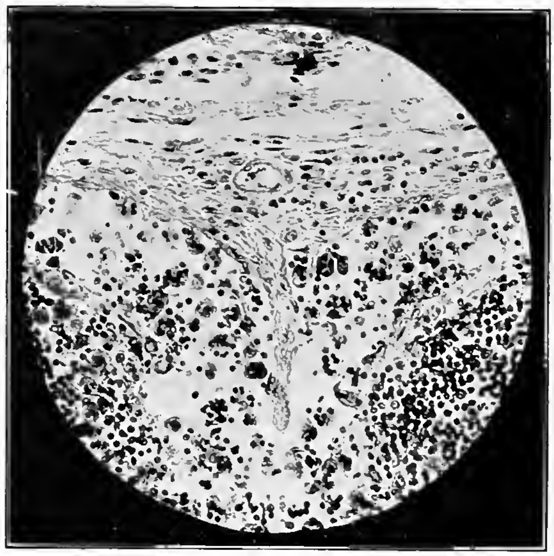


FIG. 4820.—Peripheral Sinus of Mesenteric Lymph Node Distended and Containing many Phagocytic Cells. (From Mallory.)

istration of nourishment in febrile dyspepsia. Pavy and Hoppe-Seyler have shown, however, that the stomachs of animals in a pyretic state may be made to yield a digestive fluid.

Diet in Convalescence.—When the temperature falls to normal, and convalescence begins, the vexed question of increasing the diet arises. Patients do, unknown to their doctors, eat solid food all through an attack of typhoid fever with impunity. Still more often, and this sometimes with the doctor's consent, they begin to eat freely with the return of appetite and the fall of evening temperature to the normal, and this without evil consequences. I think, however, that the old rule—if one must have a rule—to wait a week after the evening temperature remains at normal before increasing a diet as liberal as that outlined above either in amount or consistence, otherwise than very gradually and tentatively, is a good one, and that he who follows it in his practice will, in the long run, have fewer relapses and shorter and better recoveries. Eggs—raw, soft-boiled, or dropped—oyster soup with a finely crumbed cracker, porridges of various consistencies, meat juice, scraped beef, soft dipped toast, etc., may gradually be added or increased in amount, while the digestive and absorptive organs are recovering their normal activity and chemistry. Care should be taken well on into convalescence that the food, of whatever description, be taken in moderate but frequent portions.

A somewhat more generous dietetic treatment than that suggested above is allowed by some practitioners. Dr. F. C. Shattuck finds that his experience at the Massachusetts Hospital, compared with that of his colleagues, favors such a practice. Peabody, of New York, is also an advocate of more solid nourishment.

Drinks.—A fever patient should have a liberal supply of pure cold water. He is not likely to take more than he requires. All the conditions present indicate its necessity. Pieces of cracked ice, kept in a flannel crater over the top of a bowl, and covered with flannel, at the bedside, will be very grateful to the dry mouth if given occasionally. The unmedicinal, not too strongly aerated, waters are at times refreshing. Some practitioners rely a good deal upon the administration of some one of the mineral acids—dilute hydrochloric, sulphuric, or phosphoric. Water acidulated with one of these in the proportion of a drachm to the pint makes an acceptable drink. It is important to keep the mouth as clean and moist as possible, for which purpose the alkaline waters, glycerin and water, or lemon, the same with a little borax added, may be employed.

Bowels.—It is not often that interference with the bowels is required. If the diarrhœa is exaggerated, the stools being both copious and frequent—more than four or five in the twenty-four hours—after the diet has been regulated, it may be thought best to give a suppository of a grain of opium, a rectal injection of laudanum in starch or water, or some bismuth by the mouth. On the other hand, constipation may be present in such degree as to increase the dulness and pain in the head. At such times a rectal enema, or even some castor oil or a Rochelle powder, will do great service. But, as said, if the diet is properly regulated one need seldom interfere with the bowels. Some practitioners, especially among the Germans (Wunderlich, Liebermeister, Friedreich), favor the early administration of calomel—before the ninth day—in doses of eight grains, three or four times daily, for one or two days. They maintain that the subsequent diarrhœa is thereby diminished, the course of the disease is rendered lighter, and not rarely aborted, and the mortality rate diminished. Calomel is given to remove the poison from the bowel, as well as to antagonize it. The early use of calomel, which sometimes is undoubtedly attended with apparently favorable results, is a revival of an earlier practice.

Various antiseptics and eliminatives, separately or combined, have been employed in recent years to antagonize the toxic bacteria and their products in the bowel, or to remove them therefrom. To many of the most careful and experienced clinicians these measures do not commend themselves either theoretically or practically.

When tympanites is troublesome, turpentine stupes or ten drops of the oil in emulsion at intervals internally, guaiacol carbonate, five grains, a simple enema, or the careful introduction of the long rectal tube are all, at times, useful.

Fever.—In the treatment of any febrile disease, and especially of typhoid, it is not to be forgotten that a continuous high temperature is more exhausting than an intermittent or remittent temperature which reaches a higher maximum. Moreover, in estimating the bearing of any temperature the frequency and character of the pulse and the condition of the nervous centres should be carefully considered. An evening temperature of 102° F., or even of 103° F., with a morning remission, may be regarded as the normal result of the typhoid process. An evening temperature rising above 103° F., especially if the morning remission be slight, suggests the propriety of interference. The various modes of controlling temperature may be classed under the two heads of (1) the external application of cold, and (2) the internal exhibition of antipyretics.

1. Cold may be applied externally by means of sponge baths, the wet pack, sprinkling the exposed surface of the body, fan baths, tubbing, rubbing with ice, the ice cap to the head.

Baths.—Since the introduction of baths by Brand of Stettin in 1861, their therapeutic value has become thoroughly appreciated. The effect on the mortality has been very noticeable. Before this treatment was in use, the mortality in typhoid fever in hospitals was given variously as from eleven to sixteen—nineteen per cent. (twelve to fifteen per cent., Osler). The mortality now varies with the locality and in different years, but in general is a little over seven per cent. The manner of giving baths varies with the locality and with the practitioner. In the New York, Philadelphia, and Baltimore hospitals tub baths are largely given, whereas in Boston hospitals sponge or fan baths are given and sometimes wet packs are used. Baths are given every three or four hours if the temperature is 102.5° F. or more, and they usually last about twenty minutes. The tub bath is given by immersing the patient carefully, all but his head, into water at about 70° F. Continual rubbing of limbs and trunk is advisable. Patients may collapse during a bath, and a little stimulation just before or after may prevent chilliness and cyanosis. The sponge bath may be given with water at various temperatures to suit the requirements, and may expose the whole of the body or only part at a time. The fan bath is given by covering the patient with one thickness of gauze wrung out of warm water, and which is then fanned to assist evaporation. The gauze is repeatedly sprinkled with warm water, and the amount of water evaporated shows approximately the heat subtracted from the patient. These baths have been proved by experiment to be practically as effectual as tub baths, and they entail much less disturbance of the patient and are generally more agreeable. The kind of bath used may be governed by the effect on an individual case and modified accordingly.

Whatever bath is used—at whatever temperature, whether higher or lower; however prolonged, whether for a longer or shorter time; however general, whether total or partial—the effect to be sought, and which should be obtained, is a lowering of temperature, an improvement of circulation, a toning up of the nervous system, with accompanying restfulness, and often a diminution of delirium, stupor, and tremor, and consequent better sleep and digestion.

The ice cap to the head is generally grateful to the majority of typhoid-fever patients.

2. The Internal Exhibition of Antipyretics.—Among these remedies may be mentioned quinine, salicylic acid, salicylate of soda, digitalis, alcohol, and the coal tar derivatives. Of these alcohol, digitalis, quinine, and the coal-tar derivatives alone demand consideration.

Alcohol.—The administration of alcohol is to be governed by the pulse rather than by the temperature; but although its stimulant and sustaining properties are most marked, it may still be conveniently spoken of in this connection. The alcoholic treatment of fevers was introduced more than forty years ago by Dr. Todd, since when it has at times been used in an excessive and indiscriminate way, from which there has been a proper reaction, and the present tendency is to regulate the use while avoiding the abuse of alcohol in typhoid and other fevers. Sir William Jenner gives in a few words good guidance on this point. When in doubt as to the wisdom of giving alcohol, do not give it, and when there is a question of a larger or smaller dose, prescribe, as a rule, the smaller. If given, it should be for the purpose of attaining a certain definite object and for the relief of certain symptoms. Its effects should be carefully watched, and the desired results obtained with the smallest possible dose. Its administration, except as a gentle stimulant in the form of wine, of wine whey, or of milk punch, is rarely indicated before the end of the second week. In the presence of a dry brown tongue, of unusual tremor, suggesting deep sloughs of the intestine, of active delirium, or in almost any case with a rising pulse of 120, alcohol should be given, and the dose regulated according to the effects, as shown by pulse, tongue, and countenance. From four to twelve ounces of brandy in divided doses will usually be sufficient in the twenty-four hours, but in advanced cases manifesting much exhaustion, sixteen and even twenty ounces may be required, and will sometimes turn the scale between death and life. The addition of five grains of carbonate of ammonia, every two or three hours, or of a drachm of aromatic spirits of ammonia, is useful and will limit the amount of alcohol required.

Digitalis.—Digitalis was recommended by Murchison in typhoid to control the febrile movement. It is supposed to equalize the circulation by its action on the peripheral terminations of the vaso-motor nerves, to which the arteries of the mesenteric system respond more than the superficial vessels; at the same time the primary effect upon the heart is to slow and steady its action by stimulating the vagus. Too small a dose will not produce the first effect; too large a one will accelerate and then paralyze the weakened heart, and a fall in temperature will follow, as it would the exhibition of any depressing poison.

Quinine.—Many practitioners are in the habit of giving eight grains of quinine during the twenty-four hours as a tonic and stimulant to the heart's action; but to get the antipyretic action, much larger amounts in concentrated doses must usually be given. If the quinine is given in the evening, the fall of temperature coinciding with the usual morning remission will be greater; if it is given in the morning, the evening maximum will be modified. Less than fifteen grains given in a single dose, or within the space of an hour, will usually prove disappointing in lowering appreciably a high temperature; more than thirty grains so given is liable to cause cerebral and gastric disturbances. When quinine is effective, the temperature begins to fall in a few hours, reaches its lowest point in six to ten hours, and remains below the previous maximum for twenty-four hours or longer. In some cases quinine is not well borne, and in not a few it produces an inappreciable antipyretic effect or none at all. Liebermeister advocated the use of quinine, and Nothnagel still does so, regarding it as the least dangerous of all the antipyretic drugs, even when the heart is in an unstable condition.

The Coal-Tar Derivatives.—The number of these is now very considerable, and their action is better understood than formerly. Some are more effective and less depressing than others. If used at all, they should be used sparingly with caution, and as adjuvants to other measures. With regard to these, as with cold baths, the general ends to be gained should be borne in mind and not the mere temporary effect upon the temperature alone.

Antityphoid Inoculation.—Such inoculations have been practised on a considerable scale upon British troops in India and South Africa. The reports of Prof. A. E. Wright, of the Army Medical School at Netley, as to the degree of protection obtained, seem promising, but they lack precision, and the actual value of the process is still to be determined. (See Addendum on p. 951.)

Serum Therapy.—Several different experimenters have prepared typhoid antitoxins by injecting horses with cultures of the typhoid bacillus, and subsequently patients have been injected with these sera. The reports of the results are conflicting and unsatisfactory. The blood serum of patients convalescent from typhoid fever has also been used, with equally indefinite results. This question is still in an undeveloped stage.

COMPLICATIONS AND SEQUELÆ.—Although, for the sake of brevity, I have avoided describing minutely the various pathological changes and clinical complications, other than those connected with the bowels and especially characteristic of the disease, which are incident to typhoid fever, some of these are encountered in so large a number of cases, or are of such importance, that they merit separate mention.

Recrudescence and Relapse.—These are both common phases of typhoid fever, and it is not always easy to classify each return of pyrexia under the one or the other term. In general, a sudden temporary elevation of temperature would be called a recrudescence, and a more gradual and prolonged elevation a relapse. A typical simple relapse, as exhibited on a chart, shows a rising temperature following some days of normal temperature after the primary attack has run its course. According to Irvine, "the temperature begins to rise, and continues to rise, with little intermission, until it reaches its height on the fifth day of relapse; from the fifth day to the eighth or ninth day it is steady, but shows a slight inclination downward; on the eighth or ninth day it falls suddenly several degrees, possibly to subnormal levels; from such levels it ascends even to former heights, but this rise in simple cases is, so to speak, ephemeral. Fever persists to the fifteenth day, when in the simple cases a rapid, though intermittent, fall continues to the twenty-first day of the disease, at which time convalescence commences, and goes on with remarkable rapidity in many cases."

This is a very idealized picture, even of the simple relapse. Relapse indulges in quite as many freaks as the primary typhoid may indulge in. To appreciate this, it is only necessary to remember that the same case may experience several (two, three, or even four) relapses. The relapse may be engrafted immediately upon the primary attack; it may complicate or be complicated by recrudescence; one relapse may be intercurrent with another, etc. Relapse is generally accompanied by a return of the characteristic symptoms, such as diarrhœa, rose spots, enlargement of the spleen, and it is liable to any of the complications attendant upon primary typhoid. But the duration is generally shorter, and, notwithstanding the debilitated state of the patient, a fatal termination is less common than in primary typhoid.

Recrudescence is generally due to some indiscretion; true relapse is probably the result of a secondary auto-infection with the typhoid poison, and will be frequently observed where there has been no imprudence whatever, either of diet or otherwise. On the other hand, instances of various indiscretions unattended by any evil consequences, and of an early return to solid food against orders without paying the threatened penalty, are almost equally common.

Perforation.—Perforation is the most fatal complication of typhoid fever. It occurs in from one to two per cent. of all cases, and is responsible for about ten per cent. of the deaths. It occurs most often in the third week, but may be as early as the fourth day, or as late as in the fourth month during a relapse. There have been more cases in men than in women. The perforation occurs in the last two feet of the ileum in over eighty per cent. of the cases. In very many it is in the last foot. Perforation may not always be fatal. It may occur between two coils of intestine which are adherent, or probably more often it is immediately walled off by fibrin and may heal. It is unwarrantable, however, to expect a perforation to heal under medical treatment, and as soon as the diagnosis is made, surgery offers the real hope of recovery. It is of the utmost importance to make the diagnosis early, but the subject presents great difficulty.

There are causes of peritonitis other than perforation, and these may be of mild grade and recover without surgical interference. There is no pathognomonic sign of perforation in typhoid fever. The most characteristic symptom is sudden, severe, abdominal pain, persisting and increasing for some time, accompanied perhaps by collapse, a fall of temperature, a rise of pulse, nausea and vomiting, with sometimes abdominal spasm which persists, and sometimes hemorrhage. It was hoped at one time that the leucocyte count would be useful, but though in some cases it was found to rise rapidly after perforation, in others there was a diminished leucocytosis. On the other hand, there might be a leucocytosis of

28,000-70,000 in obstruction without perforation. There is then no sure diagnostic sign of perforation, but the diagnosis must be made from the group of symptoms present in a given case. However, as the benefit to be derived from operation is offered only when the diagnosis is made early, the physician should secure a consultation just as soon as the condition is suspected. Some authorities advise a small abdominal incision under cocaine to allow taking a culture from the peritoneal cavity, and to finish the operation if pus is found, but it is hardly reasonable to suppose that such a procedure would do no harm to a patient who is already very sick with an acute disease.

Hemorrhage.—Hemorrhage is a more frequent complication than perforation, but fortunately is not so fatal. It occurs in from four to six per cent. of all cases, and is probably responsible for death in about fifteen per cent. of cases. The exciting cause of hemorrhage may be an error in diet, or restlessness or distention, but it may occur in spite of the utmost care. It is most frequent in the second and third weeks, but like perforation it may be the first noticed symptom in an ambulatory case, or it may occur in the eighth week during a relapse. It is less common in children, and according to statistics less serious in women. Pain may accompany or precede hemorrhage, and sometimes hemorrhage occurs with perforation, obscuring the diagnosis. The amount of blood lost may be an inconsiderable streaking of the fæcal discharges due probably to an intense hyperæmia of the lymphoid tissue of the intestine, or it may be very copious—more than a quart—and clotted, and is then probably due to the erosion of a larger vessel.

The effect of the hemorrhage depends on the amount of blood lost. Some authorities maintain that a moderate loss of blood in a robust patient with high fever may even be beneficial. Certainly sometimes the effect of hemorrhage is inappreciable. In more severe cases there are the signs of acute anæmia, pallor, coldness, small, feeble, more rapid pulse, and there may be a marked drop in temperature. Sometimes these signs are present before the blood has appeared. The patient may even have fatal collapse and die within a few hours, before the blood appears in the stools. More commonly the hemorrhages are repeated at intervals and the patient may succumb within a few days. The treatment of hemorrhage depends on the effect. Styptics cannot be expected to check it. Opium may produce quiet, depress the heart's action, and reduce peristalsis. The diet should be restricted for a time and the baths withheld temporarily. Stimulation is not usually given, but if the patient's condition requires it, subcutaneous stimulation may be of some benefit, and subpectoral infusion of salt solution, though irrational, may possibly tide the patient over a severe acute anæmia. The local application of cold externally is resorted to, but is not to be recommended.

Epistaxis.—Nose-bleed, in the period of invasion, is so common an occurrence as to be considered almost a diagnostic detail. At this period it is usually slight, requires no treatment, and is even a source of relief to the headache and dulness. Later in the disease nose-bleed is less usual, but is apt to be more profuse, and may necessitate plugging of the posterior nares. Exceptionally life may be endangered, and an enfeebled patient may not rally from a severe epistaxis in the later stages.

Bronchitis occurs undoubtedly more often in cases in which early and suitable care has not been given to the patient, but is quite common in other cases as well. It is often due to weakness and the dryness of the buccal and pharyngeal mucous membranes, and to the consequent inability to raise and expel the bronchial secretions. The râles may be so loud as to be audible at a distance from the chest. Bronchitis is sometimes associated with a lobular pneumonia, and in the later stages with hypostatic congestion of the lungs. All these conditions disappear with the pyrexia, and their best treatment is that directed to supporting the strength of the patient and controlling the toxins.

A genuine croupous pneumonia sometimes complicates the disease; and, when appearing early, may be regarded as a direct manifestation of the typhoid poison, to which the term typhoid-pneumonia is applied.

Thrombosis.—Venous thrombosis is frequent both as a complication and as a sequel. It occurs generally in cases which have run a prolonged and exhausting course. The femoral veins and their branches are those most often affected, and of these the left more frequently than the right. An elevation of temperature, a hardness of the vein, and swelling of the leg announce and accompany the condition. Complete rest, elevation of the leg, flannel bandaging, and, later, possibly some small blisters, are indicated as treatment.

Either as a complication or as a sequel, thrombosis is sometimes painful and tedious, but fortunately only in exceptional instances does it give rise to embolism of the pulmonary artery and death.

Acute Otitis Media.—This is a by no means infrequent complication, developing usually from the second to the fourth week, and occurring in from two to three per cent. of the cases. It is generally of infectious origin by way of the Eustachian tube, and is associated with the patient's prostration and altered and accumulating buccal and pharyngeal secretions. It often complicates the temperature chart and leucocyte count, and may require special treatment.

Typhoid Psychoses.—Various psychoses may accompany or follow typhoid fever. Of all the acute diseases it is the one most often accompanied by mental symptoms. In all such cases the family history should be inquired into, especially with reference to the prognosis.

Kraepelin groups the conditions which present themselves as follows: (1) Initial delirium; (2) febrile psychoses; (3) asthenic psychoses.

Initial delirium is said to be the rarest form, to exhibit the most rapid course, and to offer the worst prognosis, over fifty per cent. ending fatally. Unsound heredity is a predisposing cause.

Febrile psychoses embrace the great majority of mental cases developing in typhoid fever, and offer a relatively good prognosis.

Asthenic psychoses are associated with the period of convalescence, and are apt to present long, weary courses and a doubtful outlook.

Neuritis.—Various forms of neuritis, local and general, accompany and follow typhoid fever. Among others, "tender toes" is mentioned by Osler, making the weight of the bed covering insupportable. The "typhoid spine" is a sequel to which Gibney called attention, and which he regarded as a perispondylitis, but which others consider to be dependent rather upon a general neurasthenic condition.

Necrosis and Periostitis.—When these occur it is usually as sequels, and such cases should be referred to the surgeon.

Disinfection.—In discussing the etiology and the pathology of typhoid fever, the occurrence of typhoid bacilli in the body and their resistance and tenacity of existence under different conditions were considered. Careful thought with regard to these matters indicates what a grave responsibility rests upon those associated with typhoid-fever patients, and what great care should be used in disposing of all exereta and in guarding in other ways against the dissemination of the germs of the disease.

In private practice, where possible, a room should be chosen which will combine good ventilation and sunshine with partial isolation and easy means of disposing of exereta and soiled linen without contaminating any more of the house than is necessary. Just as soon as the diagnosis is suspected, rigid rules should be made and enforced regarding the disposal of exereta and the disinfection of all articles which come in contact with the patient. Of course, different circumstances will require varied arrangements, but if the principles are understood and the objects to be attained are considered, the manner of their achievement is indifferent. In the city, where injury to plumbing is to be avoided, formalin and carbolic acid are the best disinfectants. Formalin is easy to use, efficacious, not very expensive, and the odor is not lasting. Fæcal discharges should be received into a vessel containing about a pint of dilute formalin (ten per cent.). After defecation the stools should be covered with the solution, then mixed thoroughly, best with a stick that can be burned, and after standing for some time they may with safety be emptied. Urine should always be disinfected. This may be done with corrosive sublimate, five per cent. carbolic acid, or chlorinated lime, but best by adding one-fortieth of its volume of formalin.

To disinfect urine in the bladder of patients *urotropin* is given in doses of from eight to ten grains three times a day for two days each week until convalescence is completed. Soiled bed linen and other articles which may be infected should be soaked in disinfectant (five per cent. carbolic-acid solution), and then when possible boiled, or exposed to dry heat in a disinfecting chamber. The sputum should be disinfected and may usually be burned. The nurses and attendants, after coming in touch with the patient, should also disinfect their hands carefully, both for their own protection and for the protection of others. The disinfection of thermometers and other utensils should not be overlooked.

In the country disinfection is exceedingly important. Any patient may be the source of a serious epidemic. Here the stools may be disinfected by mixing with an equal quantity or more of "milk of lime," which is slaked lime with four volumes of water, and after standing for two hours, they may be put in the privy vault or burned. Milk of lime should also be thrown liberally into the privy. The urine may be disinfected by chlorinated lime (1 to 32) or corrosive sublimate. The sputum should be burned, and linen, etc., all carefully disinfected. If any of those attending the sick also do farm or dairy work, especial care and diligence should be observed in preventing them from spreading the disease.

Convalescence.—Convalescence from typhoid fever is always slow, and may be very prolonged. It is always a matter of weeks, and may be a matter of many months. During this period a general supervision of the patient is desirable—care as to food, clothing, exercise, occupation, rest.

Notwithstanding the changes in our views incident to the development of bacteriology and minute histology, a better summing up of the disease process in its relation to the process of convalesence cannot be given than in the closing words of Hoffmann's volume on the pathological-anatomical changes in the organs in typhoid fever: The poisonous materials are, as a rule, taken into the body with the food, and carried into the blood from the lower portion of the ileum, as the place where the food tarries the longest, and where particularly favorable conditions for absorption are found. With this absorption, tissue changes take place in these parts which cause the onset of a severe febrile movement, and this in turn entails a parenchymatous degeneration of the various organs. Under an extreme development of these phenomena, attended by a number of unfavorable complications, the patient succumbs. But in most cases the fever declines with the return of the intestine toward health. Nutrition regulates itself, and the degenerated organs are gradually renovated.

When one therefore reflects how in all parts of the body large portions of important organs are destroyed during the typhoid process, one easily understands why typhoid patients in general experience such pronounced weakness for such a long time, and why typhoid fever is followed by so much longer convalescence than so many other less generally destructive diseases. The restoration of such a large portion of the most important portions of the system as are destroyed during the disease taxes to the utmost the ability of those which are left, and is rendered laborious precisely by the fact that the very delivery of new material for rebuilding is greatly impeded by the destruction of large areas of the lymph glands in the intestine.

Reflecting on these points, instead of being surprised at the slowness of convalescence, one is led to wonder at the recreative force which, undaunted by such impediments, builds up afresh in a comparatively short period a large part of the whole body; and, at the same time, one understands why it is that the convalescent, after passing safely through an attack of typhoid fever, feels rejuvenated and as if he were born anew.

George B. Shattuck.

BIBLIOGRAPHY.

Untersuchungen über die Pathologisch-Anatomischen Veränderungen der Organe beim Abdominaltyphus. Carl Ernst Emil Hoffmann, Leipzig, 1869.
Real-Encyclopädie der Gesammten Heilkunde, Prof. Albert Eulenburg, Artikel, Abdominaltyphus; W. Zuelzer, Zweite Auflage, Wien und Leipzig, 1885.
Archiv f. experiment. Pathologie, vol. xiii.
Virchow's Archiv, vol. lxxxi.; *ibid.*, vol. lxxxiii.
Mittheilungen Kais. Gesundheitsamte, vol. ii.
Ann. de l'Institut Pasteur, vol. xi.
A Treatise on the Continued Fevers of Great Britain, Charles Murchison, second edition, London, 1873.
Nothnagel's Encyclopedia of Practical Medicine, American edition. Typhoid and Typhus Fevers, 1901.
Twentieth Century Practice, International Encyclopedia, vol. xvi., 1899.
Practice of Medicine, Osler, fourth edition, 1901.
Studies in Typhoid Fever, Johns Hopkins Hospital Reports, 1901–1902.
Journal Experimental Medicine, vol. iii., 1898.
Connecticut State Board of Health, 17th Annual Report, 1895.
American Journal Medical Sciences, vol. cxxi., 1901; vol. cxxiv., 1902.
American Journal Insanity, vol. lix., 1902.
Boston Med. and Surg. Journal, vol. cxlv., p. 557, 1901.
Memoirs Am. Acad. Arts and Sciences, vol. xii., No. 5, 1902.
Publications American Statistical Assn., vol. viii., 1902.
United States Senate Document, No. 441, 1902.
British Medical Journal, September 27th, 1902; October 10th, 1903.
Twenty-fourth Annual Report English Local Government Board, Supplement, 1894–95.
Revue d'Hygiène, 1899–1900.
American Journal of Med. Sciences, vol. cxxvi., p. 680, 1903.

TYPHOID FEVER: BACTERIOLOGY. See The Appendix.

TYPHO-MALARIAL FEVER.—This term, which was suggested by Woodward in 1862, and has since been widely adopted, cannot be justified upon scientific grounds; for, as conceded by Woodward himself,[1] and generally admitted by recent authorities, "it does not designate a distinct type of disease, but is simply a term which is conveniently applied to the compound forms of fever which result from the combined influence of the causes of malarious fevers and of typhoid fever."

If we accept this definition of the term upon the authority of its author, we shall be obliged to admit that typho-malarial fever is simply a clinical variety of typhoid fever in which the symptoms are more or less modified by the fact that the patient has also been subjected to the influence of the malarial poison, and the propriety of making a separate heading for such cases in our nosological tables may be questioned.

If, in accordance with this definition, the sole difference between typhoid fever and typho-malarial fever consists in the presence or absence of a malarial complication, it would be reasonable to expect that the mortality from the complicated cases—typho-malarial—would *at least* equal that from the uncomplicated cases. But if we refer to the statistical tables published in the first medical volume of "The Medical and Surgical History of the War of the Rebellion," we shall find that this is not true of the cases included under this heading by the medical officers of our armies during the war. On the contrary, *the mortality from typho-malarial fever is very much less than from typhoid fever.* This is shown by the accompanying table, taken from the writer's work (1884) on "Malaria and Malarial Diseases," page 83.

We find by referring to the third column in this table that the percentage of mortality in the cases designated simply "typhoid" was, in the case of the white troops, more than five times as great, and in the case of the colored troops more than three times as great, as in the class of cases designated "typho-malarial." It will scarcely be maintained that a complication can exercise a favorable influence upon the severity and fatality of a specific disease. We are, therefore, obliged to suppose

ANNUAL RATE PER 100 OF SICKNESS AND MORTALITY FROM CONTINUED AND MALARIAL FEVERS IN THE ARMIES OF THE UNITED STATES DURING THE CIVIL WAR.

	Ratio of Cases to Mean Strength.		Ratio of Deaths to Mean Strength.		Ratio of Deaths to Cases.	
	White.	Colored.	White.	Colored.	White.	Colored.
Typhoid	2.62	2.14	1.05	1.19	39.89	53.24
Typho-malarial..	2.43	3.94	.19	1.01	7.08	17.28
Remittent	11 62	16.05	.16	.52	1.39	3 27
Intermittent	36.54	62.77	.04	.06	.18	.10
Congestive intermittent........	.53	1.32	.14	.36	26 23	31.30

either that this malarial complication only manifests itself in the milder forms of typhoid; or that a large share of the cases diagnosed "typho-malarial" are simply uncomplicated typhoid of a mild form; or that under this heading a large number of cases are included which are not typhoid at all, but belong to a distinct species of fever of much milder type. In the latter case, it is evident that it will be necessary for those who maintain the existence of a distinct form of continued fever to define its characters, and to give it a specific name, inasmuch as typho-

The disease runs its course in two or three weeks, sometimes even in less time, and then subsides spontaneously, leaving no unpleasant effects. *Such cases are often mistaken for miasmatic remittent*, especially as they not infrequently have a daily remission and exacerbation of the febrile symptoms."

Since the introduction of the term "typho-malarial fever," such cases are very commonly classed under this heading, and it is certainly a decided gain to have them rescued from the group of malarial fevers to which they were formerly so often relegated, under the convenient heading "remittent fever," a term which in this country, in Europe, and especially in India, has been made to serve as a catch-all for a variety of febrile complaints differing widely in their etiology and having nothing in common except a more or less remittent character of the pyretic movement.

The supposition that a large share, at least, of the cases which appear in our statistical tables under the heading "typho-malarial fever" are identical as regards etiology with the cases included under the heading "typhoid fever" is supported by a consideration of the data contained in the first medical volume of "The Medical and Surgical History of the War of the Rebellion."

This is shown by the following table, and remarks taken from the writer's work on "Malaria and Malarial Diseases," heretofore referred to (page 21):

WHITE TROOPS IN FIELD, GARRISON, AND HOSPITAL—GENERAL SUMMARY.

	1862.		1863.		1864.		1865.	
	Number of cases.	Ratio per cent. of cases to mean strength.	Number of cases.	Ratio per cent. of cases to mean strength.	Number of cases.	Ratio per cent. of cases to mean strength.	Number of cases.	Ratio per cent. of cases to mean strength.
Typhoid fever..................	21,565	7.60	32,166	4.87	10,116	1.49	9,739	1.50
Common continued fever........	11,769	4.06	......	....	......	....	.....	
Typho-malarial fever............	......		23,346	3.53	11,729	1.73	13,149	2 03
Malarial fevers (including intermittent and remittent)........	112,876	39.07	282,675	42.83	361,968	53.58	320,559	49.64
Mean strength..................	288,919		659,955		675,413		645,506	

malarial fever is now generally recognized as being simply a clinical variety of typhoid.

There can be no doubt that a large proportion of the cases which in our army statistical tables appear under the heading "typho-malarial fever" are in truth mild cases of typhoid. And it may be that under the influence of a malarial complication the pyrexia in such cases has a more decidedly remittent character than in similar cases without complication. But it must be remembered that uncomplicated typhoid often presents a decidedly remittent character at the outset of the attack, and that in infants the pyrexia of enteric fever commonly presents this character in so marked a manner as to have led to the designation "infantile remittent." There is reason to believe that the non-recognition of this fact leads to frequent mistakes in diagnosis, and that many cases of simple enteric fever, and especially the mild cases, are improperly classified under the headings "malarial," "typho malarial," and "remittent fever." This results largely from the fact that the diagnosis has been made at an early period in the progress of the disease, before the distinctive characters of typhoid fever have been developed, and at a time when the pyrexia is, as stated, very often remittent in its character. In speaking of mild cases of enteric fever, Dr. George B. Wood, in his "Practice of Medicine" (ninth edition), says: "In some instances the disease presents no other symptoms than those of moderate fever, with the characteristic phenomena of a slight diarrhœa or tendency toward it, some meteorism of the abdomen, and perhaps a few rose-colored spots. The tongue remains soft, moist, and whitish throughout; there is no vomiting, no considerable nervous disorder, no great prostration; in fine, none of these peculiar symptoms commonly denominated typhus.

"The figures in the tables from which our general summary has been made relate to the fiscal year, which includes the period from June 30th of one year to July 1st of the following year; the data, therefore, under the heading 1862, for example, relate to the last six months of 1861 and the first six months of 1862. The change in nomenclature, made in accordance with the recommendation of a board of medical officers, of which Dr. Woodward was a member, took effect soon after the commencement of the fiscal year 1863, and it is quite apparent from an inspection of the table that the class of fevers previously known as 'common continued fevers' subsequently fell into the group denominated typho-malarial.

"The broad fact which our table shows, is that the relative proportion of cases of typhoid fever diminished, and the relative number of cases of malarial fever increased, as the war progressed. Thus, upon comparing the first two years with the last two years, we find that the sum of the annual ratios is as follows: Typhoid fever, first two years, 12.47; last two years, 2 99; malarial fevers, first two years, 81.90; last two years, 103 22. This affords us a criterion for determining whether the group of fevers called, prior to 1863, 'common continued fever,' and subsequently 'typho-malarial fever,' is more nearly allied, etiologically, with true typhoid or with the malarial fevers Taking, as above, the sum of the ratios for the first and last two years of the war, we obtain the following: Typho-malarial fever, first two years, 7 59, last two years, 3.76 Evidently the causes which produced this group of fevers diminished as the war progressed, as did those which produced the fevers recognized as typhoid, while the relative proportion of cases of malarial fevers increased.

"The etiological deduction is apparent, and the reasons for this increase of one class of fevers and decrease of another are not difficult of comprehension. In the first place, our armies moved southward as the war progressed, and came more within the influence of the malarial poison. And, perhaps, this general movement southward, in which, however, the Army of the Potomac did not to any considerable extent participate, carried our troops, to some extent, outside of the endemic prevalence of enteric fevers. This, however, is open to question. In the second place, it is a generally recognized fact that exposure to malaria, and attacks of malarial fevers, not only do not confer immunity, but predispose to further attacks. The increased number of cases of malarial fevers is, therefore, accounted for.

"On the other hand, attacks, however mild, of the specific fevers protect those attacked, to a greater or less extent, from future attacks. That this immunity applies to typhoid, as well as to yellow fever and the eruptive fevers, there can be no doubt. . . .

"The history of armies in all parts of the world shows that new levies are especially subject to typhoid fever, and to the mild continued fever so often called by some other name, while seasoned troops are, to a great extent, exempt from it" (*op. cit.*, page 22).

In further support of the view that the etiological conditions which produce the cases denominated typhomalarial correspond with those which produce typical cases of enteric fever, we may call attention to the fact that the so-called typho-malarial fever frequently occurs in localities where intermittents and remittents are unknown; that it may prevail during the winter months, and in cities which are far removed from malarial influences, that its prevalence is often traced to insanitary conditions of the same nature as those which are concerned—as predisposing causes, at least—in the production of epidemics of typhoid; and, finally, to the fact that in fatal cases, which have been diagnosed as typhomalarial at the outset of the attack, the lesions of enteric fever are commonly found at the autopsy.

If, as some claim, there is a form of continued fever widely prevalent in the United States, which, although influenced by the same predisposing causes, is specifically distinct from true enteric fever, and also from the malarial fevers, properly so-called, then we must protest against the use of the name typho-malarial fever as applied to such cases, inasmuch as, in accordance with the definition given, by the originator of the name, this term is generally understood to designate a clinical variety of typhoid fever. *George M. Sternberg.*

[1] Transactions of the International Medical Congress held in Philadelphia in 1876, article Typho-Malarial Fever.

TYPHUS FEVER.—Synonyms: German, *Fleck-typhus, Fleck-fieber, typhus exanthematicus;* French, *typhus exanthematique;* Italian, *Dermo-tifo, typho esantematico;* Spanish, *Tifus El "Tabardillo,"* or *tifo tabardillo;* Dutch, *Vlekkoorts Kwaadardigekoorts;* Swedish, *Fläcktyfus;* Norwegian or Danish, *Nerve feber, Exanthematisk typhus.* The disease has also been known by various other names as Spotted fever, Camp, Jail, Ship and Hospital fever, Typhus Contagiosus, Typhus Petechialis, Febris Puerpera Epidemica, Morbus Pulicaris, Febris Peticularis, Catarrhal Typhus, Ochlotic Fever, Adynamic or Ataxic fever, Cerebral Typhus, Putrid or Malignant Fever, Irish Ague, Febris Hungarica.

Definition.—Typhus fever is an acute, infectious disease of unknown origin, highly contagious, so far as we know spread only by actual contact, and maintained by overcrowded conditions of population. It occurs in epidemics but may become endemic. It is characterized clinically by severe onset, early and pronounced nervous manifestations, such as prostration and tendency to mental derangement, a rapidly developing macular eruption, which is at first hyperemic but later becomes hemorrhagic, and a fever which terminates by crisis. It presents no specific anatomical lesions, and is in no way related to typhoid fever. It belongs, in all probability, to the group of diseases known as the acute exanthemata.

History.—Typhus fever, since the conditions which favor its development have always been present in the world, has probably followed upon great wars and famines since the beginning of civilization, and fevers are described by ancient writers which are thought to be typhus. In 1083 Carradi [1] and in 1463 Jacobus de Partibus [2] describe epidemics which many writers believe are the first unmistakable reports of the disease; but the great bulk of evidence points to the epidemics recorded by Fracastorius,[3] a Veronese physician, as the first which we can with a degree of certainty pronounce typhus fever. Fracastorius in 1546 published his work entitled "Contagionibus et Morbis Contagiosis," in which he describes an epidemic in Italy in 1505 and 1508, and a second epidemic which he witnessed twenty years later under the name of morbus lenticularis. This disease, though new in Italy, appears to have been well known by the physicians of Cyprus, where the disease was probably epidemic, and whence it may have come to Verona. The second epidemic in Italy, from 1524 to about 1530, spread to France and Spain, over the whole of the German Empire and even to Sweden, returning to Italy toward the end of the century.

Epidemics of typhus fever with dysentery and scurvy recurred in the seventeenth century among the train of evils entailed upon the unhappy empire by the Thirty Years' War. The disease continued to break out both in England and upon the continent during this and the succeeding century. In the eighteenth century it was endemic on the continent and became epidemic wherever want pressed more sorely than usual. In England the so-called Black Assizes became centres of contagion, when at judicial sessions prisoners communicated the disease to judges on the bench and to others in proximity. The cause of the disease was pointed out in 1735 by Browne Langrish [4] to be overcrowding and want of ventilation, so that "people are made to live in their own steams." The disease had been known by various names, chiefly as spotted fever. The name typhus was applied to it about this time (in 1760) by Sauvages.[5] The term is from the Greek, τῦφος, a smoke or fog, which was used by Hippocrates to designate a condition of stupor, and well describes the characteristic intellectual sluggishness of the sufferer from this form of fever. The extensive epidemics of the so-called "Faulfieber" in Austria (Vienna, 1757 and 1759) and Germany (1771 and 1772) were very probably typhus.

The early years of the nineteenth century saw a general epidemic of typhus on the continent. The armies of the French Republic and the First Empire carried the contagion everywhere. Napoleon lost more men by this pestilence than by the armies of the allies. When the tide of war receded the larger towns were left as centres from which epidemics spread from time to time. Great devastation was wrought by typhus among the armies of the Crimean War (1854–56), and in the war between Russia and Turkey in 1877–78 the pestilence visited the Russian camp, prostrating one hundred thousand men, half of whom died. The United Kingdom meanwhile has suffered much. Ireland has been a focus from which, during the last century, five epidemics have radiated. The most severe of these was in 1846. The mortality was very high and the disease spread to England, where it reached its height in the almost incredible number of one million cases (Murchison), and thence to the continent. In the century just closed the epidemics have shown a tendency to confine themselves to the vicinity of the place of origin, a result no doubt traceable to improved sanitation. The ravages of the disease among the Russian forces in the Crimean and Turkish wars were due directly to the horrible sanitary condition of the camps. In the Crimean War the English, whose camp was better managed, suffered less from the pestilence.

In the New World the disease is pandemic in Mexico, where it has existed since the advent of the Spaniards; if it was not known before the conquest under the name of "cocolistle." It is thought by some that the disease in Mexico has been confused with malaria and typhoid fever, and that typhus is exceedingly rare. In the United States there have been several local epidemics during the last century. The first was in New England in 1807. The disease broke out in Philadelphia in 1812, and lurked in the city "in lanes and alleys" until 1821 when Wood, then a student of medicine, studied and reported the disease. Philadelphia suffered another visitation in 1836, the history of which was written by Gerhard[9] who was the first, in this country at least, to establish the difference between typhus and typhoid. Since that time epidemics have visited sundry American cities and have been described by Flint, Da Costa, and Loomis. Typhus was not epidemic on either side during the Civil War. It is true that seventeen hundred and twenty three cases were reported to Washington, but these, as Hutchinson maintains, were typhoid accompanied by conditions which misled the army surgeons in diagnosis.

Few and mild have been the epidemics during the latter part of the century just closed. As Osler has remarked: "The gradual disappearance of typhus fever is one of the great triumphs of modern medicine."

ETIOLOGY.—*Geographic Distribution.*—If the history of typhus fever is reviewed, it will be found that no country of Europe has been exempt from the disease. England and Ireland, Italy and Russia are known as the classic homes of typhus fever, places in which the disease lurks, and from time to time epidemics, whose origin is traceable to these places, occur in neighboring and distant countries, whither they have been brought by means of merchant ships. Immunity from typhus has been claimed for France, but this claim, according to Hirsch, is not warranted, as recorded cases will show. The disease is not unknown in Iceland. In Africa and in Asia, outside India, the disease is, according to Murchison, unknown, but here again Hirsch found trustworthy evidence of occasional cases of the malady in Asia Minor, Syria, Persia, Egypt, Nubia, Tunis, and Algeria. New Zealand and Australia, the Mississippi valley, and the Pacific maritime states have remained free. In Mexico and Central and South America again Hirsch affirms, while Murchison denies, the existence of typhus.

MODES OF CONVEYANCE.—*Contagium.*—The contagium develops and reproduces itself in the body of the typhus-fever patient. The manner in which it is given off from the body is as yet only a matter of speculation. It is thought that the contagium exists in the secretions and excretions of the body and in the exhalations from the lungs and skin. There can be no question on the other hand that the disease is transmitted by so-called common carriers or fomites. The contagium clings to particles of dust, articles of clothing, furniture, and conveyances of various kinds, and retains its pathogenic properties for months. The literature abounds in instances where the disease has been conveyed to hitherto uninfected localities in articles of clothing, etc. The contagium has been carried by dead bodies.

Typhus fever may be transmitted through the air, but not for great distances. It has been demonstrated that in well-ventilated and uncrowded wards, where three or four typhus-fever cases are being cared for, the other patients remain uninfected, while those who have the immediate care of the cases are very frequently affected. On the other hand, in crowded wards or buildings with poor ventilation all are affected who are exposed.

That the disease is of a specific nature and does not occur spontaneously is shown by the fact that articles of clothing containing the contagium cannot infect after they have been subjected to a temperature of 100° to 120° C.

The contagium may be transmitted at all stages of the disease, including the stage of incubation. The period of greatest danger is during the beginning and at the acme of the febrile stage. Upon this point most writers are now agreed, while many of the older writers maintain that the contagium is more often transmitted during the stage of convalescence.

Bacteriology.—We still remain in the dark as to the true nature of the contagium. Whether it is a bacterium or a parasite of some other order is a question yet to be solved. In this disease as in the acute exanthemata many researches have been made, the purpose of which has been to demonstrate the specific cause, but little if anything has been accomplished. It will be unnecessary to more than mention the work of those whose efforts thus far have apparently no other than an historic value.

As early as 1868 E. Hallier, of Jena, described an organism which he called typhus fungus (rhizoporus), and fifteen years later, in 1883, Mott[7] reported the finding of motile spirilla in the blood of a typhus fever patient. Little importance, however, was attached to these reports at that time or since. In 1888 Moreau and Cochez[8] isolated, from the blood and urine of typhus-fever patients, bacilli which they describe as resembling the bacillus typhosus. A year later, in 1899, Hlava, of Prague, made observations on forty-five typhus-fever cadavers. In twenty of these and also in one living subject he found a streptobacillus in the blood, but was unable to demonstrate its presence in any of the organs. Cornil and Babes were unable to confirm Hlava's conclusions. In 1892 Lewaschew[10] described coccus-like bodies in the spleen blood which, when stained, were seen to possess long cilia. He also observed free flagella, to which he gave the name spirochaëte exanthematicum, and these, he thought, represented a different stage in the life history of the organism. He succeeded in growing the organism on ascitic fluid. In the same year Thoinot and Calmette[11] described a flagellate and ameboid organism in the spleen blood of five living patients and from the pulmonary blood of one after death. In 1893 Cheesman[12] described his bacillus sanguinis exanthematicus. In 1894 Dubief and Brühl[13] described their capsulated diplococcus exanthematicus which they found much more commonly in the air passages and sputum than in the blood. When planted on agar a luxuriant orange-yellow growth was obtained. Animal inoculations, in their opinion, were successful in producing a condition which resembled typhus fever. Porter[15] in 1899 isolated a diplococcus in eighty-eight per cent. of one hundred and forty-three cases of typhus, but was also able to demonstrate the same organism in typhoid patients. Obermeyer[14] has reported the finding of a spirillum in the blood, but in his case as well as in similar cases reported by others it is highly probable that relapsing fever was associated with typhus. A field as yet unexplored, and which may prove a source of knowledge, is a systematic bacteriological examination of the eruption itself.

The Influence of Age.—No definite periods of life can be absolutely settled upon at which typhus fever is especially liable to occur. Many statistics have been gathered, and if we were to base our conclusions upon them we should say that in adult life, between the ages of twenty and forty, the disease is most common. However, all things being equal, social and physical conditions, occupation, environment, etc., the first statement must be accepted as the correct one. The disease occurs at the extremes of life. Wiess[16] (1862) *reported a case in which a fœtus of five to six months* showed irregular black petechiæ with vesicles the size of a pea scattered over the body. The spleen was enlarged, and measured 1.5 by 3 cm. Peyer's patches and the mesenteric glands were swollen. The epidemic from which the mother suffered was true typhus exanthematicus, and in this form of typhus the tendency toward abortion is slight. So far as I am able to ascertain, this is the only case of typhus in the fœtus reported. Buchanan[17] reports a case of typhus in an *infant two weeks old.* Older children, however, are more frequently affected than younger ones. The disease is not uncommon in the aged, in which respect typhus differs from typhoid. Buchanan reports a case in a man of eighty.

Influence of Sex.—It has been demonstrated that if males and females are equally exposed to infection they are equally affected. Men are more frequently affected because they are more frequently exposed. Sex therefore plays a subordinate part in the etiology of the disease.

Influence of Race.—No significance appears to be attached by the majority of authors to race influence. But in the Philadelphia epidemic of 1836 "negroes and mulattos suffered from it more severely than others."

Influence of Occupation and Social Conditions.—Only in so far as occupation and social conditions may bring the individual into actual contact with the disease, as in the case of physicians and nurses, can they be regarded of any etiological importance; that is to say, no particular trade either predisposes to or protects against infection. The contrary view, however, is held by many English physicians, who maintain that butchers and workers in fats, such as candle-makers, are relatively immune. Curschmann,[18] however, does not incline to this opinion, as he has seen as many cases in butchers as in other workmen.

Influence of Season and Meteorological Conditions.—The disease is rare in tropical climates, and flourishes chiefly in colder countries, during the winter and spring months, where imperfect ventilation and crowding of population among the poorer classes supply the conditions favorable to its development. Some large epidemics have occurred, however, during the warmer months, notably the one described by Gerhard. Very low altitudes and damp places, as seaport towns, are thought by Hirsch to be important predisposing factors.

Individual Predisposition.—It is generally conceded that influences that tend to lower the bodily tone of an individual, such as illness, poverty, and worry, are powerful predisposing factors. In this respect a striking contrast is offered to typhoid fever which so commonly attacks young, robust individuals. Even among the classes in better circumstances, where hygienic conditions are more perfect, if any be affected it is almost invariably one whose physical strength is at a low ebb. Convalescents from long-continued or acute diseases are unquestionably predisposed to the disease. It was thought by Hildebrand and his followers that tuberculosis gave a relative immunity to typhus-fever patients. Murchison and Curschmann, on the other hand, do not incline to this opinion, as they not uncommonly found the two diseases together. Littlejohn and Ker[19] in their description of the Edinburgh epidemic (1899) inform us that most of the fatal cases occurred in large, muscular men. They are of the opinion—contrary to the observation of others—that a good physique is a disadvantage in typhus.

Immunity.—Typhus fever resembles the acute exanthematous diseases, in that one attack usually protects for many years and often for life. Murchison was attacked twice, and there are other instances of second attacks that might be mentioned. The disease does not, however, recur with the same frequency as does measles. Hildebrand believed that a certain immunity was obtained by physicians and nurses and those who, by constant attendance upon the disease, became accustomed to the poison. Loomis, who in all his well-known experience in typhus fever never contracted the disease, thought that his immunity was due to some personal idiosyncrasy.

Morbid Anatomy.—There are no characteristic post-mortem changes in typhus fever. The external findings are those which accompany all of the acute exanthematous diseases. Traces of the rash are seldom present. The organic changes that occur are those resulting from the pyrexia. Certain phenomena, nevertheless, occur with such frequency as to demand attention. The most important of these are the following:

Changes in the Respiratory Organs.—To a certain extent in almost all cases the respiratory tract is affected. Tracheal and bronchial catarrh and hypostatic congestion are among the more constant conditions met with, and cases presenting these characters have been designated by Rokitansky bronchotyphus and pneumotyphus respectively. In Ireland they are commonly called catarrhal typhus. In some epidemics laryngeal disease is very common. There may be simply reddening and swelling of the mucous membrane or suppuration may supervene. Not infrequently a unilateral perichondritis, which at times resulted in necrosis, was noted by Curschmann, and in fifteen per cent. of his Berlin cases lobar pneumonia was the immediate cause of death. This, however, is an inconstant factor, as is shown by the fact that Murchison rarely encountered it in England, and Thoinot and Netter make no mention of its occurrence in France.

Changes in the Circulatory Organs.—The chief changes in the circulatory organs are those on the part of the heart. Changes in the blood-vessels have been seldom observed. During the course of the disease unilateral dilatation and infectious myocarditis may be said to be of fairly constant occurrence, but other changes that have been noted in the appearance of the heart are unquestionably due to post-mortem influences.

Changes in the Muscles.—The muscles in general have a brownish-red and dry appearance. They show little sign of wasting. Small ulcerations have been frequently observed in the recti and thigh muscles, and the changes described by Zenker—atrophy of the fasciculi and granular and fatty degeneration—also obtain here, but to a less extent than in typhoid fever. Sometimes hemorrhages take place into the muscles.

Changes in the Liver and Spleen.—The liver is usually enlarged and soft. When death occurs after the ninth or tenth day the spleen is almost invariably found enlarged, if before this time it remains normal in size.

Changes in the Kidneys.—In severe cases the cortex is swollen, opaque, and has undergone more or less fatty change. Cloudy swelling of the epithelial cells of the convoluted tubules may also be seen.

Changes in the Gastro-Intestinal Tract.—Affections of the stomach and intestines are not frequent. Peyer's patches and the mesenteric glands are likewise rarely involved, and infiltration and degeneration are never found.

Symptomatology.

General Description.—*Incubation.*—The stage of incubation lasts for from one to fourteen days, oftenest eight to twelve. Reliable records inform us that its duration may be only a few hours, and that it is very rarely prolonged more than fourteen days. During this stage symptoms seldom manifest themselves. Occasionally a history of headache, loss of appetite, depression, and general inaptitude for work is given.

Invasion.—The outset is, as a rule, sudden. Repeated chills within the first twenty-four hours are common. The temperature rises quickly and may, on the first day, reach 104° F. Headache, pain in the back, and along the course of the larger nerve trunks are quite constant features. Prostration soon sets in, and even the most robust individual takes early to bed. The chills may recur for a few days, and are not infrequently accompanied by nausea and vomiting. The mind, which is at first clear, soon becomes clouded; the patient is uninterested in things about him, his talking is fragmentary, and his expression is dull and stupid. Mild delirium may set in, and in severe cases may develop into maniacal storms. The pulse is rapid, but full in volume; dicrotism is rare. The face soon shows a reddish flush, often a peculiar œdematous appearance, and the conjunctivæ are injected. The intensity of the color in the face is said to be an index of the severity of the disease. The tongue is dry, tremulous, and covered with a yellowish-brown coat.

On the third, fourth, or fifth day the rash appears on the skin of the abdomen. With its occurrence the temperature remains high and the symptoms in no way abate. In severe cases the heart may become enfeebled, respiration accelerated, and death may ensue from exhaustion. In more favorable cases the crisis occurs about the end of the second week, the patient often falls into a refreshing sleep and awakens with a clear mind.

Special Features and Symptoms.—*The Temperature.*—The fever rises steadily and may be 104° F. the evening of the first day. It continues to rise with but slight morning remissions for four or five days and reaches its maximum, 106 to 107 F., about the end of the seventh day. Having reached its height it continues with remarkable constance between 104 and 105 F. until the thirteenth or fourteenth day, when it falls by

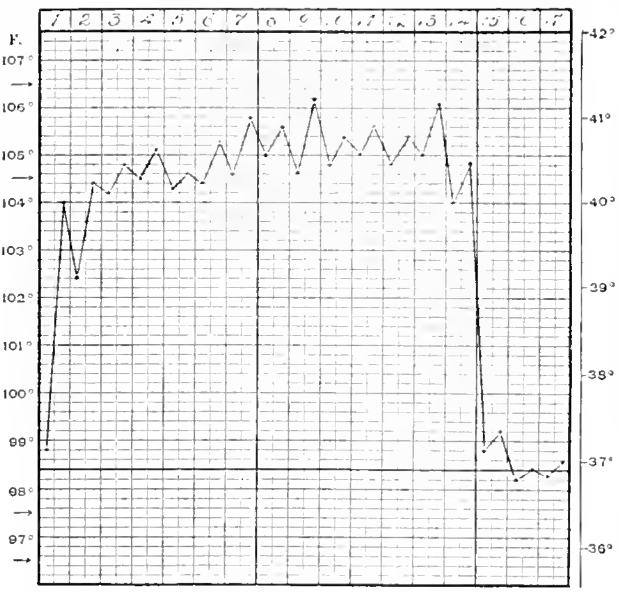


FIG. 4821.—Typical Fever Curve of a Moderately Severe Uncomplicated Case of Typhus Fever, Diagrammatic.

crisis. The crisis is one of the most characteristic features of typhus fever. The temperature may fall in a few hours from 105 or 106 F. to normal or slightly below. A longer time, however, is usually required, and there is frequently a rise of a degree or more before the normal point is reached.

Variations from the typical temperature curve occur, but not as frequently as in typhoid fever. In mild cases the temperature rarely rises higher than 103 F. Much importance has been attached by Wunderlich and his followers to a so-called characteristic drop in the fever on the seventh day, but it has been repeatedly shown that this symptom is the exception rather than the rule. The fever may reach its height within the first twenty-four or thirty-six hours. In many cases defervescence is protracted. This is more noticeable in mild than in severe cases. There are abortive cases in which the onset is severe and the crisis occurs on the fifth or sixth day. A rather remarkable feature, just before death, is the so-called pre-agonic rise to 109 or 110 F.

The Eruption.—Between the second and the eighth days, more frequently on the fourth or fifth day of the disease, the eruption first appears. Salomon[20] reports a case in which the eruption was delayed until the eleventh day. The spots come out first upon the abdomen, chest, and back, then upon the extremities and face. The sequence of the eruption, however, is by no means definite. It develops quite rapidly, so that by the end of the second or the beginning of the third day after its appearance it is all out. It does not come out in successive crops. The eruption is marked on the extremities. The flexor surfaces of the forearm are first involved. In many cases the spots are quite noticeable on the dorsum of the feet. The face is generally exempt, although in some epidemics the eruption on the face has been marked.

In the *stage of hyperæmia* there is at first a fine dusky red mottling just beneath the cutis. The spots soon appear as irregular rose-pink maculæ. They range in size from that of a pinhead to that of a lentil, and may be slightly elevated above the skin. At first they disappear completely when pressed beneath a glass slide later they become a dirty-red color, begin to undergo hemorrhagic change, and give up their color sluggishly when pressed upon. During the early part of this stage, particularly in dark-complected people, the eruption even in the best light may be difficult to see. In children the rash quite frequently resembles that of measles, and because of its peculiar mottled appearance has been called mulberry rash.

In the *hemorrhagic stage* "there is an infiltration of dissolved hæmatin into the tissues of the cutis." This change begins in the centre of the spot and extends to the periphery. The spots soon cease to be hyperæmic, the color only partially disappears on pressure. At first they are bluish-red and as the hemorrhagic change goes on they become a dark livid color. They are more numerous in the inguinal regions, or where the skin is loose. Sometimes the spots appear to be undergoing a true petechial transformation. Indeed, Murchison, Moor,[21] and many others describe the petechiæ as dark purple points in the centre of the spot, or speak of the maculæ being converted into petechiæ. Strictly speaking, these statements are not correct. Hemorrhagic changes that ordinarily occur in the spots must be distinguished from the true petechiæ.

The *petechial stage* is characterized by the occurrence of *direct* hemorrhages into the skin. These little bluish red spots do not disappear on pressure, and are not preceded by a stage of hyperæmia. They occur usually at the height of the disease, and are more common in some epidemics than in others. When they are present in small numbers no importance is attached to them; but when they are abundant and combined with extensive hemorrhages into the skin, they are of bad omen. Hemorrhages into the conjunctivæ are common during this stage. All these, together with the livid spotted body, present a most horrible picture.

The stage of eruption lasts for from seven to ten days, and traces may remain for several days longer. If hemorrhagic changes do not occur the primary rose spots remain but a short time. They may have all disappeared by the end of the first or the beginning of the second day. When the eruption is petechial it may last well into convalescence. The abundance of the eruption appears to be uninfluenced by age or the severity of the disease. It depends rather upon some unknown influence in the character of the epidemic. A peculiar "rotten-straw odor" is described by some authors as occurring during the stage of eruption. Littlejohn and Ker[19] noted it in the somewhat recent Edinburgh epidemic, and assert that it was of great help to them in diagnosis. Gerhard

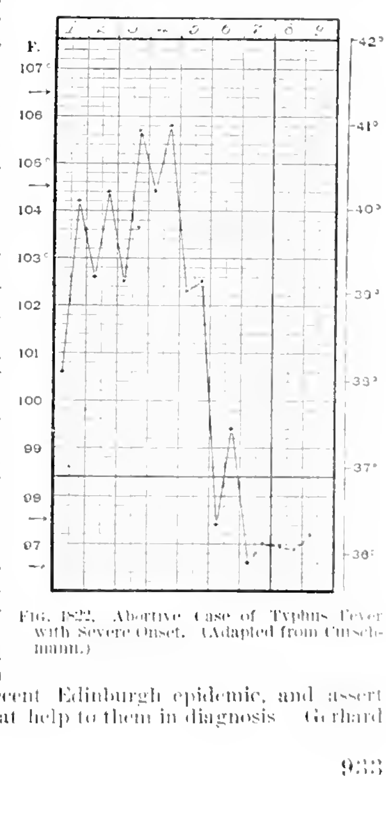


FIG. 4822. Abortive Case of Typhus Fever with Severe Onset. (Adapted from Curschmann.)

describes the odor as "pungent, ammoniacal, and offensive."

Other changes occur in the skin, among which may be mentioned herpes facialis, which is not infrequent, miliaria crystalina (sudamina crystalina), icterus, abscesses, and bedsores.

Nervous Manifestations.—Foremost among the many nervous manifestations of typhus fever is the early and pronounced prostration. The patient is quickly overcome by the intensity of the toxin and immediately takes to bed. Symptoms of nervous excitement often precede the prostration for a few days. He complains of severe frontal headache, pain in the eyes, vertigo, and pain in the sacrum. Insomnia soon becomes a prominent symptom; and if he does sleep, frightful dreams disturb him. Consciousness is maintained for some days, but sooner or later he grows dull and apathetic. Hallucinations of impending harm are very common. Toward the end of the first week the stupor increases, consciousness is finally lost, he mutters to himself, and picks at the bedclothes; there is subsultus tendinum. He may lie with his eyes wide open, unconcerned as to what takes place about him (coma vigil). Delirium of varying degrees is almost constantly present. Even after the temperature has returned to normal delirium may persist. Not uncommonly during the height of the disease, especially in young robust individuals, it takes on a maniacal form; they seek to escape from their terrifying hallucinations by suicidal attempts. On the other hand, depression may predominate. Among other nervous phenomena which deserve a passing notice are convulsions, hemiplegia, and meningitis. Sensory disturbances probably exist at times, but of this we have little definite knowledge.

The Blood shows few important changes; a moderate leucocytosis has been observed. The other changes are those of secondary anæmia—reduction of the red corpuscles and hæmoglobin. This is more noticeable during convalescence from a severe attack. No degenerative changes in the red cells have been observed. The serum does not agglutinate the bacillus typhosus. Little significance is now attached to the changes in the coagulability of the blood, described by the older writers.

Special Senses.—*Eye.*—Of the disturbances of the special senses those of the eye are perhaps the most prominent. Catarrhal conjunctivitis, and even in mild cases keratitis sometimes leading to the perforation of the cornea, and conjunctival hemorrhages may occur. In severe cases the pupils often become markedly contracted in the later stages of the disease; vitreous opacities and choroiditis, iritis and atrophy of the optic nerve have been observed.

Ear.—Disturbances of hearing are common. They usually occur during convalescence; very seldom when the disease is at its height. Hartmann found aural disease in forty-two of one hundred and thirty men during convalescence. The conditions most frequently met with are catarrhal inflammation of the Eustachian tubes and tympanic membrane, purulent otitis media, and perforation of the tympanum.

Renal System.—The ordinary febrile characters of urine are usually present. Retention is not uncommonly met with in women, but is rare in men. More or less definite changes occur in the solids. The chlorides are markedly diminished, and in the later stages of the disease it may be impossible to demonstrate them. Uric acid is almost always increased, but there is practically no variation in the percentage of urea. During the height of the disease there may be a transitory polyuria. At this time the urine is very pale. Albuminuria is common; when moderate it is of no significance. It may, however, be severe and accompanied by hæmaturia, epithelial and hyaline casts, and all the indications of parenchymatous change in the kidneys.

The diazo reaction, as has been pointed out by Vierordt and others, occurs with considerable regularity. Littlejohn obtained it in fifteen of his eighty-two Edinburgh cases. Gerhard's ferric chloride reaction is not infrequently obtained.

Generative System.—Orchitis is even more rarely met with in typhus than in typhoid fever. Menstrual changes are particularly common. The menses may be copious and appear prematurely; but if the disease develops soon after a menstrual period, menstruation may be suppressed until convalescence is well established. Pregnancy exerts no influence on the course of the disease; abortion is very uncommon. The fœtus may be infected (placental transmission), as has been described in the section on etiology.

Respiratory System.—Tracheal and bronchial catarrh occurs so frequently that it may be considered a part of the disease. It is present in the beginning and continues through the height of the disease. It manifests itself by frequent cough with slight expectoration of a glairy, sometimes blood-streaked sputum. Pneumonia and hypostatic congestion are among the not infrequent complications which involve the lungs. No cases associated with true diphtheria are to be found in the literature, though diphtheroid conditions are frequently mentioned. Laryngeal complications, such as swelling of the mucous membranes, erosions, fissures, and ulcerative changes in the cartilages, may also occur.

Digestive System.—Aside from the nausea and occasional vomiting which accompany the chills in the beginning of the disease there are no prominent symptoms referable to the digestive apparatus. It is thought by some that the tongue shows fairly constant characters. At first it is moist and is soon covered with a thick yellowish-brown coat; later it becomes dry, cracked and fissured, and tremulous. Sordes collect on the lips and teeth. There may be constipation or diarrhœa.

Varieties of Typhus.—Typhus fever is subject to many variations in its course. The older writers recognized four distinct forms.

1. Inflammatory typhus which occurs in robust young people and is characterized by headache, high fever, and delirium.

2. Ataxic or nervous typhus in which delirium, stupor, and subsultus tendinum are the most prominent manifestations.

3. Adynamic typhus, characterized by marked prostration, enfeeblement of the heart's action, and early tendency to collapse.

4. Ataxo-adynamic typhus, a term applied by Murchison to those cases which possess characters both of the ataxic and of the adynamic varieties. These forms, as it will be seen, are simply modifications of the ordinary form of typhus due to the prominence of certain symptom groups.

Ambulatory typhus has been considered very rare. Buchanan,[15] however, states that he has often seen the eruption out on patients who have walked to the London Fever Hospital; and there are other well-authenticated instances of this form. According to Griesinger and Wyss the greater number of cases of this form occur in young children.

Mild and Abortive Forms.—Mild forms of typhus are less frequent than in typhoid. In these cases the onset is generally mild. The fever is often irregular, and reaches the normal after many days. These are known as "*febris exanthematica levissima.*" In abortive typhus the onset is usually marked by a violent chill, and the temperature reaches its height by the end of the first or beginning of the second day. It continues with remissions for four or five days, when it drops by crisis, reaching the normal point within a few hours. (See temperature chart, page 933).

Malignant cases, whose duration may be rapidly fatal, occur. They are known as typhus siderans and blasting typhus. Subfebrile and afebrile cases have been reported.

Relapses and recurrences are not common; indeed it has been questioned whether relapses occur at all. Nevertheless a few undoubted cases have been reported. Buchanan records one among five thousand cases at the

London Fever Hospital and Curschmann two among his cases. Curschmann is inclined to regard his cases as anomalous.

DIAGNOSIS.—During an epidemic the diagnosis of typhus fever is not difficult. Unless isolated cases are typical and can be watched for a number of days until the eruption develops, it may be impossible to be certain of the diagnosis. There are a number of diseases which may be confounded with typhus fever. They are here given in the order of their importance:

Typhoid Fever.—The chief clinical differences between typhus and typhoid are to be found in the temperature and the eruption. The gradual step-like ascent of the fever in typhoid is practically never seen in typhus. The onset in typhus is sudden, the temperature reaching a high point within the first twenty-four hours. The morning remissions are very much smaller in contradistinction to those of typhoid. The temperature curve during the first week in typhus is so characteristic as to be almost pathognomonic. The defervescence in typhus, which never occurs later than the fifteenth or sixteenth day, is always by crisis. So all through the course of the disease it will be seen that the temperature maintains typical differences from that of typhoid. The development of the eruption on all parts of the body, and its tendency to become hemorrhagic, are so different from what occurs in typhoid as to leave little chance for error. However, we are not unacquainted with extensive eruption and the occurrence of petechiæ in typhoid. It is characteristic for the eruption of typhoid to develop in successive crops; such is not the case with the typhus eruption. Early appearance and prominence of psychic disturbances point to typhus. The diazo reaction obtains in both diseases, but the presence of the Widal reaction and the isolation of bacillus typhosus from the blood, urine, or stools are distinctive of typhoid.

Smallpox.—The onset symptoms in smallpox and typhus have much in common. There is very little difficulty in distinguishing between variola vera and typhus, as exactly opposite clinical manifestations are present at the beginning of the eruption in each. *Variola Vera:* Eruption on the fourth day, temperature normal or thereabouts, general symptoms abated. *Typhus:* Eruption variable, third to fifth day, temperature then at its height, general symptoms at their acme. It is often wellnigh impossible, on the other hand, to distinguish typhus from hemorrhagic smallpox—purpura variolosa—as in the latter there is a somewhat diffuse hyperæmic rash on the lower part of the abdomen and in the groins, which soon extends and undergoes hemorrhagic change. Small petechial spots and hemorrhages into the conjunctiva are also seen in this disease. The initial rashes in smallpox seldom confuse the diagnosis.

Measles.—While the catarrhal symptoms very frequently accompany the onset in typhus they are not so marked as in measles. The eruptive stage offers the greatest difficulties. In both the temperature is high and remains so after the eruption appears—the fourth or fifth day. The eruption develops rapidly, is macular, and of a rose-pink color. That of measles occurs first on the face, while in typhus the face is usually exempt. In the early part of the disease Koplik's sign and the crescentic arrangement of the spots in measles are very characteristic. A few days will always suffice to determine the diagnosis, for by this time the hemorrhagic changes begin to appear in the typhus spots.

Relapsing Fever.—Typhus and relapsing fever frequently exist together. Under these circumstances, for a time at least, the diagnosis is obscure. The early finding of spirilla in the blood and the later appearance of a rash speak for relapsing fever and typhus respectively.

PROGNOSIS.—Typhus fever is one of the most dangerous of the acute infectious diseases. The mortality is in direct relation to hygienic and sanitary conditions. It is lowest among those affected at large (ten per cent.); highest where only the poorest hygienic conditions are attainable. Under such conditions the death rate may be as high as fifty per cent. At the London Fever Hospital, for twenty-three years ending 1870, the mortality was eighteen to twenty per cent. Such symptoms as subsultus tendinum, pinhole pupil, coma vigil, and relaxation of the sphincters are exceedingly grave.

Among factors which influence the prognosis age stands foremost. The mortality is low under twenty, high between twenty and thirty, higher between thirty and forty, and highest after forty. The disease is almost always fatal in the intemperate. Other factors which influence the prognosis are weather and season, occupation, and individual predisposition. These have been sufficiently considered elsewhere.

PROPHYLAXIS.—As has been stated before, the prevalence of typhus fever is in direct relation to the efficiency of the sanitary conditions of the locality. "Its appearance in well-regulated civilized communities, where sanitary laws are observed, no longer occasions more than passing alarm." Public and personal hygiene must be carried out with the utmost precision and rigid quarantine instituted. There are three measures that demand more than passing consideration.

1. *Isolation.*—Under all circumstances patients should be segregated in well-appointed special hospitals. Expense is not to be spared by municipalities in establishing such institutions. History has shown us again and again that there is neither reason, philosophy, nor common sense in so doing, for here both patient and public are better served.

2. *Abundance of Air and Ventilation.*—In the warmer months these conditions are well met by placing patients out of doors in open tents. In hospitals the beds in wards must be so arranged that each patient has at least fifteen hundred to two thousand cubic feet of air. Free ventilation calls for the interchange of three thousand cubic feet of air per hour.

3. *Disinfection.*—Linen, urine, stools, cooking utensils, furniture, thermometers, or anything that has in any way, directly or indirectly, come in contact with the patient must be disinfected by the most rigid methods. None of these points should be slighted, the more so since we are entirely unacquainted with the specific cause of the disease, and whether it is present in urine, stools, or the exhalations. To accomplish this, carbolic acid, corrosive sublimate, milk of lime, formalin, and *fire* are necessary. Dead bodies should be cremated.

After recovery the patients should be detained in a detention ward for at least two weeks, and bathed frequently with warm water and carbolized soap.

TREATMENT.—The general management of typhus fever is the same as for typhoid. The patient's strength requires attention from the beginning. It is necessary, therefore, that the proper amount of nourishment be furnished. Nothing accomplishes this better than the milk diet employed in typhoid fever, and upon which so much has been written. It has been shown that the digestive processes go on more perfectly when patients are fed at frequent intervals. Systematic daily examinations of the stools for undigested particles should be made. It may be necessary to administer hydrochloric acid; indeed during the height of the fever it is good practice to give small doses—fifteen to twenty drops—as a means of stimulating the gastric secretion, which under such circumstances is decreased. Predigested foods are frequently indicated. Because of the large number of inert digesting agents on the market it is absolutely essential that one be used whose value has been recently tested and found up to the mark. Alcohol is to be given when the indications call for it, and coffee appears to have a beneficial effect upon the stupor.

The fever is best controlled by hydrotherapy. Its use in typhus has not been so general as in typhoid, partly because of the unfavorable circumstances which so frequently accompany epidemics of typhus, and partly because of an unfounded opposition on the part of members of the profession. There can be no question but that the mortality has been greatly reduced by this method of treatment. The statistics of Combemale,[22] while not as large as might be wished for, are nevertheless not without value. He found that with the expectant plan of treatment the mortality was 35 per cent.; that in patients who received two cold baths daily, after the specifications of Brand, it was 33⅓ per cent., and that among those who received six cold baths daily the mortality was reduced to 16.5 per cent. Curschmann advocates the use of hydrotherapy. He speaks favorably of the water-bed method. The patient is allowed to remain for hours, even all day, in water whose temperature is never carried below 68° or 70° F. The water can be conveniently changed from time to time without disturbing the patient. Curschmann employs the Brand method only in the most severe cases.

Among other hydrotherapeutic measures may be mentioned the cold sponge bath, cold packs and half packs, lukewarm baths, and the graduated full bath. For headache and psychic symptoms the ice cap will be found of great value. Whichever method of treatment is decided upon it must be carried out with great regularity.

The cold baths influence not only the fever, but all the resultant cerebral, circulatory, and respiratory symptoms. At times little decrease in the temperature is observed after the bath, but improvement in the general condition is always seen.

The open air treatment has already been referred to under prophylaxis, and has much to recommend it. Special nervous, circulatory, and pulmonary symptoms are managed the same as in typhoid fever.

Specific Treatment.—Little has been accomplished in the way of specific treatment. Legrain[23] tells certain of the beneficial effects of the serum treatment. He treated with success a number of cases in a prison by the injection of serum from convalescent typhus-fever patients. Chantemesse also reports success with this method. Because of the limited number of patients treated, little importance can be attached to these reports. It is unfortunate that more work along this line has not been done. It offers another field of research that has probabilities of fruitfulness.

Methylene blue has been considered to have some specific action in typhus fever. Nefedieff,[24] however, reports unfavorable results with this method of treatment. Other so called specific methods of treatment, as by carbolic acid, sulphocarbolates, and the sulphides, have proved to be of no value.

David Murray Cowie.

BIBLIOGRAPHY.

[1] Corradi: Handbuch der Historisch-Geographischen Pathologie, von Hirsch, Stuttgart, 1881.
[2] Jacobus de Partibus: Commentar ad Avicenn, 1498. Reference to in Pepper's System of Medicine, 1885.
[3] Fracastori: Opera Omnia de Contagionibus et Morbis Contagiosis, Venet. 1555. Quoted by Murchison.
[4] Brown Langrish: The Modern Theory and Practise of Physic, p. 354, London, 1764.
[5] Sauvages: Quoted by Murchison.
[6] Gerhard: The American Journ. of Med. Sciences, February and August, 1837.
[7] Mott and Blore: Brit. Med. Jour., December, 1883.
[8] Moreau et Cochez: Gaz. hebd., No. 28, 1888.
[9] Hlava: Arch. Bohême de Méd., 1889, T. iii., 1; Centralbl. f. Bakt., 1890.
[10] Lewaschew: Deutsch med. Woch., No. 13, 1892.
[11] Thoinot et Calmette: Ann. de l'Institut Pasteur, 1892.
[12] Cheesman: Medical Record, June 25th, 1893.
[13] Dubief et Brühl: Arch. de Med. exper., No. 2, 1894.
[14] Obermeyer: Real-Encyclop. der Gesam. Heilkunde, Eulenburg, s Fistel p. 13.
[15] Balfour and Porter: Edinb. Med. Journ., vol. xlvii, p. 11, December, 1899.
[16] Weiss: Allg. Wiener med. Blatter, 1862, p. 329.
[17] Buchanan: A System of Medicine, Reynolds, London, 1866.
[18] Curschmann: Nothnagel's Encyclopedia of Practical Medicine, Amer. edition, 1903.
[19] Littlejohn and Ker: Edinb. Med. Journ., vol. xlvii, p. 555, 1899.
[20] Salomon: Deutsch Arch. f. klin. Med., 1880.
[21] Moor, J. W.: Allbutt's System of Medicine, 1897.
[22] Combemale: Quoted by Wilson; An American Text-Book of Applied Therapeutics.
[23] Legrain: Gaz. des Hôpitaux, July 4th, 1895.
[24] Nefedieff: Gaz. Hebdom. de Méd. et Chir., August 6th, 1897.

UKIAH VICHY SPRINGS.—Mendocino County, California

ACCESS.—Viâ San Francisco and Northern Pacific Railroad to Ukiah, thence a drive of three miles to the springs.

This pleasant resort, otherwise known as Doolan's Vichy Springs, lies nestled among enchanting hills, which fringe the boundary line of Lake and Mendocino Counties. This region has a combination of advantages which make it a natural sanitarium. From April to November the climate is delightfully balmy and the atmosphere is pure, clear, and invigorating. The scenery is of a pleasing and attractive character, and the neighborhood of the springs affords excellent fishing and gunning. The waters belong to the alkaline-carbonated class, and are clear and sparkling, with an agreeably pungent taste. Their chemical composition is not unlike that of the celebrated Vichy Springs of France (Grande Grille), and their physiological action on the human economy is practically identical with that exercised by those waters. Following is Anderson's analysis: One United States gallon contains (solids): Sodium chloride, gr. 28.60; sodium carbonate, gr. 195.52; sodium sulphate, gr. 0.36; potassium chloride, gr. 0.09; magnesium carbonate, gr. 19.75; calcium carbonate, gr. 18.14; ferrous carbonate, 0.07; silica, gr. 5.92; and traces of potassium carbonate, potassium sulphate, strontium carbonate, barium carbonate, lithium carbonate, borates, arseniates, and salts of alumina. Total solids, 268.45 grains. Carbonic acid gas, 224.75 cubic inches. Temperature of water, 93° F.

The French Vichy contains 408.95 grains per United States gallon. As an antacid, tonic, aperient, diuretic, and alterative mineral water the Ukiah Vichy ranks among the best in the country. It has proved highly beneficial in irritable states of the gastro-intestinal mucous membrane, dyspepsia, torpidity of the bowels, sluggish action of the liver, etc. Excellent results have also been observed in Bright's disease, acid states of the blood and urine, rheumatism, and gout. The waters are soon to be used commercially. There are numerous other springs on the premises, but their waters have not yet been analyzed. Good accommodations and bathing facilities are provided for visitors.

James K. Crook.

ULCER, ULCERATION.—The proper definition of the word ulcer, and exactly what limitations and restrictions should be placed on the term, have always been matters of considerable difference of opinion. Warren,[1] Curtis,[2] Tillmann,[3] and others follow with slight modifications the definition of Billroth, who defines an ulcer as "a loss of substance with no tendency to heal." Warren even goes further and says: "The term implies that the wound or granulation surface is stationary or enlarging, and that it has developed by death of the part piecemeal."

He further states: "An open granulating wound is not an ulcer, but it may become one if the granulations begin to break down and the edges begin to melt away." On the other hand, Park[4] defines an ulcer as "a surface which is or ought to be granulating," thus agreeing with Golding Bird,[5] whose definition is "a limited area of granulation tissue on the surface of the body."

Thus we have two absolutely contradictory ideas. If we accept the first definition, we must exclude all those ulcers which have begun to granulate in a healthy manner, and to which the name "healing ulcer" has been given; while if we accept the definition of Golding Bird, we leave out all those ulcers which are not granulating, such as rapidly spreading phagedenic ulcers, or those whose bases are formed by the underlying tissues (raw ulcer), or that condition known as croupous ulcer. Park, however, overcomes this difficulty by saying "is or *ought to be* granulating." Moreover, although a granulating wound cannot be distinguished pathologically from a healing ulcer, the term ulcer conveys a different impression; a definition which includes all cases would be: An ulcer is a solution of continuity or superficial loss of substance of the skin or mucous membrane which is, or has at some time been, progressively enlarging by inflammation. This definition would include all of the above-mentioned cases, and exclude healthy granulating wounds which have been the result of traumatism.

Ulceration is a word which by many authors is very loosely used. By some it is used synonymously with ulcer. Others employ the term where several ulcers exist, or where a considerable surface is the site of ulceration, as in ulceration of the rectum; but it seems better that the term should be restricted to the pathological process by which ulcers are formed, *i.e.*, a superficial molecular gangrene or disintegration of the skin or mucous membrane.

VARIETIES.—Since Bell,[6] as early as 1778, classified ulcers according to whether they were due to some local cause, or were symptomatic of some constitutional vice, his classification has with certain modifications been largely followed by subsequent writers. A satisfactory classification, however, is rendered difficult by the fact that there are often several etiological factors which may be present in any one case, as, for example, varicose ulcers where frequently traumatism, infection, phlebitis, periphlebitis, œdema, or eczema, either together or separately, may determine the formation or non-formation of an ulcer. Furthermore, an ulcer may be dependent on a certain poison acting in two different ways, either by primary infection or constitutionally, as in the initial lesion of syphilis and in tertiary syphilitic ulcers.

From an etiological standpoint ulcers may be divided into three great classes:

1. *Non-specific ulcers*, including all those cases not due to some particular infection or to malignant disease, but whose etiology depends on: (*a*) traumatism; (*b*) infection with some of the pyogenic or saprophytic bacteria; (*c*) interference with the circulation either of the arteries or of the veins or lymphatics; (*d*) interference with nutrition through the trophic nerves; (*e*) pressure from without as from splints, apparatus, or even the bedclothes, as in the case of bedsores; or from within as from benign tumors, gouty tophi, etc.; (*f*) skin diseases, as pemphigus, eczema, ecthyma, and herpes; (*g*) constitutional disease, as scurvy or diabetes; (*h*) the various causes of ulcers of the mucous membranes (excluding specific infection and malignant disease), as uræmia, mineral poisons, abdominal burns, etc.

2. *Specific ulcers*, including those due to: (*a*) syphilis; (*b*) tuberculosis; (*c*) typhoid; (*d*) diphtheria; (*e*) various forms of dysentery; (*f*) malaria; (*g*) glanders; (*h*) actinomycosis; (*i*) leprosy.

3. *Malignant ulcers*, among which are included superficial malignant new growths which break down and ulcerate, or deeper ones which involve and destroy the skin or mucous membrane overlying them. These malignant ulcers may follow the types of carcinoma, sarcoma, epithelioma, or rodent ulcer, being due to the breaking down of the primary growth, or an old chronic ulcer may become malignant by undergoing epitheliomatous or more rarely sarcomatous degeneration.

Besides this classification according to etiology, various names are given to ulcers depending on their condition at the time of examination. Thus we have:

1. Healing.
2. Spreading: (*a*) inflamed; (*b*) phagedenic; (*c*) sloughing.
3. Chronic: (*a*) with feeble, indolent or exuberant granulations; (*b*) with callous edges; (*c*) with a croupous base; (*d*) with a raw base. And in addition the terms fungating ulcer and scirrhous ulcer are sometimes used to describe ulcers due to malignant disease. By some authors these names depending on the condition of the ulcer are used as a basis of classification; but in reality they are only phases through which various ulcers may run during their course.

ETIOLOGY.

We have seen in considering the classification of ulcers that there may be several factors in the etiology of one of these lesions, or that one cause may act alone. The etiology may therefore best be studied by dividing it into:

1. Predisposing causes: (*a*) general; (*b*) local; and
2. Exciting causes.

1. PREDISPOSING CAUSES.—(*a*) *General — Age, Sex, Occupation, Social Condition, etc.* Age can hardly be considered as an important factor in the etiology of an ulcer, as there are so many other elements which have a more direct bearing on its causation. To be sure, old age is accompanied by retrogressive tissue changes, atheroma of the arteries, impaired circulation, etc., and one would therefore expect the statistics to show a greater proportion of ulcers during the later decades of life. But that ulcer is not relatively more frequent in the aged is probably due to the fact that such frequent causes as tuberculosis prevail in the early decades, and syphilis in early middle age, and also that traumatism in the early and middle decades is more frequent than among the aged. As regards sex, it has been shown by statistics that ulcer is three times more prevalent in men than in women. This is probably due to the fact that men are more exposed to traumatism, and that they are more likely to neglect a slight wound, which with infection becomes an ulcer. Also the greater prevalence of syphilis and alcoholism in men may in some measure explain why ulcers are more common among them than among women. Occupation seems to have little t do with the etiology of ulcer beyond the fact that it may predispose to traumatism or various forms of infection and that it may prevent cleanliness. It is in this latter element that we have one of the most important etiological factors in the causation of ulceration. The non-specific and non-malignant forms of ulcer are infinitely more common among the poorer classes, among whom lack of means or lack of intelligence, as well as untidy habits, will allow filth, and with it of course infection, to enter a wound the result of some slight abrasion, or the lesion of some skin disease; and the formation of an ulcer is the consequence.

Constitutional Disease.—Many of the constitutional diseases such as diabetes, lithæmia, scurvy, anæmia, tuberculosis, and syphilis, as well as the exhausting fevers, as typhoid, scarlatina, etc., lower the vitality of the tissues, while other conditions, such as valvular disease and fatty degeneration of the heart, general obesity, and atheroma, by preventing proper circulation predispose to the formation of ulcers when there is in addition some exciting cause.

(*b*) *Local Predisposing Causes*—1. *Interference with the Arterial Circulation.*—There may be a predisposition to ulceration as a result of embolism which cuts off the nutrition of a part, or the embolus may be infected and thus cause the formation of an abscess, which, if superficial, may result in the development of an ulcer. Atheroma of the blood-vessels, by interfering with nutrition, may also act as a local cause. Certain vaso-motor disturbances, such as occur in frost bite, chronic ergotism, and Raynaud's disease, may produce small areas of localized gangrene, and these areas may become subsequently the seat of ulceration.

2. *Interference with the Venous Circulation. Varicose Veins.*—When œdema results from interference with the return of venous blood from a part, it is obvious that such a condition would predispose to the formation of ulcers. The exact relation of varicose veins to the formation of ulcers is, however, a matter of dispute. There are many people who have varicose veins even to a severe degree, who never suffer from ulcer; consequently we must look for some other element in the etiology. Schreider[7] tried to prove this other element to be the gouty diathesis, and he considers both the varicose veins and the ulcers to be the result of lithæmia. Quénu[8] found a neuritis secondary to the varicose veins, and considers the formation of the ulcer to be due to trophic disturbance. In this view he is upheld by Silvy.[9] On the other hand, Mr. A. Pearce Gould[10] writes of "those troublesome ulcers of the lower third of the leg nicknamed varicose." There is one condition, however, which certainly has a direct bearing on the relationship of varicose veins to ulcer, and that is

phlebitis. Where phlebitis and periphlebitis occur, especially in the smaller venous radicles, small abscesses often form, the adjacent skin becomes involved, and an ulcer develops, or the rupture of the diseased wall of one of the

FIG. 4823. Ulcers due to Lymphatic Obstruction. (From Dr. B. Farquhar Curtis.)

small veins may, in the case of a person of uncleanly habits, readily prove the entering point of infection. Then, under the favoring influence of an impaired circulation in and poor nutrition of the part, such a rupture is not unlikely to end in the formation of an ulcer.

3. *Interference with the Lymphatic Circulation.*—Occasionally, in the treatment of extensive cellulitis, it is found necessary to make deep incisions, and the contraction of the resulting scar tissue may interfere with the lymphatic flow and give rise to stasis and thickening of the part. Under such conditions, and especially when they occur in the leg, ulceration is very likely to take place. A similar condition is found in elephantiasis (Fig. 4823).

4. *Trophic Changes.*—In the discussion of the so-called varicose ulcers, it has been mentioned that Quénu and Silvy believed the ulcer formation to be due to trophic changes. There are many other conditions, however, in which the relationship of ulceration and disease of the nerves or nervous system is more apparent. In infantile paralysis, in which the nutrition of certain parts is impaired by reason of the diseased condition of their centres in the spinal cord, all that is needed for the production of an ulcer is often a slight traumatism plus infection. Perforating ulcer of the foot is a frequent complication of locomotor ataxia. Also myelitis, peripheral neuritis, and other pathological conditions of the nervous system may, either through trophic changes or by reason of impaired sensation, be directly related to the formation of an ulcer.

EXCITING CAUSES.—*Traumatism, etc.*—One of the most frequent direct causes of ulcer is an injury of one kind or another. The degree of the injury may of course vary greatly, and whether or not it will produce ulceration depends on one or more of the predisposing causes already mentioned. A severe traumatism may be necessary entirely to destroy the vitality of a part in a healthy person; while a slight injury might do so in the presence of lowered vitality, constitutional disease, impaired circulation, trophic nerve disturbance, or where the amount of subcutaneous tissue between the bone and skin is slight in amount, as over the malleoli for example. Moreover, the nature of the traumatism may vary. The skin or mucous membrane may be destroyed by a contusion, laceration, friction, or a burn, so that it must heal by granulation. If healing occurs in a healthy manner at once, without any infection, we have a clean granulating wound. If, however, infection takes place and the wound becoming unhealthy extends by a process of molecular gangrene, then we have an ulcer. Pressure from within or from without may cause ulceration, mainly by the cutting off of nutrition and thus producing localized gangrene. As illustrations of ulcers caused by pressure from without may be mentioned bedsores, as also pressure sores from too tightly applied splints and badly fitting orthopedic apparatus. Ulceration may also be caused by pressure from within outward, as in the case of the end of the bone in faulty amputations, and in that of the growth of a benign tumor. In the same manner foreign bodies, such as deposits of biurate of sodium (gouty tophi), may result in ulceration of the overlying skin. Or the ulcer may be produced by the irritation caused by the presence of a foreign body beneath the skin, as in the case of a dracuncular ulcer caused by the filaria medinensis or guinea-worm.

Infection.—Roswell Park [4] says: "The idea underlying ulceration is infection, and when limited to its proper significance, the term should never be used for a process in which infection and consequent breaking down of tissues do not virtually comprise the whole process." The development of an ulcer from a clean granulating wound or abrasion usually depends on infection with some of the ordinary saprophytic or pyogenic germs. Or, in another class of cases, infection with consequent suppuration or gangrene of the skin resulting in ulcer formation, may take place through the circulation. Rapidly spreading ulcers, such as occur in phagedena and hospital gangrene, and some of the rapidly spreading forms of tropical ulcer, are usually due to some particularly virulent septic infection, acting on a weakened subject. The chancroid is also an ulcer depending for its existence on infection, whether it be due to the ordinary pyogenic germs, or to a specific bacillus, such as has been described by Ducrey, who found a rod-shaped bacillus with rounded ends in the secretion from chancroidal ulcers. In old chronic cases the bacteriological infection is of a mild type. Bukovsky [11] examined bacteriologically one hundred cases of ulcer of the leg, and found that the number of bacteria, even in foul cases, was much less than he expected, in many cases only a single species being found. The bacillus pyocyaneus was most frequently found. Other organisms found were the staphylococci, streptococci, B. coli, B. proteus, and (in a single instance) Friedländer's pneumococcus. Less interesting were the micrococcus albus, M. sulphureus, B. lactis aërogenes, B. mesentericus, B. subtilis, B. tumescens, and sarcinæ. On the other hand, certain definite forms of ulceration depend on infection with some specific germ or virus, *e.g.*, syphilis, tuberculosis, leprosy, typhoid, glanders, etc.

Syphilis.—This disease in its various stages is one of the most frequent causes of ulcer formation. In the primary stage the chancre is usually an ulcerative lesion. The ulcerative manifestations of secondary and tertiary syphilis may develop from a tubercular, pustular, or pustulo-crustaceous syphilide. But it is in the tertiary stage which, according to the statistics of Haslund,[12] develops in twelve per cent. of all cases infected, that we find the form which is most often spoken of as a true syphilitic ulcer. In this stage gummata form in the subcutaneous tissues or deeper parts, the overlying skin becomes involved and breaks down, the gumma due to its poor nutrition and deficient blood-supply sloughs out, leaving either the typical "punched-out" syphilitic ulcer or else a deep ragged ulcer with overhanging edges. In addition to the tertiary ulcer originating from a gumma, an obliterative endarteritis due to syphilis in its late stage may, by interfering with the nutrition of a part, predispose to ulcer formation.

Tuberculosis.—Ulcerative lesions due to infection with the tubercle bacillus are common both in the skin and in mucous membranes. In the skin they may be due to direct infection by the tubercle bacillus and they then take one of three forms: tuberculosis cutis, which is due to a local infection, but is part of a general tuberculosis; tuberculosis verrucosa cutis, which is frequently spoken of as anatomical tubercles or post-mortem warts, and is usually found in dead-house attendants, butchers, and those who have to do with animals; and lupus vulgaris. The fourth and most common form of tuberculous ulcer of the skin, known as the scrofuloderm, is due to indirect infection of the skin. It occurs usually in young subjects, most frequently in the neck, or over some group of lymphatic glands, or over a joint which has been the seat of tuberculous inflammation. Suppuration occurs in the infected part and the pus is discharged through a sinus leading to the surface, where a typical tuberculous ulcer develops. The same form of ulcer may develop from a deposit of tuberculous material in the subcutaneous tissues, quite independently of any gland or bone involvement, the tuberculous tissue breaking down and involving the overlying skin. There is still another ulcerative skin lesion which has been attributed to tuberculosis, but its exact etiology is still a matter of dispute; I refer to erythema induratum or Bazin's disease. Thibierge and Rayaut,[13] Colcot Fox,[14] and Philipson[15] believe it to be of tuberculous origin. Tenneson,[16] Leredde,[17] Audry,[18] and Johnson[19] came to the opposite conclusion. Whitfield[20] suggests that there are two diseases included under the same heading. On the mucous membranes tuberculous ulcers may occur as a primary lesion, but most frequently they are secondary to tuberculosis in some other part of the body, usually the lungs.

Other Forms of Specific Infection.—There are, besides tuberculosis and syphilis, several other forms of ulcerative lesions of the skin and mucous membranes due to specific infection. Glanders or farcy due to the bacillus mallei may be contracted by human beings from horses or mules. Soft nodules form in the mucous membranes (usually of the nose) or in the skin, and these rapidly break down, leaving ragged ulcers. The lesions of actinomycosis, or "lumpy jaw," due to the ray fungus, usually at an early stage become infected with pyogenic bacteria, suppurate and form abscesses which discharge by fistulæ, and if close to the surface form ulcers. A form of chronic perforating ulcer of the foot, known as "Madura foot," is caused by a fungus closely resembling the actinomyces. Leprosy due to the lepra bacillus, discovered by Hansen in 1874, is also an ulcerative disease, the ulcers being due to the breaking down of the leprous tubercles or to trophic nerve changes, or else they are caused by the fact that the impaired sensation prevents recognition of an injury.

There are many other specific infections which result in ulceration of the mucous membranes. Thus, for example, ulceration may be produced by the typhoid bacillus, the diphtheria bacillus, the amœba coli, the dysenteric bacillus of Shiga,[21] and, as has been recently reported by Haller,[22] the malarial plasmodium. (For further details with regard to these the reader is referred to the special articles on these subjects.) Two of the forms of intestinal ulceration are, however, of especial interest from an etiological point of view: the ulcers of the duodenum secondary to cutaneous burns and those described by Mathieu and Roux,[23] which are due to uræmia.

Skin Diseases.—Certain forms of skin diseases, such as herpes, especially when it occurs on the genitals, ecthyma, and pemphigus, where infection of the primary lesion occurs, and there is a lack of cleanliness, may result in the formation of ulcers. This is particularly so in eczema, where the inflamed, thickened, serum-infiltrated skin is easily abraded and apt to break down and form ulcers. The ruptured vesicles of eczema also make an excellent point for entrance of infection, and when eczema accompanies varicose veins of the leg, it is often very difficult to prevent ulcer formation.

Action of Drugs.—Besides the local escharotic effects of certain drugs, as an etiological factor in producing ulcers, some drugs produce ulceration of the mucous membranes by their elimination. Mercury by its elimination by the salivary glands may cause an ulcerative stomatitis; by elimination in the colon, an ulcerative colitis. Phosphorus, by causing a necrosis of the maxilla, may result in ulceration of the buccal mucous membrane.

Malignant Disease.—Primary new growths of the skin usually take the form of epithelioma, which may develop on any surface of the body where there is squamous epithelium. Nearly three-fourths of these neoplasms occur on the face and lips. Rodent ulcer, a form of epithelioma, nearly always is found on the upper half of the face. These lesions are ulcerative from the beginning. Sarcoma of the skin—viz., the melanotic form—does occur, but it is rare in comparison. Carcinoma and sarcoma may also produce ulceration by secondary involvement, as when by rapid growth and subsequent breaking down of growths lying close to the skin, the latter is destroyed, and an ulcer is established. In addition to these primary and secondary ulcerating neoplasms a chronic ulcer in an old person may undergo epitheliomatous or, more rarely, sarcomatous changes and become malignant.

Etiology of Regional Ulcers.—In addition to the varieties of ulcer already spoken of, we may mention here briefly the various forms of ulcerative stomatitis due to traumatism, infection, gastritis, and sprue, as well as to mercurial poisoning. Ulceration of the rectum also deserves to be mentioned here. Although it may be due to several causes, in a large number of instances it is due to tertiary syphilis, and especially to the breaking down of gummata. Tuberculosis, either primary or secondary to tuberculous deposits in other parts of the body, dysentery, acute proctitis, traumatism from hardened fæces or foreign bodies in the fæces, pressure from a polypus or from a displaced uterus in women—all these may be causes of ulceration of the rectum.

Fissures, or those forms of ulcer which occur at the junction of the skin and mucous membrane of the nose, mouth, or anus, and on the nipples of nursing women, may also be considered under this heading. Fissures at the angle of the mouth, due to tuberculosis, have been already mentioned under the name of tuberculosis cutis. In infants suffering from hereditary syphilis, fissures are frequently found about the mouth and anus. The usual form of fissura in ano, a small, extremely painful linear ulcer, ordinarily found near the posterior commissure, is due to abrasion with hardened fæces or to infection after scratching, or to the breaking down of a herpetic vesicle. Ball considers anal fissure to be due to a broken-down anal valve. The lesion is prevented from healing by the movement of the sphincter at defecation and the turning in of the edges of the ulcer. Fissures of the nipples are due to infection following an abrasion or injury caused by the infant's nursing, and are prevented from healing by motion of the part.

Pathology.

The pathology will vary somewhat with the conditions causing the ulcer, although in the non-specific forms of ulcer we shall find the phenomena of congestion, exudative and necrotic inflammation, together with reparative inflammation or granulation, making up the whole process. In the stage of development of the ulcer the degenerative process predominates, in the healing stage the reparative.

When the ulcer develops from without, as when infection enters the skin through an abrasion, or through a wound of a different character, congestion first occurs. This is rapidly followed by the emigration of leucocytes, by a diapedesis of red blood cells which rapidly disintegrate, and by an exudation of serum and fibrin. At the same time there is a proliferation of the epithelial cells of the rete mucosum lying on the papillary layer of the corium, and also a proliferation of the connective-tissue cells of the corium. The tissues next become softened by the exudate between the cells. Then, as a result of the pressure of the exuded serum, of the crowding by the leucocytes, and of the cutting off of the blood supply, and also in some measure through the effects of the toxins furnished by the bacteria, there occurs necrosis or death of the cells, which are thrown off from the surface with the products of exudation, until there is formed an ulcer with its base consisting of spheroidal and a few epithelioid cells developed from the connective-tissue cells by proliferation.

The process of molecular gangrene just described does not represent the only way in which an ulcer may form; it may develop from a blister, by the sloughing away of an area of localized gangrene, from an infected wound with loss of substance, by the destruction of the skin over a superficial abscess, or by pressure from within. After its formation it may heal, continue to spread, or become chronic.

If an ulcer in its complete stage of development be examined, it will show the following pathological condition: The surface is covered with a layer formed by the overproduction of new round cells, together with the exudate of serum, fibrin, and the cellular elements of the blood. When the discharge from the ulcer is profuse, this may be constantly washed away. When the ulcer is sluggish, it may be in a condition of coagulation necrosis. In this condition a croupous material covers the base of the ulcer, and below this is a more or less distinct layer largely composed of cellular elements, with very little intercellular substance, the cells being spheroidal and epithelioid in character and mingled with polynuclear leucocytes. As we go deeper, the amount of intercellular substance increases, and we find a number of transparent fibres and fusiform cells. In this layer of granulation tissue are also the newly formed blood-vessels, the most superficial branches being vertical to the surface, and developing by a process of budding from the endothelial cells of the capillaries deeper down. This layer is paler in color than the layer made up of the cellular elements, but may contain pigment from the disintegration of the red blood cells. It gradually merges into a layer of cicatricial connective tissue which lies beneath the ulcer. A section of the edge of a chronic ulcer would show an enlargement and prolongation of the papillæ, with a marked proliferation of the epithelial cells covering them. This is most marked in the condition known as callous ulcer, where the edges may by this proliferation be considerably raised above the level of the surrounding skin, and often overhang the base of the ulcer, as if nature were trying to bridge it over.

Under proper treatment the reparative process proceeds faster than the degeneration of the cells and the ulcer begins to heal by granulation. Small sprouts or buds of protoplasm protrude from the capillaries below or in the base of the ulcer, developing from the cells in their walls. These are hollowed out by the blood pressure and form new blood-vessels which anastomose with others. Nuclei form in the protoplasm and thus endothelial cells develop. At the same time small spheroidal cells developing from the connective-tissue cells become grouped around the blood-vessels. These at first are closely crowded together, being only separated by a small amount of fluid intercellular substance. Some of the round cells then become larger and fusiform or branched. The larger cells are known as epithelioid cells. Some of the fusiform and branched cells, called fibroblasts, develop the new delicate fibrillar intercellular substance, while others form the connective-tissue cells. Gradually the fibrous intercellular substance increases in amount, while the cells become fewer and flattened, and cicatricial tissue is formed. The contraction of this cicatricial tissue constitutes an important element in the healing of an ulcer.

During the process of granulation, more of the round cells are produced than is necessary. These die and are thrown off in the discharge. Healthy granulations should be small, even, and of a reddish-pink color. Where the growth of the blood-vessels proceeds more rapidly than the development of the cells and the formation of connective tissue there is produced a soft, pale, flabby condition known as exuberant granulations. On the other hand, both the cells and the blood-vessels may develop very slowly, forming indolent or sluggish granulations.

In order that the ulcer may heal it must eventually become covered with epithelium, and this (unless grafting is practised) can only develop from the epithelium at the edges of the ulcer. Under favorable conditions, when the granulations reach the level of the surrounding skin, the epithelium begins to spread in a thin bluish-white line from the edges, out over the surface, until it is entirely covered, when the ulcer is healed. The rapidity of this process differs in different cases. Deutsch[24] measured one hundred healing ulcers, exclusive of traumatic cases, and found the average growth of epithelium to be from 2 to 3.5 mm. per week. The influence of contraction of the base of the ulcer, however, must also be taken into account.

The scar left by the healing of an ulcer is always considerably smaller than the original lesion, due to contraction of the cicatricial tissue, and this contraction, especially when the ulcer has occurred on the face, may lead to considerable deformity. The healed surface differs from normal skin in the absence of hair follicles and of sebaceous and sweat glands. In the mucous membranes, on the other hand, regeneration to a condition more nearly approaching normal occurs.

Modifications of the Course in Special Forms of Ulcer.—The pathological condition which has been described above applies to the simple forms of ulcer; but it practically forms the basis of all cases of non-specific and non-malignant ulcer with certain modifications due to the conditions present and to the etiology. These pathological changes are found not only in the ulcer itself, but also in the adjacent tissues. When an ulcer becomes acutely *inflamed*, a condition of cellulitis exists in its base and edges and in the tissues surrounding it. In a *spreading* ulcer there is little or no attempt at a reparative process, while degeneration and death of the cells proceeds rapidly. This may occur to such an extent in *phagedenic* or *sloughing* ulcers that we find, in addition to a process of molecular gangrene, considerable areas of necrotic tissue in the base and edges of the ulcer. In certain chronic cases there may be very little or no formation of granulation tissue, and the base would then be formed by the underlying body tissues instead of the layer of round cells already described. This condition is known as *raw* ulcer. In other cases the base may be smooth and shining like mucous membrane, or may be covered with a *croupous* layer formed of the material exuded. In *scorbutic* ulcers the base is covered with an adherent spongy, fœtid, dark-colored crust, and bleeds very easily.

In the case of *varicose* ulcers there is usually more or less pigmentation of the surrounding skin. Often œdema of the skin and subcutaneous tissues, and in many cases eczema, is present. When the latter occurs there is apt to be more than one ulcer. The veins are dilated, thickened, and tortuous, and show marked insufficiency of their valves. These changes are more marked in the superficial than in the deep veins, and cases vary as to whether the dilatation of the larger veins or that of the smaller radicles forms the more prominent feature. The walls of the veins become the seat of a phlebitis, which may be suppurative in nature, producing a periphlebitis, and thus frequently, by involvement of the skin, causing the formation of a new ulcer. The arteries may show an endarteritis. The nerves, as previously mentioned in connection with the etiology, show the signs of chronic neuritis. In old, chronic cases the connective tissue, muscles, and even the underlying periosteum and bone may be affected by a chronic productive inflammation.

Syphilis.—The pathology of syphilitic ulcers differs from that of the cases previously described, in that the ulcerative process is preceded by a productive one. In the chancre we have first an infiltration of the connective tissue at the site of the lesion with small spheroidal cells and an occasional giant cell, together with a proliferation of the connective-tissue cells. This breaks down and ulcerates at the surface. The superficial ulcers of the late secondary or of the tertiary stage are preceded by a round-cell infiltration, which may break down at once and form a pustular lesion from which an ulcer develops, or one or more tubercles may form which then break down. It is by the spreading and marginal growth of one of these tubercles or the progressive involvement of others, while healing is going on at one part of the ulcer, that the serpiginous ulcer forms. The deep ulcers of tertiary syphilis develop from gummata. These are variously sized deposits, largely made up of small spheroidal cells with some polyhedral and occasional giant cells. They are poorly supplied with blood-vessels and undergo coagulation necrosis, but do not tend to suppurate until infected. Sooner or later the overlying skin becomes involved, either with or without a secondary pyogenic infection, and the gumma then sloughs out, leaving the typical syphilitic ulcer. A bacillus, which has been described by Lustgarten,[25] and which is very similar to the tubercle bacillus, is found in small numbers in the lesions. Lustgarten was unable to cultivate it artificially. Van Niessen,[26, 27], however, succeeded in cultivating from the blood of syphilitics and from the discharge from syphilitic condylomata a bacillus which when inoculated on monkeys developed a primary lesion and general glandular enlargement similar to those seen in man.

Tuberculosis.—The gross pathological condition of ulcers due to tuberculous infection varies greatly, depending on the variety of the lesion. It may take the form of discrete, shallow ulcers as in tuberculosis cutis, or that of the ulcerative warty lesion of tuberculosis verrucosa cutis. Lupus vulgaris, characterized by its brownish red, semi-translucent, smooth, shiny, apple-jelly-like tubercles, also due to tuberculosis, may form an ulcerative lesion, but the non-ulcerative form is more common in this country. Erythema induratum begins as a varying-sized nodule under the skin which subsequently breaks down. The forms mentioned above, together with the irregular ulcer with livid overhanging edges, known as the scrofuloderm, the origin of which has already been mentioned, show how great a variety exists in the gross pathology of tuberculous ulcerative lesions. The minute pathological examination, however, shows all of these forms to be dependent on the formation and subsequent breaking down of tubercle tissue. The latter may be localized, forming miliary tubercles, or it may be diffuse. The tubercle bacillus and its toxins cause a productive inflammation, with proliferation of the connective-tissue cells, the tubercle tissue thus being made up of small spheroidal or polyhedral cells, or of the latter together with a fibrous stroma and cells resembling leucocytes, or of giant cells. At times the tubercle tissue very closely resembles granulation tissue. There is very little production of new blood-vessels, and the tubercle may undergo coagulation necrosis and caseous degeneration. The process may cease by encapsulation of the lesion with fibrous tissue, but the most frequent course is that in which the lesion breaks down, either as a result of secondary infection or directly without the intervention of infection. The pus which is formed as a result of this breaking down finds its way to the surface, along the course of least resistence, and gives rise to the scrofuloderm.

Neoplasms—Malignant Degeneration.—When an ulcer occurs as a result of a benign tumor, the cause being pressure, the pathological process is similar to that of the simpler forms of ulceration, although in some cases, as for example in cystadenoma of the breast, the rapid growth of the tumor may cause the tissue of the new growth to form the base of the ulcer. When, however, the ulcer is a result of malignant new growth, whether primary or secondary, the ulcerative process is due to a breaking down of the cells forming the new growth and an involvement of the adjacent structures with cancer cells. There may also be more or less production of granulation tissue. Primary malignant ulcers may be due to sarcoma, but far more frequently they are of the epithelial type—carcinoma, epithelioma, or rodent ulcer. Both sarcoma and carcinoma may secondarily involve the skin and produce ulceration. The former has a markedly less tendency to do so than the latter, but sarcomatous ulceration, when it does occur, is apt to take on the characters of the fungating variety. In all of these malignant ulcers the base and edges are made up of the cells of the neoplasm. For the minute pathology the reader is referred to the articles on *Carcinoma*, *Sarcoma*, and *Epithelioma of the Skin*.

Old chronic ulcers, especially in elderly patients, may undergo epitheliomatous degeneration and become malignant. This process, when it occurs, begins in the edge of the ulcer, taking its origin in the epithelial layer of the skin, and by its growth both base and edges of the ulcer become formed by the malignant epitheliomatous tissue, and the appearance then presented is that of a foul, hard, warty, easily bleeding ulcer. Sarcomatous degeneration of a chronic ulcer has also been reported. Here the new growth takes its origin in the connective-tissue cells instead of the epithelium.

Symptoms and Course.

Non-specific Ulcers.—The appearance and symptoms of the various non-specific ulcers will vary with the etiology of the ulcer and the pathological condition present at the time of examination. These differences will manifest themselves in the shape and size of the ulcer, in the appearance of the base and edges, in the character of the discharge, and in the condition of the surrounding tissues.

Acute Traumatic Ulcer.—When an ulcer is formed as a result of infection of an area where the skin has been destroyed by some form of traumatism, the symptoms are those of an acute inflammatory condition. The base of the ulcer is usually only slightly depressed, and is of a gray or dirty-yellow color, or sloughing in appearance. There are few or no granulations, the edges are clean-cut, soft, and inflamed, the surrounding tissue is red and congested, and the discharge is thin, sero-purulent, or blood-stained and containing débris. The shape of the ulcer will vary with the nature of the traumatism. These cases are accompanied with more or less pain. Such an ulcer may begin to granulate and heal, may spread or become chronic; and these conditions, which are more or less common to the various forms of ulcer, subject to modification depending on the etiology, will next be described.

Granulating or Healing Ulcer.—All ulcers which have reached the healing stage, irrespective of their cause, present practically the same appearance. The shape is round, or that of the original injury. The base is of a light-red color, even with the edges, or slightly depressed, not tender, and showing no evidence of hemorrhages. It should be covered with medium sized, regular, even granulations. The edges are soft, shelving, not thickened, and marked by a bluish-white border of newly formed epithelium, which is spreading over the surface of the ulcer from the epithelium of the skin, and will finally cover the surface. The peculiar bluish white color of this border is due to the presence of new blood-vessels which show through the translucent young epithelial cells. The surrounding area is soft, and not inflamed. The discharge is slight in amount and consists of a thick yellowish purulent material which is really not pus, as it is not the result of the death of leucocytes in an effort to combat infection; it is due rather to the throwing off, from the surface, of the unnecessary cells formed as a result of overproduction. The discharge is not very irritating and contains very few bacteria. An ulcer in this stage is not painful.

Spreading Ulcer.—Either from the start or later, as a result of a new infection or of some other complication, an ulcer may begin to increase in size. Its shape becomes irregular. The base is uneven, is gray or of a dirty-yellow color, and may be blood-stained. The process of degeneration is greater than that of repair, and there are no granulations. The edges may be thickened, by reason of the presence of an inflammatory exudate that forms while the ulcer is spreading slowly, or thinned out and undermined, on account of the rapidity with which the ulcer is spreading. The discharge is increased in amount, is thin, semipurulent, contains more or less débris thrown off by the rapid death of tissue, and is often foul and irritating. When such an ulcer becomes inflamed, the base, edges, and surrounding tissues become red, congested, and the site of a cellulitis. Often phlebitis, periphlebitis, and acute eczema are present. There are pain and throbbing in the part, and the discharge becomes profuse, purulent, and often blood-stained.

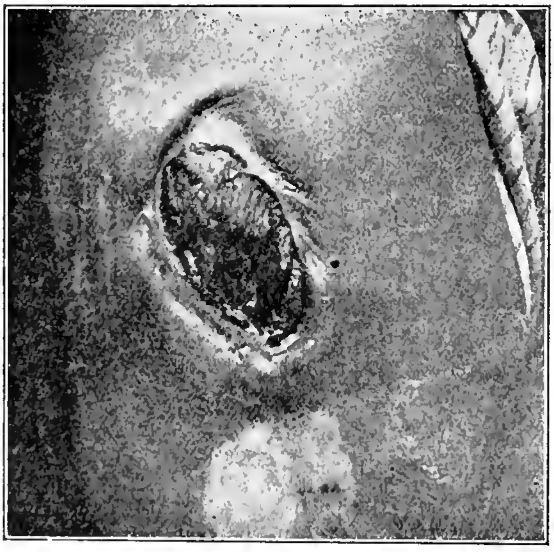


FIG. 4824.—Chronic Traumatic Ulcer, showing Raw Base, Absence of Granulations, and Thickened Adherent Edges.

The variety of spreading ulcer, known as *sloughing ulcer*, is particularly apt to occur in old persons of low vitality, with senile leg ulcers that have developed after exposure. The base is irregular and covered with sloughs or even with small areas of gangrene. There are no granulations. The edges are irregular, excavated, sloughing, and necrotic, or may be gangrenous in small areas. The discharge is profuse and foul, and contains the products of necrosis. Those very rapidly spreading cases, known as *phagedenic* ulcers, are fortunately, since the development of aseptic surgery, rare. They occurred in hospital gangrene, in some cases of venereal infection, and were more apt to be found in tropical climates, and where the patient was weakened by fever and disease. A severe grade of infection acts as the exciting cause. The base is irregular, sloughing, and covered with a grayish, fœtid, pulpy material. There may be large areas of gangrene. The edges are thinned out and undermined, the subcutaneous tissues disappearing before the skin, and are often gangrenous in places. The discharge is very foul and irritating.

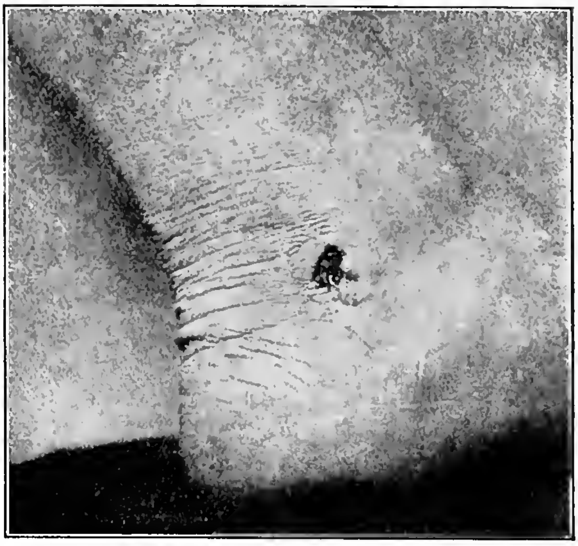


FIG. 4825.—Typical Erethistic Ulcer, showing Usual Situation and Appearance.

Chronic Ulcer.—Any ulcer may, from a variety of causes, fail to heal and become chronic. The most usual position, however, in which these ulcers are found is on the inner side of the lower third of the leg. They show great variety in size, shape, and appearance of base, edges, and surrounding area, and in accordance with these differences many different names are applied to them. The size varies from the small ulcer less than 1 cm. in diameter, sometimes found with varicose veins, to the large ulcers which surround the leg, and which are called *annular ulcers*. They may be round, very irregular, or funnel shaped, as in *perforating ulcer of the foot*. The base may be much or slightly depressed, or the granulations may be at a higher level than the surrounding edges. When the granulations are large, irregular, and bleed easily, they are spoken of as *exuberant* or *fungating;* when pale, soft, and flabby, as *weak* or *œdematous;* when small and slowly growing, as *indolent* (Plate LVII., Fig. 5). Sometimes the base is covered with a grayish or yellowish-white necrotic layer formed of fibrin and necrotic cellular elements. When this layer is removed no granulations appear, but instead a smooth shining base resembling mucous membrane. This form is known as the *croupous ulcer*. In some cases the base of the ulcer is formed of the body tissues (muscle or connective tissue), and the lesion may look like a fresh injury. These are called *raw ulcers*. The base of a chronic ulcer may be pigmented. The edges also vary greatly. They may be irregular or sharply cut, moderately thickened, or very much so, due to chronic congestion and œdema, with enlargement of the papillæ and proliferation of the epithelial cells. When this is a prominent feature the name *callous ulcer* is applied. The edges may be adherent to the deeper structures and thus prevent contraction and healing (Fig. 4824); they may be rounded, elevated, undermined, or overhanging. Usually they are of a uniform height, rarely worm-eaten. When a chronic ulcer shows no tendency to heal it is never shelving, and there is an absence of the bluish-white border, mentioned in connection with healing ulcer. The discharge from a chronic ulcer is usually slight in amount, serous in character, and contains very few pus cells. The surrounding area may be swollen, red, congested, œdematous, eczematous, pigmented, or the ulcer may be surrounded by smaller ulcers, vesicles, or masses of varicose veins. As a rule there is an absence of severe pain accompanying chronic leg ulcers, unless there is an exposure or involvement of some nerve filaments. But frequently, after the patient has been on his feet for a long time, there is a dull aching sensation in the part, due to chronic congestion, which causes tension in and about the ulcer.

A peculiarly painful form of chronic ulcer is found over the inner malleolus, most frequently in women of middle age, although it also occurs in men. It is often associated with varicose veins, and in women with menstrual disorders. It is known as a *congested, irritable*, or *erethistic ulcer* (Fig. 4825). These ulcers begin as a small area of congestion over the internal malleolus. This area gradually increases in size, and becomes darker and more dusky in the centre, due to a deposit of blood pigment caused by the chronic congestion. The skin next becomes hard, dry, scaly, and pigmented, while the subcutaneous tissues lose their elasticity, becoming inflexible, hard, and adherent to the deeper structures. Then, as a result of slight traumatism or even without injury, the centre of the area breaks down and an ulcer develops. It may be circular or irregular in shape; it may be quite deep or superficial. The edges are sharply cut, and both base and edges are tightly bound down to the deeper tissues. The intense pain characteristic of these ulcers is supposed to be due to pressure upon the terminal nerve filaments in the dense sclerotic tissue. This form of ulcer is often very difficult to cure, and shows a tendency to return after healing.

Varicose Ulcer.—To chronic ulcer of the leg associated with varicose veins, especially of the smaller venous radicles, the name varicose ulcer has been given (Fig. 4826). Such an ulcer occurs most frequently on the lower or middle third of the leg. In shape it is usually irregular, but when it has existed for some time it may become round. The size varies from the small ulcers less than 1 cm. in diameter, formed by the breaking down of an area of periphlebitis around a small vein, to those several inches in diameter. Several ulcers may be present on one limb. The base is irregular, bluish, and pigmented. It may closely overlie an inflamed vein, the rupture of which may cause a severe hemorrhage. The granulations of the base of a varicose ulcer are apt to be weak and flabby. The edges are irregular, undermined, and bluish. Two or more ulcers may become connected by undermining of the skin between them, the skin subsequently melting away so that only one irregular ulcer remains. After a varicose ulcer has existed for a considerable time, the edges may become callous. The discharge is thin, serous, mixed with débris, and may be blood stained. The skin surrounding a varicose ulcer is often of a brownish-blue color, due to a deposit of pigment. Frequently in a leg in which there are varicose veins, or which is œdematous from other causes, attacks of acute eczema occur. The vitality of the part is lowered by the impaired circulation and by infiltration of the tissues with serum, and as a result of infection of the vesicles, often by scratching, numerous small or large *eczematous ulcers* are formed in an area of hot, red, moist, itching, inflamed skin.

Perforating Ulcer.—This variety of ulcer may occur over the fingers or toes, but is most frequently found on the sole of the foot over the head of the metatarsal bones, especially the first. They usually occur in men over forty years of age, and are often associated with, and believed by many to be due to, some pathological condition of the nerves or nervous system; either to trophic disturbance, as in locomotor ataxia, or to impaired sensation. Tomaszewski[28] believes that they are not always due to impaired sensation and trauma, but that an isolated sclerosis of the plantar arteries plays a part in the etiology. This element might account for their presence in diabetes and late syphilis. A perforating ulcer of the

FIG. 4826.—Varicose Ulcer of the Leg, showing Multiple Lesions and Irregularity of Edges and Base.

foot usually begins by the formation of a small abscess beneath a mass of callous skin overlying the head of one or more of the metatarsal bones, the abscess being due to the trauma of walking and pressure. Frequently not much attention is paid to it on account of impaired sensation. Then the bone becomes involved, undergoes a rarifying osteitis, and breaks down. The callous skin over the abscess then sloughs and disappears, and there is left a painless, funnel shaped ulcer, extending down to the dead bone, which, together with a few reddish, warty granulations, forms the base of the ulcer. When a perforating ulcer has existed for some time, the epithelium grows down the sides, often almost to the bottom, lining the inner surface of the "funnel." This, together with the existence of dead bone at the base, makes these ulcers very hard to heal. The discharge is foul, purulent, and may contain fragments of dead bone.

Gouty Ulcer.—An ulcer may form as a result of the infection and breaking down of gouty tophi. It is usually irregular in shape, and may be elevated. The edges are thin, or, if the ulcer is old, they may be thickened. The base is made up of indolent granulations when the deposit of biurate of soda has been discharged; or, in the fresh ulcer, there may be deposits of sodium biurate in the walls and base of the ulcer. The discharge is a thin purulent serum containing needles of biurate of soda.

Scorbutic Ulcer.—In severe cases of scurvy there is a marked tendency of the skin to ulcerate, not only as a result of breaking down of the subcutaneous indurated swellings which are a symptom of the disease, but also under other circumstances, as when a previously existing sore, a fresh abrasion, or even an old scar becomes the site of a rapidly spreading scorbutic ulcer. Such an ulcer is characterized by a spongy, dark-colored, fœtid, adherent crust, the removal of which causes considerable bleeding, leaving a base covered with large livid granulations. The edges are swollen, tumid, and sharply cut. The discharge is a profuse, foul, sanious pus.

Diabetic Ulcer.—Diabetics suffer from a number of skin lesions. They are liable to carbuncles, furuncles, eczema, and acne; and, owing to the poor circulation, lowered vitality, endarteritis, and the circulation of abnormal products in the blood, they sometimes become the subjects of gangrene. Any of these lesions may result in an ulcer. When an ulcer occurs in a diabetic it is apt to be sloughy and to spread rapidly. The skin around it is often red and inflamed, and the ulcer as well as the surrounding tissues may be the seat of a cellulitis.

Tropical Ulcers.—There are several varieties of ulcer which are peculiar to certain parts of the tropics. They usually derive their names from the locality in which they occur. Other tropical ulcers, such as dracuncular ulcer, are named according to etiology.

Penjdeh ulcer, also known as Delhi, Lahore, and Kandahar sore and a variety of other names, occurs in India, Central Asia, the Levant, Algeria, and the Malay peninsula. It usually appears on some exposed surface of the body, as one or more papules, which develop into boils and then undergo slow ulceration. The ulcers are usually oval in shape. They may develop rapidly, and several ulcers may merge into one, with a ragged, thickened edge surrounded by an areola of inflammation. The base of the ulcer may be smooth, but is usually uneven, healing at one place and breaking down at another. The ulcer runs a very chronic course, lasting sometimes for months, and is at one time painful, at another not. When it shows a tendency to heal a crust forms, which has to be removed daily to allow healing to occur. It leaves a scar which is depressed, puckered at the centre, and pigmented of a bluish-brown color. According to R. H. Firth,[29] although there has been a want of uniformity in the results of the study of the etiology by different observers, we are warranted in saying that there are found in all cases, especially in the epithelial cells, certain coccoid bodies that stand in direct causal relation to the morbid process. Nearly all observers have attributed the Oriental sore to the domestic water supply.

Annam ulcer is a form of phagedena which occurs in Annam, Yemen, Aden, Cochin China, and Mozambique. B Scheube[30] believes that all the cases of this form of phagedena described as occurring in these regions are identical. It usually begins on the foot or leg with an area of infection. This area sloughs and the ulcer grows more or less rapidly, preceded by an area of inflammation. The base is made up of unhealthy granulations, which bleed very easily. The surface is covered with a foul pus or a grayish pseudomembrane. The edges are undermined. The base and edges of the ulcer may be gangrenous to such a depth as to expose to view the underlying tendons and muscular tissue. In some cases the muscle may also be gangrenous. The ulcer is very painful. Syphilis, anæmia, poor general condition, bad hygiene, and poverty, are believed to create a predisposition to the disease. The lesion is very difficult to heal.

Gaboon ulcer, described by Gaucher,[31] is a form of tropical ulcer found in the natives of Gaboon. It occurs on the limbs and is similar in appearance to syphilitic ulcer, especially in the character of the scar. It is not improved by treatment with antiseptics, but is most amenable to treatment with hot water.

Dracuncular ulcer is endemic in parts of India, Bokhara, Turkestan, Arabia, along the coast of the Red Sea, tropical Africa and parts of tropical South America. The ulcer is due to the filaria medinensis or guinea-worm, a species of thread worm, averaging three feet in length, but which may be as long as six feet. Its habitat is in the subcutaneous tissues. As the worm approaches maturity, she (for only the female is known) works her way toward the surface, usually downward to the leg, foot, or ankle, in order to discharge her eggs. When she reaches the derma, she pierces it and forms a bulla beneath the epidermis. This becomes infected, the skin breaks down and discloses an ulcer with a small hole in the centre, from which part of the worm may project. Usually in about two weeks the worm has emptied her uterus, and can be gradually extracted by gentle intermittent traction. According to Patrick Manson[32] the formation of the ulcer can sometimes be avoided by the injection of 1 in 1,000 bichloride of mercury into the tissues as soon as the parasite begins to irritate the skin. This kills the worm and it becomes absorbed like a piece of aseptic catgut.

Veldt sore is a form of ulcer occurring in South Africa. It was common among the British troops campaigning there, especially the cavalry and artillery branches of the service. It is least common in cold weather and high altitudes. Most frequently the sores are found on the exposed surfaces of the body—the hands, forearms, and feet. The etiology is a matter of dispute. Ogston[33] grew an almost pure culture of a peculiar micrococcus, called the micrococcus campaneus, from the serum obtained from the sore. Harmon[34] believes the staphylococcus aureus, which has become attenuated in its virulence, to be the cause. Pridmore[35] believes the infection to be carried by the horse tick. The sore may begin in the deep layers of the epidermis and assume the form of a bleb, or its first appearance may be that of an abrasion. The ultimate lesion is a slowly extending chronic ulcer, spreading very gradually at its periphery. It is most amenable to treatment by moist antiseptic dressings.

SPECIFIC ULCERS.—*Syphilis, Chancroid.*—The initial lesion of syphilis and the chancroid have both been described in special articles, so we need refer here only to the symptoms and appearance of secondary and tertiary ulcerative syphilitic lesions. These occur on both the skin and the mucous membranes. When a syphilitic ulcer develops on a mucous membrane it assumes one of two types: the superficial and the deep. The superficial ulcer which involves only the mucous membrane has indurated, slightly elevated, sharply cut, perpendicular, "punched-out" edges, and an indurated base covered with a yellowish film of tenacious secretion. These ulcers arise from mucous patches, deposits of round cells, or "mucous gummata." The deep syphilitic ulcers arise from the breaking down of gummata in the deeper part of the mucous membrane or in the tissues beneath it. They are irregular with an indurated, sloughing base, and ragged undermined edges surrounded by an area of induration. The adjacent tissues may become involved in the syphilitic process and undergo destruction. In this way the cartilage of the nose or of the larynx, or the bones of the hard palate or the nose, may be destroyed. After the healing of a syphilitic ulcer there may have been such a destruction of tissues that strictures of the pharynx, larynx, œsophagus, or rectum ensue.

On the skin three distinct types of syphilitic ulcer are found: the superficial, the serpiginous, and the deep. The *superficial ulcer* may appear comparatively early in the disease. It usually varies in size from a quarter to a half dollar; it has a circular outline, with sharply cut edges, and a dirty-yellowish, purulent base. Several of these ulcers may unite to form an ulcerating area with

EXPLANATION OF
PLATE LVII.

EXPLANATION OF PLATE LVII.

Fig. 1.—Rodent Ulcer, of Ten Years' Duration. No glandular involvement. (From a case of Dr W. C. Lusk.)

Fig. 2.—Carcinomatous Ulcer, Secondary, in Pre-auricular Region

Fig. 3.—Syphilitic Ulcer of the Ankle, showing Punched-out Edges and Sloughing Base.

Fig. 4.—Epitheliomatous Ulcer of the Scrotum, showing Everted Edges and Large Granulations. (From a case of Dr. B. Farquhar Curtis.)

Fig. 5.—Chronic Traumatic Ulcer of the Leg, showing Irregular Shape, Depressed Base, and Indolent Granulations.

Fig. 6.—Tuberculous Ulcer, showing Usual Situation, Thin Overhanging Edges, and Exuberant Granulations.

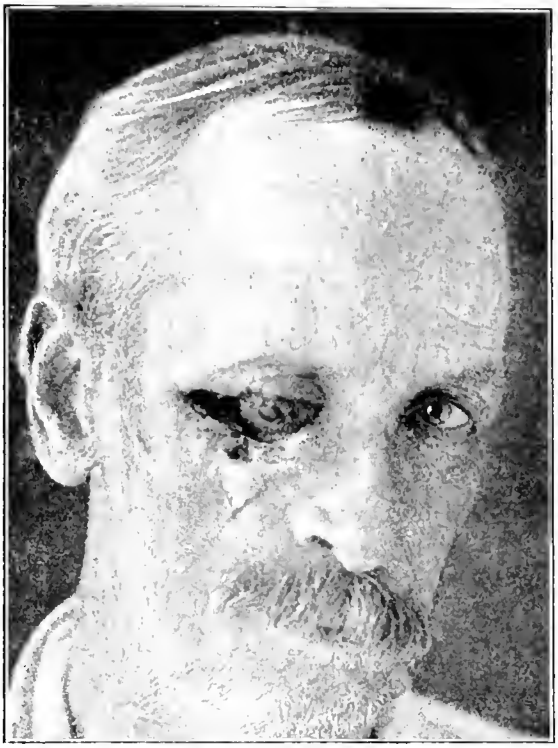


Fig. 1

Fig. 2

Fig. 3

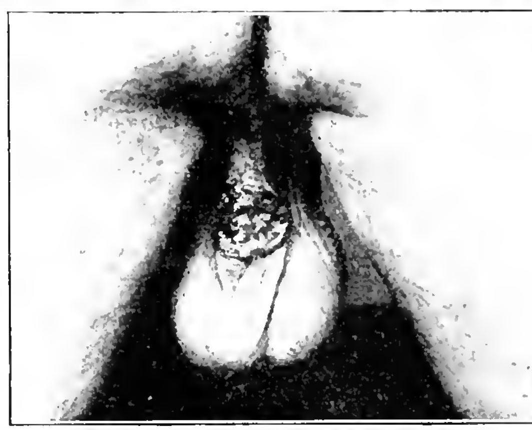


Fig. 4

Fig. 5

Fig. 6

DIFFERENT VARIETIES OF ULCERS

a scalloped margin. The superficial form is most frequently found on the face and legs. The *serpiginous ulcer* may originate from a single circular ulcer, which heals at one side, while it progresses at the other; or it may take its origin in the breaking down and coalescence of several tubercles. Subsequently the new tissue thus formed at one part of the ulcer also breaks down. It is on the back, at the junction of the hairy scalp with the face and neck, and on the extremities that the serpiginous ulcer is most frequently found. The *deep ulcers* result from the breaking down of gummata (Plate LVII., Fig. 3). They are at the beginning surrounded by a reddened area of inflammation, the smaller ones being crater-like with punched-out edges, the larger ones having overhanging, thin, soft, inflamed edges. The base is of an angry, dusky-red color, dirty or sloughing in appearance, the slough being often of a greenish color. The discharge is thin, often bloody, and contains débris from the broken-down gumma. Under treatment and after they have existed for some time, they lose their characteristic appearance and take the form of simple chronic ulcers. The scar remaining is characteristic. It is thin, of a dead-white color, pigmented here and there, and when pinched up wrinkles like tissue paper. This form of syphilitic ulcer may occur anywhere on the surface of the body, but is particularly apt to be found on the upper half of the leg. In fact, an ulcer occurring on the upper half of the leg, unless directly due to traumatism, is nearly always syphilitic.

Tuberculosis.—Tuberculous ulcers, like those due to syphilis, occur both on the skin and on the mucous membranes, being more frequent on the latter. When occurring on the mucous membranes they may be primary, but are more often secondary, and are frequently part of a general tuberculosis. They result, as has been mentioned under Pathology, from the breaking down of tubercle tissue. In the mucous membranes of the mouth, tongue, larynx, and pharynx, tuberculous ulcers are as a rule painful, shallow, oval in shape, and irregular in outline. The base is made up of pale, flabby, anæmic granulations. The edges are bevelled and not undermined. The surrounding area is slightly swollen and pale, this pallor of the surrounding tissues being characteristic of tuberculous ulcers of the mucous membranes. These ulcers, although superficial at first, may become deep, and may result in the destruction of the deeper structures by extension of the tuberculous process, as in the larynx. In the intestine the ulcer usually begins by the deposit of tuberculous material in the Peyer's patches or the solitary follicles and the subsequent breaking down of this material. The ulcer is at first small, then becomes larger, irregularly oval in shape, and tends to run transversely around the lumen of the bowel. The edges are slightly elevated, thickened, and not undermined. The base is thickened from the presence of inflammatory and caseous tissue. It is usually roughened and irregular, sometimes sloughing. The process involves all the coats of the intestine, and there is usually a local peritonitis set up on the outer wall of the serous coat, through which white or yellowish tubercles may frequently be seen. In the rectum tuberculous ulcers are irregularly oval, often deep, and there may be a marked infiltration of tubercle tissue about them. They sometimes perforate the wall of the rectum and give rise to the formation of sinuses and fistulæ. In the bladder tuberculous ulcers, when secondary to tuberculous disease of the kidney, are most frequently found about the orifices of the ureters. Ulcerative lesions of the vulva and vagina may be found secondary to tuberculosis of the uterus and adnexa. Lupoid ulceration of the mucous membranes occurs only on those mucous surfaces which are near the natural openings of the body, and usually by extension from without, although cases primary on the mucous membrane have been reported. It occurs on the mouth, tongue, larynx, pharynx, nares, conjunctiva, vulva, vagina, and anus. It has the general characteristics of lupus of the skin, and will be described under this heading in the following paragraph.

On the skin tuberculous ulcers follow five distinct types. *Tuberculosis cutis*, a rare form, occurs almost exclusively about the mucous orifices—mouth, anus, vulva, and glans penis. It is part of a general tuberculosis, but the ulcers are due to local infection. It consists of one or more discrete, shallow, painless ulcers, with a reddish-yellow granular base and an irregularly eroded, moderately infiltrated edge. The discharge is thin and scanty, and is apt to dry and form crusts. When the ulcer extends to a mucous membrane, small yellow miliary tubercles may exist near them. The ulcers never heal and may attain considerable size, and by coalescing with others become serpiginous. *Tuberculosis verrucosa cutis* occurs as one or more brown or livid-red warty patches, ulcerating on the surface, varying in size from about a lentil to a silver half dollar, and surrounded by a narrow zone of erythema. Several patches may unite to form an irregularly shaped lesion, with a scalloped border. Usually there are no subjective symptoms, but there may be slight pain on pressure. It is most frequently found on the hands. *Lupus vulgaris* occurs most frequently on the alæ nasi, at the junction of the skin with the nasal mucous membrane. When an ulcerative lesion occurs, it is preceded and surrounded by small, soft, brownish-red, s nitranslucent tubercles which resemble apple jelly in appearance. These easily break down and ulcerate. The base of the ulcer may be quite superficial and smooth, composed of pale flabby granulations, covered by a crust, or the process may destroy the cartilages and the ulcer become deep and irregular. The edges are sharp, soft, irregular, and eroded, and, when the ulcer is spreading, surrounded by small lupoid tubercles. The development of the disease is very slow. It has a tendency to cicatrize at one portion while spreading at another, and leaves a thin, red, irregular scar, in which new tubercles may form and break down. When an ulcer occurs as a result of *erythema induratum*, it is preceded by a subcutaneous nodule, the skin over which later becomes red, then purple in the centre. If it breaks down, the nodule sloughs or suppurates and leaves a round, excavated ulcer with a grayish base. The edges are not undermined. The lesions are apt to be symmetrical, being most frequently found on the legs, especially on the outer and posterior aspect. The origin of that form of tuberculous ulcer which is known as the *scrofuloderm*, has already been mentioned (Plate LVII., Fig. 6). The base of the ulcers is covered with pale flabby granulations which are often exuberant; its edges are thin, undermined, and of a peculiar livid or violaceous color. The discharge is a thin, sanious pus. Frequently the ulcers are connected with other tuberculous ulcers, or with tuberculous glands, bones, or joints. They are usually painless. When the ulcer has healed the scar left is usually puckered and disfiguring, and is often bridled. Tubercle bacilli may be found in the tissues and discharge of any of the tuberculous ulcers, but they are infrequent, and often in old ulcers cannot be obtained.

Other Specific Ulcers.—The symptoms arising from ulcers due to typhoid, diphtheria, dysentery, leprosy, glanders, actinomycosis, etc., together with those due to certain skin diseases, such as pemphigus, ecthyma, herpes, and eczema, are those rather of the disease than of the ulcer, and the reader is therefore referred to the special articles in this work on these subjects.

Malignant Ulcers.—*Epitheliomatous Ulcer.*—The most frequent form of malignant ulcer is that of epithelioma. It is infrequent under forty years of age. Its usual situations have already been mentioned. The base of the characteristic epitheliomatous ulcer is hard, nodular, and irregular, made up of hard warty granulations and often covered with sloughs. It bleeds easily and has a foul discharge. The edges are hard and everted (Plate LVII., Fig. 4). The amount of pain, the involvement of neighboring lymphatic glands, and the rate of growth vary. Epitheliomata which develop from congenital warts, moles, or nævi are apt to be very malignant. When epitheliomatous degeneration occurs in a chronic ulcer, it begins to get hard about the edges, which become everted and bound down to the deeper tissues. The granulations about the edges become large, red, nodular, hard, and bleed very readily. This condition spreads over the whole ulcer, and it assumes a sloughing and foul character. The tissues immediately surrounding the edges may show a stony-hard induration, due to extension of the malignant process. The diagnosis is confirmed by the microscopical examination of a section cut from the edge of the ulcer.

Rodent Ulcer, or, as it is sometimes called, Jacob's ulcer, is histologically a form of epithelioma, although it may be differentiated from it clinically. It occurs on the upper half of the face, beginning as a small nodule like a wart. Various observers have believed its origin to be in the hair follicles, sebaceous or sweat glands, or the deep layers of the rete. J. M. McFeely[36] states that the deep layers are involved first, but that the disease shows a tendency to avoid the hair follicles. The ulcer grows very slowly. Its base is smooth, glossy, and depressed, being lighter in color than epithelioma (Plate LVII., Fig. 1). The edges are hard from infiltration, smooth and rolled over. The discharge is slight and apt to form crusts. The deeper tissues are not involved until late and the ulcer is movable. There is a tendency toward cicatrization. Caustics retard its growth, while, unless they are thoroughly applied, they stimulate epithelioma. Rodent ulcer never forms metastases, causes cachexia, or involves the lymphatic glands. Auche[37] reports a case of the disease which existed for twenty years without glandular involvement.

Scirrhous Ulcer occurs usually with scirrhous carcinoma of the breast in women over forty. The slow-growing tumor gradually involves the skin, which breaks down and ulcerates. The ulcer is deeply depressed, with a pale pink, smooth base and no granulations. It is intimately adherent to the new growth below; in fact, its base consists of the new growth. There is slight discharge. The edges are raised and very hard, but may be undermined by ulceration. The surrounding skin is often atrophic, wrinkled, and adherent to the new growth. The ulcer increases in size very slowly, as this is a very slowly developing form of carcinoma.

Fungating Ulcer.—Rapidly growing carcinomata and sarcomata, which are near the surface, may either involve the skin or protrude from an operation wound; they form large, foul, exuberant masses composed of cancerous and granulation tissue which are covered with sloughs, bleed easily, and have a foul, sanious discharge. They grow very rapidly (Plate LVII., Fig. 2).

The symptoms caused by malignant ulcers of the mucous membranes would be those of the new growth, and would not be included within the scope of this article.

Ulcers of the Mucous Surfaces.—Besides those forms of ulcer on the mucous membrane which are due to malignant disease and the various specific infections previously mentioned, there occur the ulcerative forms of stomatitis, gastric, duodenal, and other intestinal ulcers, as well as ulcers of the rectum, bladder, vagina, and vulva from various causes. For the symptoms of these, together with the symptoms of ulcer of the cornea, and fissures of the nipple and anus, the reader is referred to the special articles on these subjects.

Differential Diagnosis.

The diagnosis of ulcers does not as a rule present much difficulty, but occasionally it may not be easy to determine the form of ulcer present. To facilitate this a number of tables are given below, showing the points which determine the differential diagnosis of those forms in regard to which confusion is most apt to occur.

Lupoid ulcer and a tuberculous syphilide might easily be confused. From the latter lupus is differentiated by the facts that it usually appears at an early age, that it develops very slowly, that it is characterized by the presence of apple-jelly-like tubercles, that the ulcers are more shallow and have only insignificant crusts, that there is no tendency on the part of the disease to involve the bones, that other syphilitic symptoms are lacking, and finally that potassium iodide produces no benefit.

Complications and Sequelæ.

The most frequent complication of ulcer of the skin is cellulitis. This may sometimes be so severe as to necessitate operation. Erysipelas may also complicate cutaneous ulcers. After the healing of an ulcer the resulting cicatrix may by its contraction cause severe deformity—distortion of the features when the ulcer is upon the face or neck, or partial ankylosis in the case of extensive ulcers, as those resulting from burns, in the neighborhood of a joint. Keloid formation occasionally occurs in the scar resulting from an ulcer. Hemorrhage, especially from a varicose ulcer, is a common complication and has been fatal. Involvement of the lymphatic glands and destruction of the deeper structures (cartilage, bone, muscles, or joints) may occur in malignant, tuberculous, syphilitic, or phagedenic ulcers. The continuous drain on the system from the profuse discharge from an extensive ulcerating surface in a debilitated subject may cause such weakness as to indicate amputation. Malignant ulcers may form metastases in other structures.

In the case of ulcers on the mucous membranes, besides the destruction of the deeper tissues, the complications most common are perforation of the stomach or intestines, and hemorrhage. An actual perforation is frequently prevented by the formation of adhesions due to the localized peritonitis which occurs when the serous coat is involved in the inflammatory process. Strictures are frequent sequelæ to ulceration of the mucous membranes.

Treatment.

The treatment of ulcers is both constitutional and local. The constitutional treatment consists in building up the system by tonics when this is necessary, and in treating those general conditions and diseases which act as direct or predisposing factors in the etiology of the ulcer (such, for example, as the gouty diathesis, arteriosclerosis, diabetes, scurvy, etc.). It is also important to improve the hygienic surroundings, to administer mercury and the iodides for syphilis, to prescribe cod-liver oil, the hypophosphites, and a change of climate for tuberculous conditions, and iron and arsenic for anæmia, etc., thus making it possible to obtain the best results from the local treatment.

Local Treatment.—In considering the subject of local treatment, it must be remembered that there are several things which we should aim to accomplish. These are: (1) the reduction of inflammation in and about the ulcer; (2) the cleansing and sterilization of the ulcer; (3) the stimulation of the granulations; (4) the relief of congestion and the establishment of a proper blood supply; (5) the promotion of new epithelial growth and cicatrization.

Reduction of Inflammation.—Frequently, when an ulcer comes into the hands of the surgeon for treatment, the ulcer and the surrounding tissues are in a state of considerable inflammation and cellulitis. For the reduction of this inflammation and the relief of pain moist dressings are the most effective form of treatment. A solution of alum acetate, made by adding 5 parts of lead acetate and 1 part of alum to 100 parts of water; or a one-per-cent. aqueous solution of ichthyol; or Thiersch's solution (1 part salicylic acid, 5 parts boric acid to 500 parts water)—any one of these solutions applied on a thick gauze compress and kept moist and cool, acts admirably in this condition. The permanent bath of Kaposi,[38] consisting of clean or if possible sterilized water, but containing no antiseptics, acts in the same manner. It has no advantages over the former treatment, except perhaps in the case of ulceration following extensive

Tuberculous, Syphilitic and Epitheliomatous Ulcers, and Rodent Ulcer.

	Tuberculous Ulcer.	Tertiary syphilis.	Epithelioma.	Rodent ulcer.
History	Of previous glandular, bone or lung disease.	Of syphilis	Sometimes of small abrasion or irritation.	Often of wart or papule.
Age	Generally youth	Any age. Most frequently middle life.	Seldom before thirty-five or forty.	Seldom before forty-five or fifty.
Base	Soft, pale, œdematous granulations.	Smooth or sloughy. Apt to be of a dirty-greenish color.	Hard, wart-like granulations. Bleed easily and apt to slough.	Hard, smooth, depressed. May show evidence of cicatrization.
Edges	Thin, undermined, violaceous color.	Punched out or undermined. Dusky red. May heal at one point and advance at another.	Very hard, elevated, nodular, everted.	Hard, sharply cut. Not much elevated.
Glands	Usually involved. Not necessarily secondary to ulcer.	Not involved	Usually in from three to six months.	Not involved or very late.
Course	Slow	Rapid without treatment. Heals with it.	Varies. Malignant	Usually very slow.
Other symptoms	Other signs of tuberculosis—sinuses, bone disease, etc.	Other signs of syphilis	May be cachexia or metastases.	Usually none.

Leg Ulcers.

	Traumatic.	Varicose.	Syphilitic.
History	Injury	Varicose veins or phlebitis	Syphilis.
Situation	Where injury occurred	Usually lower third of leg anteriorly or laterally.	Usually upper third of leg. Often posterior aspect.
Base	Shallow, inflamed, often grayish yellow.	Bluish, pigmented granulations; sluggish. Usually superficial.	Dirty, sloughing; often greenish. Deep.
Edges	Not elevated or thickened	Undermined or thickened. Shape irregular.	Punched out or thin and undermined, deep dusky red. Shape round or serpiginous.
Surrounding area	Red and inflamed	Pigmented. Varicose veins; often œdema and eczema.	Dusky red. Scars of old, syphilitic ulcers.
Healing	Rapid under antiseptic treatment.	Support of veins necessary	Mercury and potassium iodide necessary.

Ulcers of Tongue.

	Chancre.	Tertiary syphilis.	Tuberculosis.	Carcinoma.
Age	Usually before thirty	Usually before forty	Any age. Rare before puberty.	Usually after forty.
History	Sometimes of infection	Previous syphilitic	Usually of pulmonary tuberculosis.	Often of irritation and of cachexia.
Number	Single	Often multiple	Generally single	Single.
Situation	Usually tip or anterior part of edges.	Often mid-line toward median or posterior surface of dorsum.	Usually tip or anterior portion of dorsal surface.	Most common on one side at middle or posterior third.
Shape	Generally round	Round or oval	Sinuous outline or oval	Irregular.
Base	Hard, smooth, superficial	Deeply excavated. Sloughy, not much induration.	Pale, flabby granulations	Hard, irregular, vascular, sloughy, purulent.
Edges	Hard, indurated, sloping	Ragged, irregular, undermined, or sharply cut.	Bevelled. Surrounding area pale.	Raised, everted, thickened, indurated.
Pain	Slight, if any	Slight	Painful	Very painful.
Glands	Subhyoid in six weeks	Usually not	May or may not	Usually in a few months.
Course	Rapid healing with development of secondary syphilis.	Heals with antisyphilitic treatment.	Slow progression. Part of a pulmonary tuberculosis.	Generally rapid. Floor of mouth or pillars of fauces involved. Loss of speech.
Microscope	Round cells	Gummatous tissue	Tubercle bacilli	Carcinoma cells.

burns or gangrene on the trunk, where it is difficult to keep dressings applied.

Cleansing and Sterilization of the Ulcer.—Before healthy granulations can form on an ulcer, the removal of sloughs and cleansing of the base must be accomplished, with as much sterilization as is possible. Many means toward this end may be effective. A one-half to one per cent. solution, or rather emulsion, of creolin, is very useful in cleaning up those extensive, dirty ulcers from which a profuse foul discharge escapes. A one-per-cent. solution of formalin is of great value in cleaning up smaller ulcers, especially those due to tuberculous disease. The destruction and removal of sloughs may be hastened by cauterization with the solid stick of nitrate of silver and the application of iodoform or naphthalin powder, the latter particularly. The use of certain ferments, such as brewers' yeast, papoid, caroid, or protonuclein, may help in the clearing up of a chronic ulcer which shows a tendency toward a croupous condition. The most frequent means employed for the cleansing and sterilization of the ulcer, previous to the application of some stimulating dressing, is washing its surface with bichloride-of-mercury solution (1 in 1,000) or one of carbolic acid (1 in from 40 to 80), or with hydrogen peroxide. In addition to these means of sterilization and also with the aim of promoting healing, Zeimer[39] recommends a one-per-cent. filtered solution of chloride of lime. Colleville[40] suggests that the ulcer be subjected, for a period of from twenty minutes to one hour, to the heat radiated from a plate of metal that has been brought to a dull-red heat, and that is held at a distance of ten inches from the ulcer. Von Langsdorf,[41] recommends the application of calomel and salt, the chlorine from the salt uniting with the calomel to produce bichloride of mercury. This method is often very painful. Tarabrin,[42] employs the Paquelin cautery at a dull red heat, holding it at a distance of 5–6 cm. from the ulcer; nearer if no pain ensues. Bukovsky[43] uses a culture of B. pyocyaneus fourteen or fifteen days old, diluted with a solution of potash and hydrochloric acid. Stone[44] recommends twenty grains of mercurol in one ounce of vaseline. Tshitsherin[45] reports favorable results from the employment of phenosalyl, especially in ulcerating gummata.

Stimulation of the Granulations.—Having reduced the inflammation and succeeded in cleansing the ulcer, the next thing to consider is the means by which granulation may be stimulated. This may be done by applications in the form of powders, solutions, or ointments. In the form of powders are used iodoform, aristol, nosophen, xeroform, orthoform, bismuth subnitrate and subgallate, boric acid, salol, antipyrin, sulphur, charcoal, lycopodium, zinc oxide, and other substances. In the form of solutions one may employ argentic nitrate, zinc and copper sulphate, potassium permanganate, formalin, ichthyol, balsam of Peru, camphor, myrrh, and benzoin. In the form of ointments, zinc oxide, boric acid, ichthyol, mercury, balsam of Peru, Lassar's paste, salicylic acid, and camphor are available. All of these drugs have their advocates. One of the oldest and best of the stimulant applications is balsam of Peru, which has a powerful effect in increasing the growth of granulations; but often, after this has been accomplished, the granulations are apt to become exuberant, with little tendency to cicatrization. In some cases it has considerable irritant action and may cause a dermatitis. Unna[45], twenty years ago, made a study of the action of certain drugs in regard to their effect on granulations. He found that carbolic acid, bichloride of mercury, and salicylic acid favor the growth of granulations, but hindered cicatrization. Iodoform and boric acid favored both, while pyrogallic acid, sulphur, and ichthyol particularly favored the growth of epithelium. The latter drug, which was introduced by Unna,[46] is useful not only for favoring the growth of epithelium, but also for reducing inflammation and stimulating granulations.

When an ulcer is particularly indolent, the application of the solid stick of nitrate of silver, or of solutions of nitrate of silver, zinc, or copper sulphate in strengths of from two to ten per cent., may, by inducing some inflammatory reaction, hasten granulation. The application of antiseptic and astringent powders finds its chief use when the discharge is profuse, the ulcer being covered after the application with a soft absorbent dressing. They may also be applied to advantage when the ulcer is quite small, with so little discharge that it may be healed under a scab. In painful ulcers orthoform is of great value on account of its analgesic action. In the majority of cases the best results are obtained with moist dressings, which, while they stimulate granulation, also absorb the discharge. Balsam of Peru and ichthyol have already been mentioned. In addition to these, one of the most valuable applications for promoting the healing of an ulcer is "red wash," made up after the formula: Zinc sulphate, gr. xx.; compound tincture of lavender, ʒ ss.; distilled water, ℥ viij. This solution has a powerful astringent action and promotes cicatrization, especially when there is a tendency for the granulations to become exuberant. Walbaum[47] recommends the application of wine of camphor under rubber tissue after sterilization of the parts and reduction of inflammation with liquor aluminis acetatis. Kundler[48] has obtained good results in the treatment of chronic ulcers with hot water, using two litres of water as hot as could be borne, and allowing it to fall on the ulcer from a height of six feet. This was repeated two or three times a day, and the procedure was followed by the application of iodoform or dermatol.

In regard to the employment of ointments, it may be said that their use is generally contraindicated where there is a very profuse discharge, as they prevent its absorption by the dressing. It has also been observed that there is often a tendency for the granulations to become soft and flabby under their influence. They are often valuable, however, in combination with the fluid applications, especially where the discharge is small in amount and apt to dry, and also when the ulcer is surrounded by an area of eczema or dermatitis. Under both these circumstances the ulcer may be dressed with gauze soaked in balsam of Peru, red wash, etc., and then, over this and the surrounding area, some form of bland ointment, such as Lassar's paste or zinc oxide ointment, spread on lint, should be applied. When used in this manner the ointment prevents the rapid absorption of the discharge by the underlying dressings and the subsequent drying and irritation of the ulcer; at the same time it exerts a soothing effect upon the surrounding inflamed skin. Schultz[49] strongly recommends the use of camphor in the form of an ointment for chronic leg ulcers. He says: "Of all the remedies, new or old, for ulcer of the leg, camphor gives the best results." He gives two formulæ: (1) Triturated camphor, ʒ ss.; zinc oxide, ʒ viiss.; lard, ad ℥ iv. (2) Triturated camphor, ℥ ss.; zinc oxide, ℥ iij.; and olive oil, ℥ iij.

In addition to the use of the above applications, various other therapeutic measures have been employed for stimulating granulations and promoting healing of chronic ulcers. Oxygen gas has been recommended by Semple.[49] Galvanism and high-frequency electric currents have been used by several since the publication of the cases of Meyer and Blackwood,[50] but apparently they have little to recommend them as being superior to other methods. Heeve[51] reports favorable results in the treatment of chronic leg ulcers by means of the x-ray combined with the brush discharge. Zarabin[52] and others have also cured varicose ulcers by means of the x-ray. The subject of radiotherapy and phototherapy will be taken up in the consideration of the treatment of special forms of ulcer. In a certain number of cases in which there has been a considerable loss of substance, which it is desirable to replace by granulations, the method of sponge grafting, introduced by Hamilton,[53] may be of use. Briefly, this consists in the application of a sterilized piece of sea sponge to the area to be grafted, the aim being to cause the granulations to grow into and fill the spaces in the sponge, which latter is subsequently absorbed, its place being taken by the granulation tissue. Sometimes this is successful, but frequently the sponge acts as an irritating foreign body.

Relief of Congestion and the Establishment of a Proper Blood Supply.—In the case of chronic leg ulcers, and especially those associated with varicose veins, it is impossible to effect a cure until the chronic congestion of the limb is relieved and the blood supply of the part approaches normal. Often all that is necessary is a muslin or flannel bandage properly applied over the dressing, and reaching from the toes to the knee. Volkmann[54] in 1862 first suggested the use, for ulcers of the leg, of occlusive cotton dressings. He used a thick layer of cotton, bandaged on with firm even pressure and left in place until the odor of decomposition appeared. Lister's method was similar to this, only he used protective over the ulcer, after sterilizing it and the limb, and then enveloped the latter in borated cotton. Martin's[55] rubber bandage, when applied with moderate, even pressure, has for its purpose the relief of congestion, but in some cases the rubber has an irritating effect on the skin. Unna's paint as a dressing for chronic leg ulcers is strongly recommended by Michel.[56] It is made from glycerin and water, āā 10 parts, gelatin and white oxide of zinc āā 4 parts. The leg should be cleaned, rubbed with alcohol, and dried thoroughly. The paint is warmed until it becomes fluid, and then it is applied all over the leg, including the ulcer, from the toes to the knee. A wide-meshed gauze bandage is then applied without reverses, care being taken to avoid wrinkles and to exert an even pressure. Over this is then painted another coat of the mixture. When cold the dressing looks and feels like white rubber. If properly applied, such a dressing should last for from four to eight weeks. If there is much discharge, a window may be cut over the ulcer, through which it may be dressed. Gaudin[57] employs a somewhat similar method, using traumatol and starch bandages, so applied as to draw the edges of the ulcer as much together as possible.

When the granulations are almost on a level with the surrounding skin, and also when there is considerable thickening of the edges of the ulcer, the best means of keeping up an even pressure, and causing absorption of the thickened margins, as well as hastening epithelial growth, is to apply zinc oxide adhesive plaster in strips one-half to one inch in width. These strips should overlap to the extent of about one-third of their width, should be evenly and smoothly applied, and should extend about three-fourths of the way around the limb. They should be started about one inch below the ulcer, and should run up one inch above it. When the callosity of the edges is very marked, it can often be made to disappear by the application of a piece of wood or metal a little larger than the ulcer, tightly strapped on so as to overlap and make firm pressure on the edges. In a considerable number of chronic leg ulcers, however, it will be found that the various methods which I have described are inadequate, and that satisfactory results can be attained only by putting the patient to bed and keeping the leg slightly elevated. Probably a great many of the favorable results obtained from the various therapeutic measures so highly recommended by different writers, are largely due to the adoption of the measures last named. It is also necessary in some cases to immobilize the limb when the ulcer is over a joint, for the motion of the latter prevents healing.

When varicose veins are associated with chronic ulcers of the leg, which fail to heal under the above methods of treatment, various operative measures may aid in effecting a cure. Multiple ligation of the veins with or without excision, or ligation of the internal saphenous after the method of Trendelenburg, may, by directing the circulation through the deep veins, relieve the superficial congestion, and aid in effecting a cure in obstinate cases. Wenzel[58] has obtained very favorable results in the cure of varicose ulcer by means of a circular incision at the junction of the lower and middle thirds of the thigh, and the resection of from one-half to one and one-half inches of all the cutaneous veins in the wound. In this connection should be mentioned the operations advocated by several French writers, who believe that the relationship which exists between an ulcer of the leg and varicose veins is effected through the nerves, the degeneration or chronic inflammation of which produces trophic disturbances. Silvy[9] recommends fascicular dissociation of the sciatic nerve. Chipault[59] reports favorable results in cases of chronic ulcer by stretching the musculo-cutaneous, internal saphenous, sciatic, and external popliteal nerves. Thernot[60] reports the cure of a recurrent traumatic ulcer by stretching the external popliteal and saphenous nerves, with resection of the saphenous vein.

Promotion of Cicatrization and New Epithelial Growth.—The value of nitrate of silver and red wash as stimulants of the healing process has already been mentioned. They are also of value in producing cicatrization and promoting the covering of the ulcer with new epithelium. If the solid stick of nitrate of silver be touched very lightly to the edges just inside the pale bluish line of advancing epithelium, so as to produce a white film on the surface, this slight cauterization will be found to aid in strengthening and cornifying the new delicate, previously invisible epithelial cells, and in preventing them from being washed away by the discharge from the ulcer. The solid stick of nitrate of silver is also of value in destroying exuberant granulations which project above the surface of the surrounding skin; and often by piercing these flabby granulations in several places with the solid stick held perpendicular to the surface, cicatrization is hastened. After the granulations are level with the surrounding skin, the covering of the ulcer with new epithelium is hastened by the application of some smooth surface, along which the epithelium can spread. For this purpose zinc oxide adhesive plaster, thin rubber tissue, or protective may be used.

In a number of old chronic cases healing is prevented by the fact that the base of the ulcer cannot contract, owing to its being bound down by fibrous scar tissue. This binding down of the base and edges of the ulcer also tends to cut off the blood supply, and therefore in this additional manner the healing of the ulcer is hindered. For the relief of this condition a number of operations have been devised. Gaffky[61] employed mattress sutures, introduced through the normal skin beyond the edges of the ulcer and passing beneath it, out through the skin on the other side. By tightening these sutures over a button or metal plate the ulcer was lifted from the underlying tissues. Liston[62] introduced the method known as starring of the ulcer. He made a series of radiating incisions through the base and edges of the ulcer, the point from which the incisions radiated corresponding with the centre of the ulcer. In this and in the following operations, in order to obtain a favorable result, it is necessary that the incisions pass completely through the cicatricial tissue that forms the base and edges of the ulcer, into normal tissue. "Cross-hatching" of the base of the ulcer by means of a series of incisions at right angles to each other, and at a distance of about one half inch apart, was suggested by Harbordt,[63] and is often of value in aiding healing of a chronic ulcer, the continued existence of which and failure to heal having been due to its thickened, adherent base and edges. The method of circumcision of the ulcer was introduced by Nussbaum.[64] This consists in making a circular incision around the ulcer, through the normal skin surrounding it. The procedure was modified by Hodgen,[65] who made a series of overlapping, short, curved incisions surrounding the ulcer, instead of the single circular incision. In these last two methods it is necessary that the incisions be made through normal skin, and that the wounds be made to gape—if necessary, by packing them with gauze.

When an ulcer is of considerable size, it is often impossible to secure healing, even by these methods. It may for a time appear as if it were going to heal, and a pale blue line of newly formed epithelium may spread out from the edges; but instead of the epithelium continuing its progress, at a subsequent dressing it will be found to have melted away. In these cases as well as in those in which the size of the ulcer would necessitate a long wait for a cure, or in which the subsequent contraction of the scar (as on the face or palm of the hand, for example) would produce deformity, skin grafting, skin transportation, or some form of plastic flap operation is indicated. The method of Reverdin, as modified by Thiersch,[66] is the one most frequently employed. (For the details of this method see the article on *Skin, Transplantation of.*)

The method of skin transportation, as devised by Wolfe,[67] and also by Lefort,[68] and which was further developed by Esmarch, consists in the use of the whole thickness of the skin, removed from a healthy surface, and tacked down by a few stitches to the edges of the surface to be covered. The advantages which this method possesses over the Thiersch method are these: the cosmetic result is better, the tissues are more elastic, and less contraction takes place. It is, however, much easier to make the Thiersch grafts adhere, and the area from which they have been obtained is easier to heal than if the entire thickness of the skin has been removed. Kellock[70] has suggested a method which consists in a combination of both skin grafting and skin transportation. After marking out an area of skin which is to be removed in its entire thickness, he cuts with a sharp razor, from the skin surrounding the marked-out area, a number of small, thin, superficial grafts, one edge of each being left attached to the margin of that area of skin which is to be removed in its entire thickness. The thin grafts are then reflected up over the central area where the skin is dissected up in its entire thickness, and the fat is removed from its under surface. Thus is obtained a graft, the centre of which consists of the entire thickness of the skin, the margins being only of thin epithelium. When the graft is put in its new position special care must be employed in spreading the thin margins, as they adhere first and retain the whole graft in position. This method has all the advantages of skin transportation, and the new graft is more apt to adhere than when the old methods are used.

The use of plastic flaps was first suggested by Graefe and Maas.[71] In this method a flap of skin from some neighboring part, left attached by a pedicle, is applied to the area to be covered, and after it has become adherent so that it can obtain its nourishment from its new base the pedicle is cut. Flaps may be taken from a part near the area to be covered, or from some other surface of the body. Thus, for example, a flap from one leg may be used to cover an ulcer of the other leg, or, in order to cover a raw surface on the hand or wrist, two parallel incisions may be made on the anterior chest wall, the skin between them detached from the underlying muscle, and the hand passed beneath this flap, where it is held in place by a plaster-of Paris dressing. When it has become adherent the attachments of the flap are gradually divided. Finally, if none of these methods of treatment should prove successful, the question of resection of the part or amputation must be considered.

Special Forms of Ulcer.—The above methods of treatment are those applicable to the usual forms of ulcer. The specific or special forms of ulcer, however, require special treatment. A syphilitic ulcer requires the use of mercury locally as well as mercury and the iodides internally. A tuberculous ulcer is best treated by thorough curetting of the diseased tissue, after which formalin in one- to two-per-cent. solution or iodoform makes the best local application. It is also necessary to build up the system with cod-liver oil, syrup of the iodide of iron, and the hypophosphites. In order to cure a perforating ulcer of the foot, the ulcer must be thoroughly curetted and all dead bone removed from the base of the ulcer. Where the ulcer is a result of constitutional disease, as scurvy, diabetes, or gout, the disease must be treated in order to cure the ulcer.

Malignant ulcer can only be cured by the destruction or removal of the new growth. For the treatment of epitheliomatous ulcers, caustics, with or without curetting, excision, photo- or radiotherapy, may be employed. The best caustics are arsenic, chloride of zinc, caustic potash, and formalin. The objections to this method are the extreme pain, the lack of certainty as to the removal of all of the growth, the fact that the lymphatics and glands are not dealt with, and also that, unless the treatment is thorough, growth is stimulated rather than retarded. The scar is also apt to be unsightly. In most cases excision forms the best method of treatment. The incision should be wide of the ulcer, and all induration of the tissues and any lymphatics or glands which are involved should be removed. Finsen has reported a number of malignant ulcers treated by his light method, some successfully and some not, but since the publication of the cure of a case of rodent ulcer by Sequera,[32] of London, by means of the Roentgen rays, this method has been successfully tested and used all over the world in the treatment of malignant ulcers; especially good results having been reported in the treatment of rodent ulcer by Taylor[33] and others. It cannot be denied, however, that in a certain number of malignant cases this mode of treatment is absolutely without effect. Its particular use is in inoperable cases, and in those in which an operation would leave a badly deforming scar.

It is not necessary to enter deeply into the consideration of the treatment of lupoid ulceration, as it is taken up in another section of this work. The old methods of treatment by excision, scarification, the use of the Paquelin cautery, nitrate of silver, salicylic acid, resorcin, formalin, and calomel injections are still held to by many. Unna[34] has recommended the use of soap containing from five to twenty per cent. tuberculin. Hallopeau[35] recommends permanganate of potassium. Dethlifsen[36] claims excellent results, especially as to the scar, from freezing with ethyl chloride spray; but the treatment of lupus by phototherapy and radiotherapy is now receiving the most attention. Cases are undoubtedly cured by both of these methods. Many, however, are still sceptical as to the permanency of the cure, although Finsen has reported 130 out of 456 cases of lupus treated by his light method, free from recurrence for from one to five years. The objection to the method is the time required for each treatment, the large number of treatments necessary, and the great expense. The *x*-ray treatment, which is less expensive, will, according to Morris and Dore,[37] heal ulcerative lupus more rapidly than the Finsen light, although the latter is more effective in small non-ulcerative conditions. The exact action of the *x*-ray is not known, as it has been found that it does not kill bacteria in cultures, as is done by the Finsen light. But it appears to stimulate normal cell growth at the expense of morbid cells, which, being of lower vitality, are destroyed. Its application has also been shown to cause leucocytosis.

Routine Treatment of Ulcers.—While there can be no routine treatment of ulcers applicable to all cases, it may be of use in conclusion to give briefly the usual method adopted by many of the large clinics in New York city in treating the common forms of leg ulcer. If the ulcer be inflamed, the inflammation is reduced by wet dressings of alum acetate or one-per-cent. solution of ichthyol. After this is accomplished, if the ulcer is still dirty or the discharge profuse, after thorough cleansing with hydrogen peroxide and 1 in 1,000 bichloride of mercury, a one-per-cent. wet dressing of creolin is used. Sloughs are cleaned up with iodoform or naphthalin powder and the granulations stimulated with nitrate of silver. Balsam of Peru is used as a stimulating dressing except when the ulcer is painful, when ichthyol or alum acetate wet dressings are substituted, or a ten-per-cent. ichthyol ointment is applied. When the cavity is almost filled, or when the granulations become exuberant, redwash gauze is substituted for the balsam of Peru, the gauze being covered with a layer of Lassar's paste on lint. And, finally, when the granulations reach the level of the surrounding skin, the edges are very lightly touched with nitrate of silver and adhesive strapping is applied. During the whole treatment maintenance of the limb in an elevated position, for as long a peroid of time as possible, is advised, and a snug, even, muslin pressure-bandage is applied over cotton, from the toes to the knee. Complications or unusual conditions are treated according to the methods previously described. Finally, after a cure has been effected it is always well to instruct the patient in the care of the limb. It is important that he should keep it clean and dry, and if necessary powdered with talcum powder or stearate of zinc, and when varicose veins are present, he should wear an elastic stocking or bandage, thus avoiding a recurrence of the ulcer, which so frequently occurs.

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BIBLIOGRAPHY.

[1] Internat. Text-book of Surgery, 1902, vol. i., p. 74.
[2] Practice of Surgery, Wharton and Curtis, 1902, p. 37.
[3] Text-book of Surgery (English translation), 1901, vol. i., p. 536.
[4] Surgery by American Authors, 1901, p. 83.
[5] Guy's Hospital Reports, vol. xxiv., p 271.
[6] Treatise on Ulcer, Edinburgh, 1778.
[7] Thèse de Paris, 1883.
[8] Revue de Chirurgie, 1882, p. 877.
[9] Thèse de Paris, 1900.
[10] Lancet, March 1st, 1902.
[11] Ann. de Derm. et de Syph., 1899, No. xii.
[12] British Journal of Dermatology, 1892, p. 210.
[13] Ann. de Derm. et de Syph., 1899, vol. x.
[14] British Journal of Dermatology, November, 1900, p. 382.
[15] Arch. f. Derm. u. Syph., February, 1901, p. 215.
[16] Ann. de Derm. et de Syph., July, 1896.
[17] *Ibid.*, 1898, p. 895.
[18] Monats. f. prakt. Derm., 1898, Bd. xxv., p. 895.
[19] Philadelphia Medical Journal, February, 1899.
[20] British Medical Journal, September 21st, 1901.
[21] Centralb. f. Bakteriologie, 1898, xxiv., pp. 879–913.
[22] Roussky Vratch, October 5th, 1902.
[23] Archives générales de Médecine, January, 1902.
[24] New York Medical News, March 15th, 1902.
[25] Wien. med. Woch., No. 47, 1884.
[26] *Ibid.*, Nos. 11 and 14, 1889.
[27] Centralblatt f. Bakt. u. Infectionskrank., 1900.
[28] Münch med. Woch., May 13th, 20th, 1902.
[29] Albutt's System of Medicine, vol. ii., 490–494.
[30] Diseases of Warm Countries, 1903, 544–547.
[31] La Semaine Médicale, March 13th, 1901.
[32] Allbutt's System of Medcine, vol. ii., 1064.
[33] British Medical Journal, April 25th, 1901.
[34] *Ibid.*, May 25th, 1901.
[35] *Ibid.*, January 26th, 1901.
[36] *Ibid.*, November 8th, 1902.
[37] Journal de Méd. Bordeaux, November 2d, 1902.

[38] Hautkrankheiten, Wien, 1888, p. 362.
[39] Deutsch. med. Woch., May 15th, 1902.
[40] Lancet, May 29th, 1897.
[41] Centralblatt f. Chirurgie, November 20th, 1897.
[42] Roussky Vratch, June 9th, 1901, xxii. No. 23.
[43] Medical Age, April 25th, 1901.
[44] Médecine Moderne, vol. xiii., No. 7, 1902, p. 57.
[45] Berliner klin. Woch., 1883.
[46] Monatsschrift f. prakt. Derm., 1882, p. 328.
[47] Münch. med. Woch., June 25th, 1901.
[48] Cent. f. Chirurgie, November 10th, 1900.
[49] Münch. med. Woch., March 19th, 1902.
[50] Philadelphia Medical Times, 1887, xvii., 499.
[51] American Medicine, vol. iv., 1902, pp. 608 and 609.
[52] Monat. f. prakt. Derm., 1899, xxxviii., p. 808.
[53] Edinburgh Medical Journal, 1881-82, xxvii., p. 385.
[54] Arch. f. klin. Chirurgie, iii., p. 272.
[55] Trans. Amer. Med. Assn., xxviii., p. 589.
[56] Chicago Clinic, 1900, No. 8.
[57] La Caducée, May 3d, 1902.
[58] Berliner klin. Woch., February 10th, 1902.
[59] La Méd. Moderne, June 12th, 1901.
[60] Gaz. des Hôpitaux, February 4th, 1902.
[61] Berliner klin. Woch., 1878, p. 667.
[62] Lancet, 1853, i., 568.
[63] Centralblatt f. Chirurgie, 1888, p. 249.
[64] Bayer: Aertzl. Intelligenzbl., 1873, No. 14.
[65] Internat. Encyclop. of Surg., ii., p. 224.
[66] Arch. f. klin. Chir., 1888, xxvii., p. 53.
[67] Medical Times and Gazette, June 3d, 1876.
[68] Manuel de Médecine Operative, Paris, 1888, i., p. 182.
[69] Verhand. XIV. Congress Deutsch. Chirurg., 1885, i., p. 107.
[70] Lancet, November 25th, 1899.
[71] Arch. f. klin. Chir., xxxi., p. 559.
[72] British Medical Journal, February 9th, 1901.
[73] Lancet, May 17th, 1902.
[74] Sem. Méd., No. 43, 1889.
[75] Gaz. hebd. de Méd. et de Chir., March 21st, 1901.
[76] Hospitals Tidende, January, 1900.
[77] British Medical Journal, May 31st, 1902.

ADDENDUM TO ARTICLE ON TYPHOID FEVER.

(*See page 926.*)

Dr. Wright's latest reports (*British Medical Journal*, October 10th, 1903) are exhibited in the following tables:

TABLE I.—SHOWING THE INCIDENCE OF AND DEATH RATE FROM TYPHOID FEVER IN THE BRITISH ARMY IN INDIA DURING THE YEAR 1901.

	Average strength during the year.	Cases of typhoid fever.	Deaths from typhoid fever.	Incidence rate. Per cent.	Death rate. Per cent.
Uninoculated ...	55,955	744	199	1.33	0.36
Inoculated......	4,883	32	3	.66	.06

This table shows that antityphoid inoculation diminished the incidence rate of typhoid fever by one-half and the death rate by five-sixths.

TABLE II.—SHOWING THE INCIDENCE OF TYPHOID FEVER IN LORD METHUEN'S COLUMN AT THE MODDER RIVER, SOUTH AFRICA, FROM DECEMBER, 1899, TO MARCH, 1900.

	Number.	Cases of typhoid fever.	Incidence rate. Per cent.
Uninoculated	10,981	257	2.3
Inoculated.........	2,535	26	1.0

It will be noted that the table testifies to a diminution of the incidence rate by more than half during the period of observation.

Dr. Wright infers from the testimony of Table I., and from his own previous personal experience with inoculation in India, that the *minimum* duration of protection afforded by antityphoid inoculation is three years.—*G. B. S.*

END OF VOLUME VII.